



VSS

VIENNA young SCIENTISTS SYMPOSIUM

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Vienna University of Technology

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Welcome from the Organizers

On behalf of the organizing committee, it is our great pleasure to welcome you to the 2nd Vienna young Scientists Symposium (VSS).

The VSS is an innovative platform that enhances the interdisciplinary comprehensible exchange between members of the TU Wien. In addition, the VSS especially supports young researches and represents an opportunity for publishing research activities. The VSS provides a brief overview of broad research fields to speakers and audience. This is a perfect chance especially for early stage researchers to discuss about new cooperation ideas and realize them independently from department borders.

The VSS 2016 will bring you two days fully packed with talks as well as poster and prototype presentations in the research fields of Architecture and Urban Planning, Information and Communication Technology, Quantum Physics and Technologies as well as Mathematics Sciences. More than 50 members of the TU Wien submitted an abstract for presenting their research at the VSS on the 9th and 10th June 2016.

The conference will offer an excellent way to network and to share ideas. You are invited to take part in the discussions with participants from different disciplines and meet business relations in your area.



We wish you an active and fruitful Vienna young Scientists Symposium 2016!

Welcome by the Rector and the Vice Rector for Research and Innovation

The Vienna young Scientists Symposium (VSS) is a platform which aims to bring highly talented individuals and promising projects together, thus demonstrating our students' enthusiasm both for broadening their own scientific horizons and for thinking outside the box, as well as their internalised interdisciplinary perspective. This initiative serves to enhance scientific research, broadens the findings of research groups and strengthens partnerships with the industry. The sheer volume of the abstracts compiled here rather eloquently conveys the creativity of our students and young scientists, as does this fantastic event itself.

All scientific work undertaken at TU Wien rests upon the five research focal areas, an interlinking of the different disciplines in a progressive fashion demanded by ever more complex challenges. Further inter-departmental links, both within the



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university and beyond, come together to create a well-documented research matrix, resulting in competencies across numerous fields. Work is constantly ongoing to continue the development of these interconnections and to recognise fruitful cooperative possibilities and synergies that can benefit both parties.

The VSS 2016 presents research results in the fields of Architecture and Urban Planning, Information and Communication Technology, Quantum Physics and Technologies, and Mathematical Sciences. All these interdisciplinary topics provide evidence of the existing network, but they are only a small sample of the many areas of competence of TU Wien.

We would like to express our gratitude towards the organisers and supporters of VSS, who contributed to realising an outstanding event incorporating the concept of interlinking research and thereby shaping the future scientific direction of TU Wien with their outstanding research. Our young scientific talents play an important role in this regard, with the issues of tomorrow in the hands of the experts of the future. We wish you all every success and always full-power in the future.

Sabine Seidler, Rector of TU Wien

Johannes Fröhlich, Vice Rector for Research and Innovation

The image shows two handwritten signatures in blue ink. The first signature on the left is 'S. Seidler' and the second signature on the right is 'J. Fröhlich'.

Guest Lectures



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Henrietta Egerth

FFG - Die Österreichische
Forschungsförderungsgesellschaft

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**WIEN DENKT ZUKUNFT -
INNOVATIVES WIEN 2020**

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Research Field *Mathematics Sciences*

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Introduction

Architecture as well as Urban and Regional Planning are understood as two disciplines of applied sciences. They have their main focus on Design and Planning of projects or urbanized areas as well as on the target orientated influence of spatial trends and processes. On the background of manifold challenges for a sustainable development both disciplines develop and elaborate relevant approaches aiming at the design, planning or governance of the built environment on corresponding geographical scales and in corresponding time lines. These approaches are based on concepts of natural but also of social and cultural sciences. Hence, in a methodological perspective approaches have to integrate (and triangulate) quantitative and qualitative methods with respective results. Using adequate methods and instruments, in the focus of (empirical) research are predominantly questions related to the Understanding of Planning and Design, to the spatial analysis of sustainable development, to the modelling and simulation and to assessment of trends, measures or projects. Due to the complexity of the development and trends in urbanized areas, this research field contains the following specific research areas: "eco-efficient development and design of the built environment and of spatial resources", "digital technology in Architecture as well as in Urban and Regional Planning", "the European City - between self-organization and governability", "social, cultural and political dimensions of the built environment", "development and exploration of architecture".

SOCIAL INFRASTRUCTURES REDUCING SOCIO-SPATIAL INEQUALITY AND NEIGHBORHOOD VULNERABILITY

Santiago Sanchez Guzman

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INTRODUCTION

Latin America urbanization process has steadily risen during the last decade, shifting from rural and regionally distributed communities to a more spatially centralized organization with vast attracting urban poles. Today, 80% of the continent's population is concentrated in cities, placing the region as the most "urbanized" continent of the world with nearly 470 million urban inhabitants in 2010 (U.N. Habitat 2012)^[1]. However, and despite this urban growth has triggered positive and negative economic, social and environmental impacts in all of the continent's countries, socio-spatial and economic disparity indicators still place the continent as one of the most unequal regions in the world (Kingstone 2011; De Ferranti et al. 2003)^[2].

Thus, the research is an attempt to understand the interdependency of factors, effects and impacts socio-spatial Inequalities and Vulnerabilities are attached with in the highly segregated, fragmented and discontinuous urban agglomerations of the Latin American context and how can effective and strategic urban and regional development planning use Networked Social Infrastructures as a tool to reduce the gaps between asymmetrical socio economical classes and trigger community cohesion and more resilient environments.

MAIN IDEA, AIM AND MOTIVATION

Disparity is a global issue. The level of income inequality around the world is still rising dramatically, according to Oxfam "The richest 1% now has as much wealth as the rest of the world combined"^[3]. The distance between the richest and the poorest has increase during the last years and prove of that is the level of inequality seen in the urbanisation all over the planet.

Therefore the aim of the research is to critically determine how Social Infrastructures have the capacity to reduce socio-spatial Inequalities and neighbourhood Vulnerabilities in the Built environment.

Following Edward W. Soja concept of Spatial Justice, the research also aims to contribute in understanding spatial policy tools implemented and effective in reducing the big social gap of development opportunities between different socio economical groups living in the same city, and in encourage territorial cohesion. "Thinking spatially about justice not only enriches our theoretical understanding, it can uncover significant new insights that extend our practical knowledge into more effective actions to achieve greater justice and democracy."^[4]

Furthermore, allocation and interaction between distributed collective Infrastructures lead to networking, among different communities, between those communities and institutions as well as inter-institutional cooperation, enabling cohesion, participatory planning processes and more resilient urban tissues: "Multi-performative infrastructure – where (planners and) architects organize multiple functions in composite networks – can produce long-term savings that avoid redundancy. Collecting multiple infrastructure systems while also responding to local, social, aesthetic, and ecological conditions produces resilient forms of urbanism that are appropriate for the given conditions

RESEARCH FIELDS AND RELEVANCE

The research deals with the qualitative and quantitative analysis of the Social (Human and Social capital), Physical (Spatial and Material) and Institutional (formalized and informal rules and laws) dimensions of Social Infrastructures and its service provision, starting from the understanding of the comprehensive definition of infrastructure from Jochimsen R. (1966) and arriving to the contemporary global networked society of van Dijk J. and Castells M.

The relevance of the topic lies in the urgent actions Latin American agglomerations will have to undertake during the following years to undermine the high levels of spatial and social disparities and segregation have placed the continent as the most unequal region in the world.

CASE STUDY

The research looks not only to analyse the literature and build up the theoretical framework of the interlinked factors, effects and impacts of Social Infrastructures reducing Vulnerabilities and spatial inequalities but also to evaluate empirically specific meaningful cases of networked social Infrastructure built during the last 20 years in Colombia and estimate its real impacts for the communities where implemented.

Evidences from the last 10 years in Bogota show that new investments and renovation of social infrastructures related to education carried out in a decentralized and distributive spatial strategy might be effective in achieving social and spatial inclusion for the lowest income communities, tying them back to the urban, social and economic tissues.

EXPECTED RESULTS

I expect results of the research will show a correlation between the improvement of social infrastructures and the reduction of socio-spatial inequalities. Therefore results of the case study in Colombia and its indicators comparison with the Austrian and other territories cases in a global perspective are expected to determine how fragmented and unequal the spatial dimension of some built environments nowadays are and which measures are feasible to contribute and promote integration and resilient socio-spatial tissues.

ACKNOWLEDGEMENT

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REFUGEE ACCOMMODATION IN AUSTRIA – MIGRATION MANAGEMENT AS A RESILIENT REGIONAL DEVELOPMENT STRATEGY?

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INTRODUCTION

During what is now called the “European Migrant Crisis”, which can be said to have begun in 2015, a rising number of refugees and migrants have begun to make the journey towards the European Union. According to the Austrian Interior Ministry about 90.000 persons have applied for Asylum in Austria in the year 2015, which amounts to a 200 percent increase compared to the year before ^[1].

The topic is discussed hotly on many different levels – from international and EU policy to the national state and more regional scales, and it is the latter (embedded in a supraregional, national and international context) that this paper will focus on: The aim is to give a first introduction into the author’s dissertation topic by supplying a theoretical overview over main concepts and ideas, expected dimensions of analysis and first descriptive empirical results.

RESEARCH QUESTION(S)

As a starting point, Chart 1 shows the number of asylum applicants per capita accommodated in Austrian municipalities as of January 2016. It illustrates that applicants for asylum are very unevenly distributed across Austrian municipalities, with 37% (781/ 2100) without any, and several municipalities with a very high share of asylum applicants (those with large-scale quarters such as Traiskirchen) with more than 1.000 applicants.

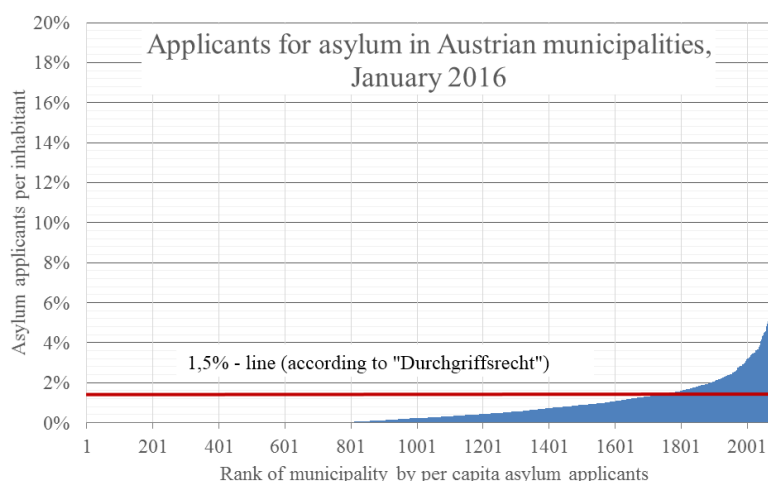


Chart 1: Asylum applicants in Austrian municipalities as of January 2016^[2]

This uneven geographical distribution of asylum seekers in Austrian municipalities and regions, which is strongly interwoven with and further exacerbated by the asylum process in Austria as it is today (e.g. with different responsible entities along the process), are a starting point for analysis. But apart from a descriptive analysis the aim of the thesis is also to give an insight into whether adapting to and managing the accommodation of people who apply for asylum in Austria – in the sense of the concept of resilience –may offer an opportunity for regional development.

THEORY AND DIMENSIONS OF ANALYSIS

Apart from an introduction to the term “**refugee**” ^[3] and a working definition of the concept of **integration** (linked to housing) – as,„[t]here is no single, generally accepted definition, theory or model of immigrant and refugee integration” and “[t]he concept continues to be controversial“ ^[4] - the concept of **resilience** and its applicability to the research question posed above will be the main

theoretical focus: The resilience framework has been suggested to offer a perspective helpful in the governance of changes, as it is “based on the complexity of the social-ecological system and takes into account the unpredictable future, as it emphasizes adaptive approaches to management”^[5]. More specifically, the idea of evolutionary resilience can be defined as „the ability of complex socio-ecological systems to change, adapt, and, crucially, transform in response in response to stresses and strains”^[6]. According to the panarchy model of adaptive cycles ^[7], which describes distinct changes in the structures and functions of a system, each system can be seen as offering windows of opportunity or times when a crisis can be turned into an opportunity, innovation and transformation.

EMPIRICAL WORK

The quantitative empirical work will focus on a first analysis of accommodation data on asylum seekers in Austria on a municipality level for five points in time (between June 2015 and January 2016). At the same time, the legal framework on asylum and integration will be summarized from a spatial perspective. Potentially, first indicative interviews with stakeholders on a regional level (such as mayors) will have also been carried out before the beginning of the conference.

RESULTS AND DISCUSSION

The results to be provided in more detail at the conference will reflect the progress made in the author’s dissertation effort, which is now concerned with three main endeavours: The development of a theoretical framework, a first overview and analysis of existing and available data, and a thorough summary of the current legal framework (of responsibilities), including its spatial implications. These will be the foundation for a further analysis of what “resilient migration management” may mean from a regional development perspective.

CONCLUSION

Based on the work described above, the long term aim is to define a clear theoretical framework, within which the thesis can be further developed.

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ACCESSIBILITY IN URBAN AREAS IN THE CONTEXT OF AN AGEING SOCIETY: CHALLENGES AND BEST PRACTICE IN THE CITY OF VIENNA

Flora Strohmeier

E230 - Institute of Transportation

INTRODUCTION

The PhD-project with the title “age-friendly mobility in urban areas” was funded by Austrian Research Promotion Agency (FFG), starting in April 2014 and lasted 24 months. It was a cooperation between the University of Technology (Institute of Transportation) and the Austrian Road Safety Board.

OLDER PEDESTRIANS AND WALKABILITY

In 2050 about 25% of the Austrian population will be older than 65 years. Therefore, the demand towards accessible public spaces and age-friendly designs is increasing, putting cities and regions in a challenging situation. Walking is a common mode of transport for the elderly due to its various advantages: it enables a person to maintain its level of activity, health and independence; it means quality of life because social interaction and inclusion is promoted. It doesn't imply costs or certain skills. Nevertheless, pedestrians are still frequently suffering from barriers and/or missing accessible environment or road networks.

There are not only obvious and visible obstacles, but also more subtle subjectively perceived barriers, which may even be more disturbing. They depend on the individual perception, personal capacities and available resources for making trips. Such barriers can sometimes be temporary, like construction sites, weather conditions or other disturbances such as broken lights, damage to the road surface, or situational like crowded places. Moreover, certain situations and conditions, lack of resources or emotional barriers may detain older people, who are a subgroup of persons with reduced mobility (PRM^[1]), from accessing services or moving independently.

OBJECTIVES

In order to improve the walkability of streets and urban public spaces and to design them accessible and user-friendly, it is important that urban and traffic planners consider different kinds of barriers and understand their influence on mobility (detours, avoidance, etc.), especially for physically impaired and older persons. Walkability is generally defined as “(...) *the extent to which walking is readily available as a safe, connected, accessible and pleasant mode of transport*”.^[2] Exploring the location, defining the user groups and, if necessary, getting further empirical evidence are indispensable prerequisites for adequate decision-making.

Another important factor for implementing pedestrian-friendly design is to accurately consider the diversification of lifestyles and mobility behaviour as well as the increasing gap between biological and calendric age.

The project focused on the perception of mobility barriers and accessibility by senior citizens in the city of Vienna. In order to describe important factors for walkability, mobility patterns of senior citizens and perceived barriers as well as their influence on mobility were investigated in detail.

The goal of the research was to enhance existing guidelines for the design of age-friendly, walkable urban spaces and roads with special consideration of the perceived safety of pedestrians and their attitude towards taken measures.

METHODOLOGY

Two different empirical social research tools were combined in order to collect and examine information about basic conditions for mobility behaviour and obstacles: mobility diaries and personal interviews. Each survey took place for one week in winter and in summer, respectively. 68 persons, ranging from 65 to 84 years of age, participated in the study; 35 of them male and 33 female. The participants documented their daily trips and described the barriers they encountered. Subsequently, the influence of perceived barriers and already implemented measures on their daily trips was evaluated in detail by means of personal interviews (plus a scoring of the respondents' health condition and physical constraints).

RESULTS AND DISCUSSION

The perceived safety of pedestrians and their attitude towards taken measures have been found to significantly affect their mobility behaviour, varying for different activity levels.

Based on the evaluation of the perception of barriers and their influence on the mobility, four common "mobility types" have been defined. Working with "mobility types" enables stakeholders, such as city planners, to consider the variety of physical capacities and constraints, together with socio-demographic data and psychological factors. Additionally, the individualization in terms of lifestyle and mobility behaviour can thereby be taken into consideration, which is especially important in the context of the demographic change.

An evaluation tool has been developed and criteria have been defined for different planning approaches in respect to their impact on improving age-friendly design for pedestrians in urban areas.

The results of this study have been summarised in guidelines for age-friendly design. These guidelines will be part of the presentation, illustrated with examples of successful measures (Best Practice).

CONCLUSION

Challenges for elderly road users and possible solutions in order to improve conditions for walking have been analysed. The main results are a new approach to handle various factors when defining user requirements (user typologies) and the comparison of measures regarding their impact for age-friendly design.

Possible applications of the „mobility typologies“ and its use for different stakeholders, who are involved in the planning process, have been identified. The suggested measures and planning strategies are considered helpful in order to raise the quality of walkability, i.e. improve the accessibility of every day destinations in urban areas for the elderly.

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AN INQUIRY INTO RELIABILITY OF OCCUPANT BEHAVIOUR MODELS FOR BUILDING PERFORMANCE SIMULATION

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INTRODUCTION

Use of advanced occupancy related models is gaining momentum in the building simulation community. In line with the activities in the ongoing IEA Annex 66, numerous monitoring campaigns of occupants' behaviour, development of a variety of occupant behaviour models, and examination of different workflows for integration of these models into building simulation tools have been collectively contributing to enhance the representation of occupants in building performance simulation [1]. However, arguably, most existing behavioural models are predominantly derived based on rather limited sets of observational data and are not subjected to external validation in different settings. In addition, as highlighted in previous publications [2,3], the relationship between the purpose of building performance simulation-based studies and the choice of occupancy-related models is arguably not well understood. Thus, the use of occupant behaviour models in building performance simulation and their predictive potential in different contexts involves potentially detrimental uncertainties.

EXPERIMENTS / FUNDAMENTAL OF THE PROBLEM / EXAMINATIONS

To encourage a systemic exploration of reliability and effectiveness of occupant models for building performance simulation, the current contribution focuses on a number of stochastic and non-stochastic window operation models [4,5,6] to a) conduct an external evaluation of the models' performance in predicting the interactions of occupants with windows, and b) explore the effectiveness of these models to improve the reliability of thermal comfort and energy performance assessments. Toward this end, we selected an office area, for which long-term data on outdoor and indoor environment, occupancy, and window operation is available. Such a test bed provides the required environmental and occupancy related input data to run, calibrate and validate the window operation models in an external setting. However, this evaluation environment disregards the feedback of the window operation models to the indoor environmental parameters [7,8]. Therefore, to evaluate the predictive performance of window operation models in a comprehensive manner, we suggest the use of a calibrated building performance simulation model as a 'virtual' test bed in addition to the 'actual' test bed used in previous studies. Besides, the calibrated building performance simulation model, together with the integrated window operation models, allow us to examine the effectiveness of these models to enhance the reliability of simulation-based assessments of building heating energy demand and occupants' thermal comfort.

Thus, the study allows us to explore a number of essential questions with regard to the use of deterministic and stochastic window operation models: To what degree do these models predict the occupant's interaction with windows in a new setting, with and without calibration to on-site data? To which extent do the results of simulations that use rule-based window control schemes or stochastic models of window operation differ from a reference building model, which utilizes actual window operation data? Does the use of existing stochastic window operation models enhance the accuracy of simulation results, even without calibration with on-site window operation data?

RESULTS AND DISCUSSION

The study results suggest that, despite the inherent advantage of stochastic models in representing the random character of occupants' operation of windows and providing ranges of possible outcomes, without proper adjustment of the models to the buildings under study, they can yield very large errors in terms of window state predictions and building performance simulation results. However, when used 'appropriately', they can outperform rule-based models, especially in terms of window operation predictions, and thermal comfort assessments in naturally ventilated buildings.

CONCLUSION

In our view the study results have implications beyond the performance comparison of the models considered. The observed possible large deviations from reality underlines the need for clear documentation of associated uncertainties with existing window operation models in different deployment scenarios as well as development of more generally applicable occupancy-related models. Moreover, both model developers and potential users need to be careful with regard to introduction and characterization of behavioural models pertaining to inhabitants' presences and actions in buildings. Specifically, statements concerning models' validity and overall applicability in the building delivery process require comprehensive empirical backing and careful – ideally double-blind – model testing procedures.

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A COMPUTATIONAL INQUIRY INTO THE APPLICATION OF VACUUM GLAZING IN BUILDING RETROFIT

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INTRODUCTION

This contribution presents a number of results of VIG-SYS-RENO project, which investigated window systems with innovative glazing, specifically vacuum glazing for building retrofit. The general concept of vacuum glazing was developed already decades ago, though commercial products were introduced into the market just recently [1]. They are declared to have a thermal transmittance between 0.3 to 0.5 W.m⁻²K⁻¹ [2]. In Europe, high-performance glazing windows are commonly equipped with double or triple glazing. Such products, however, are not suitable for certain building retrofit cases. This is partly due to their heavy weight and bulky design. Moreover, such massive windows may be optically inappropriate for historical facades. In contrast, vacuum glazing offers a light and thin construction with 8 to 10 mm thickness and a vacuum layer of only 0.15 to 0.20 mm. These attributes render it an attractive option for thermal retrofit of historical buildings. Nevertheless, application of vacuum glazing in historical casement windows (“Kastenfenster”) is a new concept and thus requires more investigation. Inappropriately designed glazing solutions could negatively influence the performance of the original construction. Possible risks include high thermal losses via thermal bridges, extensive condensation resulting into mould growth within the window assembly, and long-term durability issues.

The VIG-SYS-RENO project addressed the above mentioned issues. Different retrofit scenarios were developed and assessed towards the implications of their application. The project pursued the following objectives:

- Exploration of the performance of systems, retrofitted with vacuum glazing products. Thereby, numerical heat flow simulation of various retrofit scenarios was carried out. Such indicators as thermal coupling coefficient and U-, ψ -, and f_{Rsi} -value, were derived.
- Assessment of the energy-saving potential of vacuum glazing technology on building level. Heating demand of 3 typical Viennese buildings with various glazing-to-facade ratios constructed around 1900s was calculated under various retrofit scenarios.

METHODOLOGY

Based on the concept developed with collaborators from the Holzforshung Ausrtria, multiple retrofit scenarios were modelled. The “original” scenario assumed a conventional casement window; scenarios “VE” and “VI” referred to casement window with applied vacuum glazing in exterior and interior frames respectively; scenarios “VE-M” and “VI-M” featured casement window with applied vacuum glazing in exterior and interior frames with modified foam-based frame-glass connection. Considering the specifics of heat transfer analysis in casement windows and properties of vacuum glazing, the following assumptions were made:

- Employed simulation tool AnTherm 7.125 [3] evaluates predominantly heat conduction, according to EN ISO 10211 [4]. Therefore, thermal bridge simulation results reflect

primarily the effects of conductive heat transfer. Convective and radiative heat transfer were considered in numerical simulation in a simplified manner. For the same reason low-e coating was not included in the simulation model. Thermal conductivity of vacuum was set to $0.0001 \text{ W m}^{-1} \text{ K}^{-1}$, according to the product's data sheet.

- The simulation was focused on frame/glazing connection. Therefore, the window assembly was modelled adiabatically from the rest of the wall structure.
- The shape of stainless steel support pillars in vacuum glazing was simplified. They were modelled as rectangular-shaped pillars of the equivalent area (a single pillar of 0.197 mm^2).
- Seven control points were selected for the evaluation of retrofit scenarios (see Fig. 1). The surface temperatures in these critical locations were derived from the isothermal profiles.

RESULTS AND DISCUSSION

Defining the proper positioning of the vacuum glazing was one of the critical project questions. In this regard, surface temperatures at the selected control points were found to be very low in scenario “VI” and “VI-M” on the inner side of the exterior glazing and within the interstitial space. This implies potential freezing at sub-zero temperatures, condensation on the glazing surface, and risk of mould growth. The scenarios “VE” and “VE-M” showed the best results in overall heat transfer coefficient of the window, resulting into more than 50 % reduction of $U_{\text{effective}}$ values, in contrast to the original construction. The scenarios with modified frame-glass connection however require further detailing work. Specifically, the visual appearance must be taken into consideration.

Calculation of the heating demand of selected buildings was based on Austrian Energy Certificate Method [5] and implemented in ArchiPhysik 12 [6]. A set of input parameters was required: the geometry data of case study buildings, including size, orientation, zoning etc., and indicators from thermal bridge calculations, such as U- and ψ -values of window retrofit scenarios. The results suggest that building heating demand could be reduced to 14%, depending on the scenario and glazing ratio of the building. This implies a significant improvement, considering that window retrofit was the only applied retrofit measure of the building envelope.

CONCLUSION

The present contribution illustrates the effect of application of the vacuum glazing in historical casement windows. Furthermore, it provides an overview of the project results regarding construction, installation, and the background for developing appropriate system solutions. The application potential and detailing of such retrofit technology should be further explored in future research efforts via continuous monitoring of installed vacuum glazing, as well as 3D simulation of thermal bridges in window corners under steady-state and transient conditions.

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**THE BAU-WEB-PROJECT: EXPLORING THE POTENTIAL OF STATE-OF-THE-ART
WEB-TECHNOLOGIES FOR BUILDING PRODUCT DATA ACQUISITION AND
MANAGEMENT**

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INTRODUCTION

Coming from a variety of disciplines and occupational orientations, stakeholders and actors collaborating in the building industry have different perspectives and views on buildings as the final product of the collaboration. This multiplicity of views and lack of a common ontological understanding of a building and its components results in an information gap between the requirements of various tasks and applications (involved in the building delivery and operation processes) and the available building product representations. Informational expectations of data clients (architects, performance evaluators, engineers, craftsmen, building operators, etc.) with regard to building products are not always fully accounted for by data providers (manufacturers, 3rd party product evaluators, resellers). Moreover, due to the extent and dispersion of the already available data, extraction of useful information in the right format has become a cumbersome and error-prone process. It has been demonstrated that the difficulties in data procurement can even hinder the implementation of effective design support evaluation procedures and thus reduce the final design's quality.

METHODOLOGY

BAU_Web is an ongoing 3rd party funded research effort (FFG grant: 848583) aimed at exploring the potential of Semantic Web Technologies^[1] towards facilitating the utilization of web-based building product data. It focuses on the development of a shared ontology for building product data representation among AEC stakeholders, as well as establishment of a framework, which facilitates access to data from various web-based sources, compliant with the suggested ontology (Fig 1). For demonstration purposes, the example of a load-bearing masonry wall has been selected. The example domain involves three categories of building products: Plasters, insulation, and bricks. In order to arrive at a common ontological representation of this illustrative instance, we: i.) identified various tasks involved in the building planning and delivery process; ii.) studied the informational requirements of selected tasks, including architect's material selection, thermal/visual/acoustical performance assessment, construction management, and life cycle analysis. For this purpose, standards^{[2][3]} concerned with the above-mentioned assessment methods as well as software tools^{[4][5][6]} pertaining to the different tasks were investigated, and partly reverse-engineered; iii.) analyzed building codes^[7] pertaining to the above-mentioned product categories to identify the respective standard classification schemas and shared class attributes. iv.) examined commonly used and self-developed building data exchange formats such as IFC^[8], gbXML^[9], and the SEMERGY building model^{[10][11]} for their potential towards accommodating the inquiries considered in the first step; and v.) developed an object-oriented representation schema of the necessary building product information with regard to the investigated applications, queries, and standards. This model forms the underlying organization of a graph-based data structure that can cater for the informational requirements of the considered use cases. The project targets the implementation of the data ontology for the aforementioned domain. Moreover, a demonstration of

the automated process of data extraction from multiple web-based sources and the semi-automatic provision of user-desired data in the requested format is objected.

RESULTS AND DISCUSSION

Results indicate on a wide informational gap between the data requirements (e.g. for tools), and the currently practiced data transfer modalities. For the example domain of “load bearing external wall”, and selected tasks, illustrative tables have been prepared (required data types and formats). These templates can inform data providers regarding the specific informational needs of various stakeholders and their specialized applications. For the task of material selection in the architectural design process, new properties had to be defined for materials to facilitate educated selection. In this regard, property sets such as function, position within the building assembly, and material class were defined (e.g., Fig 2), and organized within a data structure. Material instances thus structured, can cater for semi-automated selection and smart filtering processes.

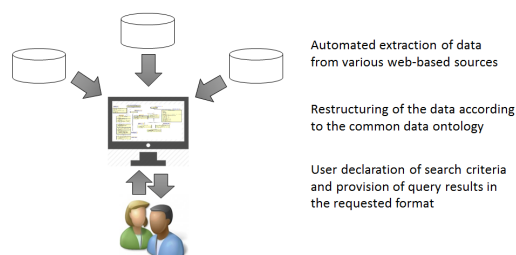


Figure 1: General structure of the BAU-WEB framework

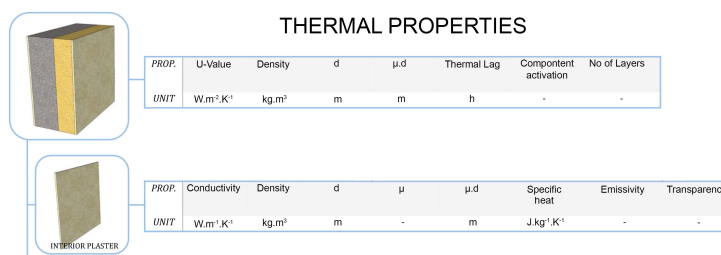


Figure 2: Informational requirements for thermal assessment and condensation risk analysis of building components.

CONCLUSION AND FUTURE RESEARCH

The ongoing development process targets the utilization of Semantic Web Technologies towards facilitating building product data acquisition for the various stakeholders within the building delivery process. The derived task-specific data templates support data providers in proper representation of their products. The ongoing effort towards generation of a comprehensive task-oriented building product data ontology is expected to cater for semi-automated and seamless data transfer among different stakeholders. The future steps of the project include the implementation of the framework for the example domain to demonstrate the feasibility of such an approach and identify SWOTs (strengths, weaknesses, opportunities, threats).

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SINGULAR VS PLURAL
THE CONFLICT OF INDIVIDUAL WORK AND TEAMWORK IN THE
ARCHITECTURAL PROBLEM SOLVING USING THE EXAMPLE OF THE
ARCHITECTURE CLASSES AT THE INTERNATIONAL SUMMER ACADEMY OF
FINE ARTS IN SALZBURG, IN LIGHT OF THE 62 YEARS OF HISTORY OF THE
SCHOOL

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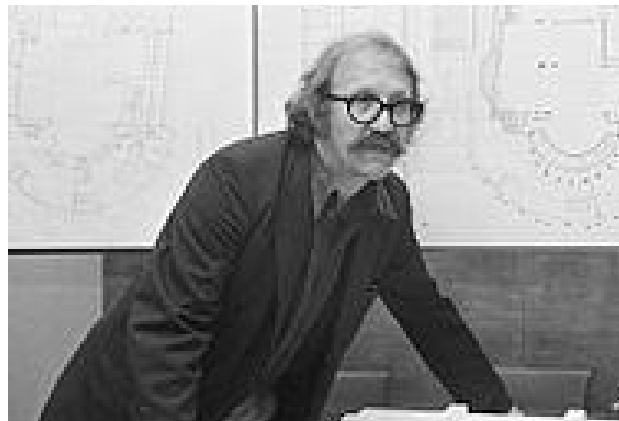
INTRODUCTION

The changes in the working field of future architects will not only be affected through globalization and networking. The complexity of the tasks continued to grow already in the past. This promoted a lot of in-process disciplines. A withdrawal of architects in the field of designing was and is the result. More and more the supervision of the construction process, and thus the control over the execution will be awarded to specialists. And that means the architect as a specialist is part of an interdisciplinary team. The evolution from individual to team is the result. But in contrast star-architects developed their brand-architecture in the last years.

FUNDAMENTAL OF THE PROBLEM

The aim of this work is to deal with the opposing team and individual working methods in the field of architecture and to show by means of selected programs of work from the architecture classes at the International Summer Academy of Fine Arts in Salzburg, when each was increasingly used from the period of the school's founding in 1953 until the present situation in 2015. 63 years of teaching architecture in the context of society, politics and art, within in a special period of time and a historical context.

An Austrian group of architects, participants of the first architecture seminar of the in 1953 the so called arbeitsgruppe^{4[1]} is used as an example for this work. In 1956 one of the members Wilhelm Holzbauer went to the United States to study. He returned in 1959 and brought back the current architectural trends of his US. At the same time the seminars of Konrad Wachsmann from 1956 to 1959 were of great importance for its partners. For Holzbauer the system to design on his own became more attractive to him, than the thesis



Picture 1: Wilhelm Holzbauer in 1981, at the Competition for the Music Theater in Amsterdam



Picture 2: Konrad Wachsmann teaching at the Summer Academy of Fine Arts in Salzburg

of teamwork after his return. These two different approaches in the architectural problem-solving process, that caused the rupture of a team, will be used as a starting point and an example for this work.

Research Question:

The present work is based on the question of how and why the teachers of the architecture classes at the International Summer Academy of Fine Arts in Salzburg inserted teamwork and individual work in their respective seminars over the 63 years of history of the school?

RESULTS AND DISCUSSION

The result of the investigation will show how the spirit of society affected the chosen method of work. In addition to the work the examination should lead to a better understanding of the development of the Austrian architectural scene after World War 2.

CONCLUSION

Architecture is a survived built expression of a culture, the generations and the process of cultural development. The different ways for architectural problem solving process in different periods of time, can then also show how the design has changed as a means of gaining knowledge.^[2]

Next Steps: The next step is to refer to the still existing in various archives material. Thereafter, selected projects, which originated in the seminars, are considered in more detail. The architectural projects are to be set by analysis and comparison of working methods.

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PICTURES

Picture 1 Wilhelm Holzbauer mit Cees Dam im Jahr 1981, Vergadering Commissie Bouw Stadhuis / Muziektheater; <http://proxy.handle.net/10648/ad04b464-d0b4-102d-bcf8-003048976d84>, Nationaal Archief, Hans van Dijk / Anefo

Picture 2 Konrad Wachsmann, International Summeracademy of Fine Arts Salzburg , Kreuzweise – x projekte der arbeitsgruppe 4, März 2010, <http://www.castyourart.com/2010/03/10/arbeitsgruppe4-ausstellung-architekturzentrum-wien/>

SMART CITY ASSESSMENT: A HOLISTIC APPROACH TO URBAN DIVERSITY

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INTRODUCTION

In the last years many initiatives have been developed under the label of the Smart City (SC). Multiple attempts have been developed in order to assess SC, but there is a need of tools to measure the effectiveness of SC initiatives and to facilitate urban planning and decision making processes taking into account the particularities of each city and context through a comprehensive approach.

DEFINING THE GUIDELINES FOR A SMART CITY ASSESSMENT METHODOLOGY

A state of the art has been developed through literature review, in order to define what a SC is, how are SCs being assessed (27 definitions and 15 methodologies) and which are the characteristics that a SC assessment methodology must include. Three main guidelines have been identified:

A. Holistic approach: either professional or scientific contributions are recognizing the potential and the need of a holistic approach regarding Smart Cities and proposals are evolving towards a more integrated vision facilitated through ICT ^[1]

B. Objectives for SC initiatives: technology cannot be a goal itself. Sustainability, quality of life and efficiency have been identified as the main objectives for SC initiatives to pursue ^[2].

C. Addressing urban challenges: A SC must be able to address the specific urban challenges that a city is facing. Those challenges are not the same for every Region or City, and a methodology for assessing SC must be able to incorporate the particularities and to enhance the city vocation ^[3].

RESULTS AND DISCUSSION

The result of the research is an integrated tool that combines 3 different steps:

A. Conceptual model: the SC as a system. The SC can be understood as a set of interrelated subsystems within the urban system, aiming to provide a physical and technological response to urban challenges (internal or external). The core of the urban system is the urban demand ^[4]. The SC can be divided into different subsystems: governance (taken here as transversal), economy, environment, mobility, people and living ^[5]. Technology (specially ICT) is understood as a tool to connect them.

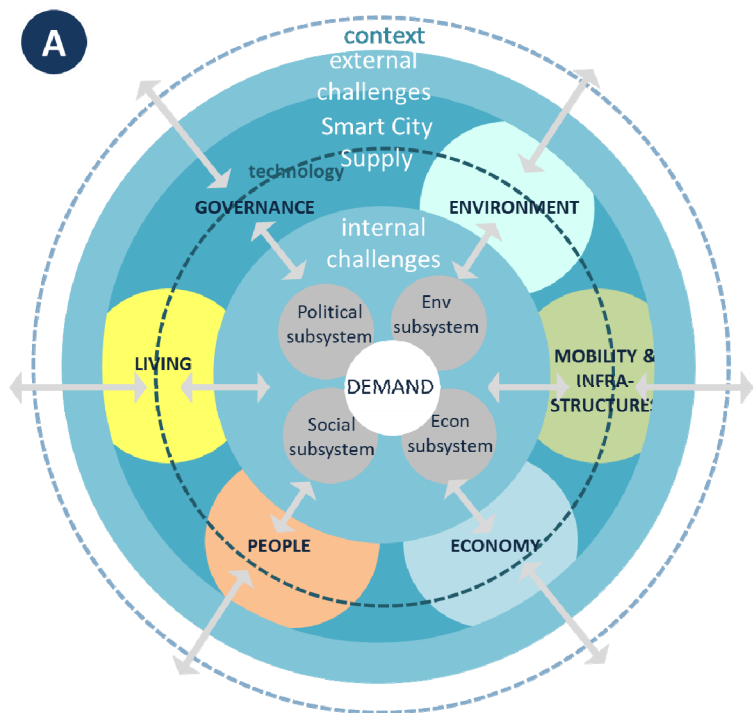


Diagram 1: Smart City System conceptualization

B. SC objectives assessment. Each of the different subsystems is assessed according to the identified SC objectives using quantitative and qualitative indicators.

C. SC integrated assessment. A matrix that interrelates the assessed SC subsystems with the identified challenges. These challenges can be developed for a specific region or type of cities to be later particularized to a specific city. Values can be provided by different stakeholders, specially municipalities.

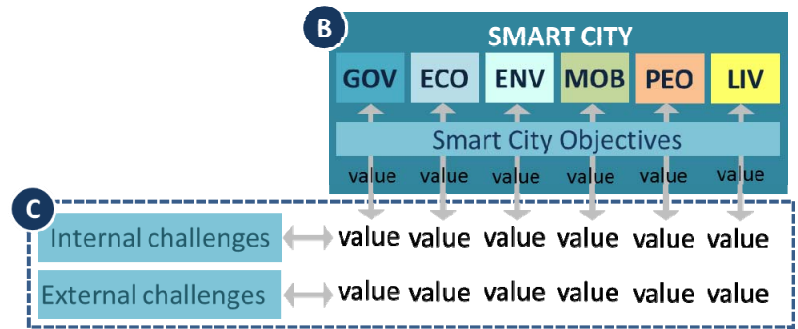


Diagram 2: Smart City System conceptualization

The evaluation through this matrix aims to allow a complete a holistic vision assigning values to the elements described in the diagram. The diagram can be modified in order to show the characteristics of the city as well as to help planners and decision makers to design strategies. Thus, a tool for a holistic approach in SC assessment has been developed

CONCLUSION

The expected result is a methodology able to assess SC in a holistic way and attending to its particular characteristics. It will help stakeholders the comprehension of the Smart City and thus to design global strategies and to take informed decisions.

The next steps to be followed are two. One step will be the definition of the specific indicators including SC, as well as sustainability and quality of life indicators. A second step will be the validation of the conceptual model by different stakeholders. Finally, the complete methodology will be validated through a selection of case studys.

Interfacing areas: This research is framed in the UPM Doctoral Program in Sustainability in Urban Regeneration, understanding SC as a way to improve the sustainability of cities. It is also linked to ASCIMER (assessing Smart City initiatives in the Mediterranean Region) a project financed by EIB which aims to develop a methodology adapted to a specific context. It is currently being developed in the Department of Spatial Planning of TU Wien in order to widen its scope.

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**3D-SHAPE-PERCEPTION
STUDIED EXEMPLARILY WITH TETRAHEDRON AND ICOSAHEDRON
AS PROTOYPES OF THE POLARITIES SHARP VERSUS ROUND**

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INTRODUCTION

Three-dimensional formations create the built environment. Their characteristic geometrical features affect the perception of them. Therefore, particular geometric features should correspond to specific, identifiable perceptions.

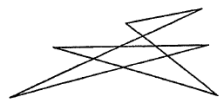
EXPERIMENTS / FUNDAMENTAL OF THE PROBLEM / EXAMINATIONS

Object of investigation - the five Platonic solids

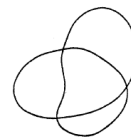
Plato identified five three-dimensional objects featuring congruent regular polygonal faces with the same number of faces meeting at each vertex ^[1]. They can be seen as embodying the geometrical base for all other three-dimensional shapes ^[2].

Opponents round versus sharp

In the 1930s, psychologist Wolfgang Köhler defined a pair of two-dimensional shape archetypes - “Takete” and “Maluma” - embodying the qualities round versus sharp^[3]. A study of Peter G. Richter and Norbert Hentsch related them to the designing process for objects of daily use and identified several associated attributes and sensations ^[4].



Picture 1: Takete according to W. Köhler



Picture 2: Maluma, according to W. Köhler

Neuroscientists Bar and Neta showed that patterns and objects of daily use with soft, round shapes are preferred in comparison to those with sharp and pointed profiles.[5] Further research demonstrated the valid transfer to large-scale surroundings like architecture and landscape by walk-through videos and photographs ^{[6][7]}.

Perception studies with walk-in models

Among the five Platonic solids, tetrahedron and icosahedron provide the clearest representation of the qualities sharp and round, respectively. We constructed walk-in models (total height 2.2m) and presented them in a public park in Frankfurt am Main, Germany, to test preferences of park visitors. A questionnaire with semantic differentials included attributes and associations devised from the study by Richter and Hentsch.

The walk-in models were assembled in turns - tetrahedron eight times, icosahedron seven times - on fifteen days during summer 2015.



Picture 3: Walk-in model of tetrahedron with participants in Niddapark, Frankfurt/Main, 2015



Picture 4: Walk-in model of icosahedron with participants in Niddapark, Frankfurt/Main, 2015

RESULTS AND DISCUSSION

A total of 288 participants took part in the study; 116 of them rated the tetrahedron, 172 rated the icosahedron. Preliminary analyses using Wilcoxon Rank-Sum tests show that the perceptions of the two solids differ in respect to several attributes. In particular, participants rated the tetrahedron as significantly narrower, more pointed, sharper, more familiar and harder than the icosahedron; the icosahedron was perceived as significantly more pliable, more endearing, more supportive, and more inspiring than the tetrahedron. These findings provide first evidence that the shapes of basic three-dimensional geometrical objects are associated with specific patterns of attributes and associations.

CONCLUSION

The fact that specific shapes may elicit distinct patterns of perceptions is relevant for all fields of design. Future studies should examine similarities and differences between the perceptions of two- and three-dimensional shapes and study attributes of more complex shapes. Additionally, attributes for the three other basic solids - Octahedron, Cube, Dodecahedron – need to be clarified.

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**HOME ON THE BACK –
THE BLACK TENT OF NOMADS IN THE WEST AZERBAIJAN PROVINCE OF IRAN**

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MOTIVATION

The black tent of nomads in Western Azerbaijan as a form of unique architecture dating back centuries ^[1] have survived and endured the test of times. This permanency and durability are the biggest motivation to take a closer look at this style of architecture (Figure 1 & 2).

How could the simple architecture of a people arising from the heart of nature who moved about looking for new grazing grounds for their livestock outlast the modern pretentious one?



Figure. 1 & 2: Black tent of nomads in the Western Azerbaijan province of Iran in different views

ANALYSIS

The most significant step in studying the sustainability of the black tent of nomads of Western Azerbaijan is the recognition of the main features of this type of architecture and its ideal compatibility to the nomadic lifestyle (Table 1) and climatic conditions of the region (Table 2)

Table 1: Black tent adaptation with nomadic lifestyle

Assertion	Prove
A shelter to provide the basic needs of nomads:	<ol style="list-style-type: none"> 1. To provide shade from the sun 2. To protect from cold, wind, sand, and dust 3. To provide privacy for the occupants ^[2]
Lightness & Portability	Can be carried easily by pack animals
Flexibility & Changeability	A black tent can be stretched or curtailed, narrowed or elongated, simply by adding more cloth widths and more tent poles. ^[3]
Simple to construct (easy to pack up and set up)	Convenient setting up and packing up: Nomad men can set up their tent in less than 20 minutes.
Inexpensive	Cost-effective for the following reasons: <ol style="list-style-type: none"> 1. Roof: made of goat hair which the women use for weaving 2. Poles: made of the existing native trees 3. Wall: made of small branches and twigs collected nearby and woven together by the women 4. Living amenities inside the tent: Carpet, back rest pillows, etc. are all woven by the women

ARP.10

Simple to repair	The nomads have sufficient skill in repairing the black tent as required and do not need any specialized workforce.
Practical (Multifunctional architecture)	Every nomad tent is a complete living quarter including specific places for sleeping, eating, entertaining guests and cooking. There is even a space for the goats – very small in measurement and dimensions, but with a high amount of efficiency.

Table 2: Black tent adaptation with climate and environment

Assertion	Prove
Harmony with surrounding landscape	The roof looks like a miniature mountain range with spirelike peaks; the tents appear to imitate the mountains in which they reside.
Renewable & non-polluting energy	Natural ventilation Use of natural light
Flexibility & Changeability	A black tent can be stretched or curtailed, narrowed or elongated, simply by adding more cloth widths and more tent poles.
Environmentally friendly material	1. Roof: goat hair 2. Poles: made of the existing native trees like poplar 3. Walls: reed mats made of thin wood of apple trees & goat hair
Proper orientation	In accordance with sunshine and wind

RESULTS AND DISCUSSION

The results of this analysis confirm the assertion that the architecture of nomads of Western Azerbaijan is not only well-suited to their nomadic lifestyle, but is also highly adaptive and compatible with the climate of the area. The reason for citing two separate angles is the fact that these people were virtually forced to have a different type of architectural style due to their nomadic living conditions, which has had the potential to be compatible with that type of lifestyle by every possible aspect. On the other hand, it is evident that the reason for its century-long existence has been its ability to adapt and adjust naturally to its surroundings.

CONCLUSION

Perhaps today more than ever before, modern architecture needs to learn a few nomadic techniques of architecture. Although we often regard our modern architecture as ‘high technology,’ in most instances it displays less durability and endurance. Understanding and analysing the housing of people living in this area, which is considered to be one of the oldest nomadic territories, could further help us in diverting more attention to the role of sustainability in today’s architecture.

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DESIGN OF A KIT-OF-PARTS STRUCTURE FOR THE INTERIOR CONFIGURATION OF A SPACE HABITAT

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INTRODUCTION

The presented work was one part of my diploma thesis *IN SITU—design of a self-sufficient human settlement on Mars* which was presented in November 2015. I chose an extraterrestrial topic for my thesis, because I am particularly interested in: (1) how sustainability and self-sufficiency can be achieved under extremely challenging technological, environmental and psychosocial conditions, (2) how spatial resources can be most efficiently used and (3) the importance of social and cultural dimensions in a field that is mainly dominated by technological and financial resources.

Space agencies and private organizations worldwide have plans for human missions to Mars. The sustainability of such missions will be greatly affected by crew health and performance as well as the ability to deal with a very limited frequency of cargo deliveries. Therefore the maximization of (perceived) spaciousness, flexibility and adaptability to varying situations and individuals as well as the possibility for development will be pivotal in the design of such space habitats.

SIGNIFICANCE AND APPROACH

Due to launch mass constraints and the challenging environmental conditions of Mars, the first crews to land on our neighbor planet will be confined to very limited habitable space. They will require constant sheltering by pressurized habitats, vehicles, or space suits. Meanwhile, the micro-society of a Mars base will be characterized by intense contact with a small number of people, while the diversity of one's social relationships and roles reduces^{[1] p. 10, [2]}. These circumstances can lead to acute or chronic stress and impede on crew health and performance^{[1] pp. 11 ff.}. Consequently, habitability is critical in the success of such a Martian outpost. Most careful interior configuration and efficient use of the extremely limited habitable volume is essential. As the first crews for such missions will likely come from a demographically and culturally diverse background, the social and cultural dimensions have to be considered carefully in the planning of such habitats^{[1] p. 145, [3]}. For a better understanding of those issues an interview with Astronaut Franz Viehböck has been conducted about living in a confined, reduced-gravity environment.

The presented design aims to enhance habitability by respecting the astronauts' needs and providing possibilities for places to be alone, varying degrees of interpersonal contact, auditory privacy, concentrated working and individuality within very limited space. It is intended to facilitate reconfiguration and to endow the users with as much freedom as possible to customize their environment. Crew quarters can be arranged to suit and reflect the individual user. Moreover, they should not only function for sleeping, but also as retreat, and enable private communication and concentrated working^[4]. Expected activities of the crew were analyzed to test and demonstrate the adaptability and flexibility of the interior configuration.

RESULTS AND DISCUSSION

The design comprises a basic mounting structure and interchangeable elements e.g. crew quarters, stowage racks and recreational facilities. This kit-of-parts approach increases flexibility and durability, as the elements are demountable, reusable, easily replaceable and can be assembled in a variety of ways to suit the users. This can bring about a maximization of actual and perceived space within a very limited habitable envelope. Moreover, it facilitates a potential development and expansion of the habitat into a small settlement. Although the original titanium elements are delivered from Earth, in due time and given the necessary facilities, those elements could even be produced from local materials, consequently increasing sustainability of the system.

In the personal, adjoinable and soundproof crew quarters the users will be able to control illumination, air conditioning as well as color of the interior surface. Rearrangeable furnishings will increase perceived space and promote psychological redefinition of areas. Additional private units for temporary use are devised for recreation and private conversations. Virtual reality will provide a personalized interface for each crewmember.

CONCLUSION

The presented design allows for very efficient use of the scarce spatial resources on a Martian base. It promises to be an efficient measure to increase sustainability by enhancing living and working conditions as well as providing crew autonomy in the usage and arrangement of habitable space.

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Figure 1: Mounting structure with crew quarter.

**CONTEMPORARY VERNACULAR – TRADITIONAL INDONESIAN BUILDING
PRINCIPLES IN 21ST CENTURY ARCHITECTURE**

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INTRODUCTION

The traditional architecture of the Indonesian archipelago is probably one of the most diverse in Southeast Asia, as a remarkable amount of cultures and hence building traditions evolved almost isolated from each other, over centuries. Those typologies are extremely well adapted to culture, climate, and local resources and therefore presenting a variety of possible solutions for socially and ecologically sustainable construction methods in the complex hot and humid tropical climate zone. Yet those local solutions are increasingly disappearing in favour to westernized building typologies, including the replacement of organic construction materials with synthetic substitutes.

The research focuses on the motives for those transformations and the question for a possible sustainable and healthy alternative, by integrating traditional principles into contemporary building tasks.

CHALLENGES AND SOLUTIONS IN INDONESIAN VERNACULAR ARCHITECTURE

After a history of colonization, suppression, following independence and globalization, those events had a huge impact on not only society and economy, but as well on the building sector. As industrial building materials became cheap, easily available and well promoted, they are currently more and more replacing traditional construction materials and therefore provoke a subtle disappearance of the elaborated methods of Indonesian vernacular architecture. Especially in the rather rural and suburban areas the yearning for modernisation and catching up with the global world is resulting in a rapid transformation towards constructions, which are mostly unsuitable for the tropical climate. Due to the inadequate use of “western” materials and building typologies, which originate from an entirely different background, this change results in unhealthy, uncomfortable and hardly sustainable residential architecture. The efficiency of the local constructions is directly linked to the materiality and synergy of its components, therefore one has to be careful to avoid an unsuitable replacement with substitute materials, such as corrugated iron for thatched roofs, or reinforced concrete for timber walls.

Following on-site documentation on the islands of Sumatra, Sulawesi and Bali, the aim of this research is to identify the performance of vernacular design principles and craftsmanship in those economically, environmentally and culturally differing regions. Further investigations on the current material and typological changes in the rather traditional rural areas, as well as on the motives for such transformations offer a deeper understanding of the driving forces for those culturally complex processes.

Regarding the long tradition of building local, there are currently tendencies towards integrating, supporting and improving traditional craftsmanship and materials and combining them with local knowledge and modern technology. To mention a few, some popular adopted principles are microclimatic improvement by the use of natural cross ventilation, e.g. through thatched roofs and permeable walls, the elevation of buildings, the use of large roof overhangs for shading and experiments with local organic building materials.

RESULTS AND DISCUSSION

The individual motives for changes in construction methods, especially regarding unregulated settlement architecture, are the result of a complicated chain of historical events, westernization, globalization and as well recent changes in culture and ecology. Nevertheless one of the most crucial factors for such choices is the perception of the family home as a prestigious object, a symbol of wealth, status and cultural traditions. In the housing sector traditional building concepts and materials are diminishing in their prestigious value, as they interfere with the image of a modern way of living.

At the same time traditional elements and local materials are being rediscovered and integrated into contemporary architecture, still mostly romanticized tourism and gastronomy projects, but also often in an innovative combination with modern technologies and thoughtful use of both natural and synthetic building materials. Following international attention and further spreading of such concepts, they could act as role models for an authentic and sustainable Indonesian architecture, which provokes a modernisation of the term “vernacular”, embraces the traditions and develops them into a contemporary language.

Interestingly enough, it appears that especially craftsmanship is an indicator on how closely intertwined architectural forms are with traditions, symbolism and identity. No matter how modern a building gets, no matter how materials and construction methods change, there will hardly be an Indonesian house without elaborate details, ornamented facades, or at least attached symbols and crafted interiors.

CONCLUSION

There are various ways to translate traditional and local design principles into present day architecture, yet this is often only reflected through a simple application of vernacular items to concrete walls or copying traditional buildings for the creation of romanticized tropical utopias. Without an understanding of the great technical value of the diverse vernacular art of building in Indonesia and the strong connection of indigenous architecture with culture and environment, there cannot be an authentic contemporary building language.

A sensitive contemporary interpretation of vernacular principles could open the discussion for the future of Indonesian architecture, as this trend is producing prototypes for a sustainable Indonesian architecture, which is at the same time respecting traditions and promoting craftsmanship, but still embracing modernisation and development.

INPUT DATA QUALITY FOR BUILDING ENERGY CERTIFICATION: RECENT PROGRESS IN THE EDEN PROJECT

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INTRODUCTION

This contribution documents recent progress of the 3rd-party funded EDEN project (**E**ntwicklung einer strukturierten und fehlerminierten **D**atenaufbereitung und **D**okumentation für **E**nergieausweise, FFG-Grant 850101), which explores uncertainties and quality of input data assumptions for building energy certificates. The European Union introduced building energy certification about 15 years ago^[1]. Each European state was requested to add energy certificates to their national legislation. Correspondingly, in Austria energy certificates are stipulated by law since 2006^[2]. Additionally, a set of rules and guidelines were published^[3]. These encompass, rules for calculation, minimum thermal quality of building components for new buildings, and maximum permissible heating demand for new buildings and major retrofits. Moreover, default values for existing building constructions of unknown assembly are included based on the year of construction. However, the existing guidelines do not comprehensively address the input data collection process and the derivation of Key Performance Indicators. Due to different practical approaches in certification and interpretation of guidelines, as well as prevailing uncertainties regarding input data and corresponding assumptions, the explanatory power of energy certificates is reduced. Moreover, regular observations show that buildings are certified differently (different results regarding key performance indicators) by different certificate issuers, even if the same set of input data was utilized. Lacking reproducibility is highly problematic, given that building permits and retrofit subsidy grants are often based on the results of energy certificates^[4]. Two major objectives are pursued in the project: i) Performing a sensitivity analysis on different input data assumptions and their effect on resulting key performance indicators within the energy certificate calculation. This encompasses gathering input data that is often prone to errors, and to define a range for the input data variance. Using a sample building database, which includes buildings of different size, usage, and age, the effect of input data variance can be explored comprehensively. ii) Development of a standardized and accurate documentation of input data for energy certificates to ensure a higher degree of reproducibility of energy certificates. Such documentation would improve the legal currency of energy certificates, and reduce errors and manipulation risk.

METHODOLOGICAL APPROACH

The methodological steps being performed within this research are illustrated in Figure 1 (In this contribution we show the categorization of potential input uncertainties, which pertains to (iv)).

RESULTS AND DISCUSSION

The identification of potential input data uncertainties is performed following a two-fold approach: i) Empirical observation of energy certificate issuers during calculations of predefined case study buildings; ii) Analysis of the input data required for energy certificate calculation in software tools. Results suggest that categorically, input data uncertainties (and occasionally, mistakes) pertain to 6

aspects (Figure 1). Unknown thermal properties of building components often require the use of default assumptions [3] for thermal properties of constituting building components of the assessed building in building energy certification. For the period between 1960 and 2007, the default values correspond with the minimum requirements of the corresponding federal state at this time. As the retrofit measures that should be proposed with the energy certificate basically depend on the calculated heating demand requirement, it is of interest to investigate the impact of the different default value assumptions on the results of energy certificates. Figure 2 illustrates both the thermal envelope of one sample building and results for an assumed construction time of 1985. Resulting heating demands range from 119 to 259 kWh.m⁻².a⁻¹, which can be considered highly critical.

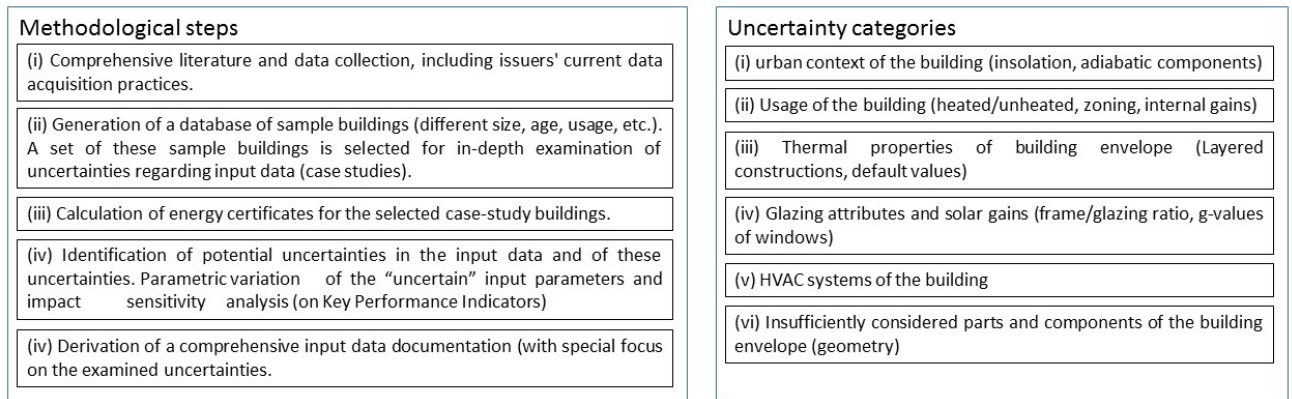
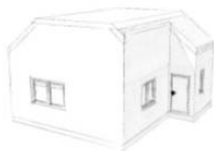


Figure 1: Methodological steps (l.) and a first categorization of uncertainty categorization regarding input data (r.)



Federal state	Heating Demand [kWh.m ⁻² .a ⁻¹]	Class (Energy certificate)	Heating demand expressed in % of overall average of all states	Mean weighted U-value of the building's envelope [W.m ⁻² .K ⁻¹]	Mean U-value expressed in % of the overall average of all states
Burgenland	258.84	G	164%	1.278	161%
Kärnten	146.31	D	93%	0.740	93%
Niederösterreich	156.30	E	99%	0.788	99%
Oberösterreich	119.34	D	76%	0.609	77%
Salzburg	124.43	D	79%	0.634	80%
Steiermark	146.31	D	93%	0.740	93%
Tirol	119.34	D	76%	0.609	77%
Vorarlberg	134.82	D	85%	0.684	86%
Wien	215.28	F	136%	1.071	135%
Average	157.89	E	100%	0.795	100%

Figure 2: Sketch and results for a sample building.

CONCLUSION

Results of this study, as well as comparable recent international efforts such as the QualiCheck-Initiative [5] underline the importance of the thorough and scientifically rigorous exploration of the uncertainties in building energy certification.

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CONCEPTION OF LOW RISE TIMBER BUILDINGS SUPPORTED BY THE ASSESSMENT OF THE ECOLOGICAL FOOTPRINT – FOCUS ON GREY ENERGY

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INTRODUCTION

Developed countries currently account for the majority of the world's existing building-related energy demand and CO₂ emissions. In the European Union, the construction sector is the largest consumer of raw materials as well as construction and demolition activities account for about 33 % of waste generated annually [7]. Buildings use 40 % of the world’s materials and energy and 55 % of the woodcut for non-fuel uses is for construction [8].

The concept of sustainability has firmly established itself in the building design over the recent years. Several methods and policies contributing to reduce the demand of energy during the period of use were developed. Over time, the building standards improved from low-energy-buildings to passive houses to zero-energy-buildings to even plus-energy-buildings.



Figure 1: Contemporary ceiling structure in comparison with former design, Venice Biennale 2014 [2]

The focus on the period of use of buildings led to an increased consumption of building materials, especially insulation products and technical building services. (Figure 1).

Due to these measures, excellent energy efficiency characteristics, even energy gains as an annual average of usage, the remaining life-cycle periods become significantly more important.

The necessary input of primary energy (particularly the fraction of non-renewable fossil energies, which currently accounts for 80 % of the worldwide energy consumption [1]) and the corresponding environmental impact (e.g. as emissions) of manufacturing, assembly and disposal phases of constructions require more and more attention. (Figure 2)

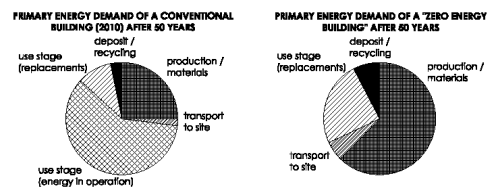


Figure 2: Primary energy demand of a building, edited source [3]

“GREY ENERGY” OF BUILDINGS

The building energy standards are defined by the amount on **Primary Energy Input (PEI)** per square meter and year. There are currently no values defining the “grey energy” standard of the building, meaning the total energy consumed throughout the product’s life cycle from its production to its disposal (Figure 3). On average, a household in Europe consumes twice as much grey energy as direct energy (heating, light, electrical appliances, etc.). Building energy consumption in the use phase can be easily measured and the yearly average determined. The study of the quantification and potential classification of the grey PEI amount shows, that the different tolerable data calculations enable a heavy deviation of the values.

To reduce dependency on the non-renewable resources, it needs new alternatives especially in the construction sector. The demand can be relieved by recycling and substitution. Focusing on the reduction of the non-renewable Primary Energy Input (PEI_{ne}) in the life cycle of buildings - exempting the use phase, timber buildings offer interesting solutions. Wood as a sustainable and an ecological material has an excellent chance to be an alternative construction material in urban areas.

The renewable raw material wood is available in a sustainable way; the basic technologies are well known and good examples of wood-based building already exist.

The most PEI needed in the production phase (growing phase and drying processes) is covered by renewable sources. At the end of the service life (end of life - EOL), wooden products can be thermally recycled and this renewable primary energy substitutes the use of fossil resources [4]. Influencing factors are e.g. system boundary, logistic, allocation methods, drying process, disposal scenarios, or electricity mix (Figure 4).

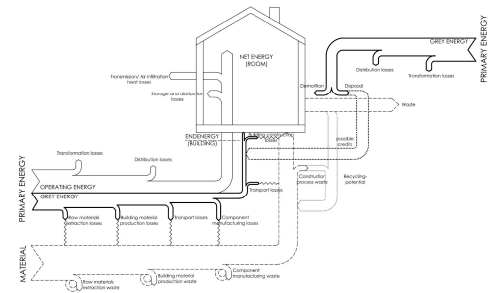


Figure 3: Primary energy input in life cycle of a building, edited source [5]

Different ecological databases are not the only influence on “grey energy” values calculations. As a consequence of the fact, that “grey energy” is saved in the materials and corresponding processes needed for their production, logistic, removal and disposal, the unit for grey energy, common used in the calculations makes difficult further comparison of buildings. Part of the study is to develop a new, objective grey energy unit for low-rise timber buildings.

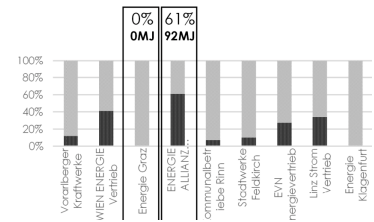


Figure 4: Supplier based mix in Austria 2014 (selected) - sawing process of 1m³ timber – non-renewable input on primary energy, data source [6]

CONCLUSIONS

Only after defining transparent marginal conditions and including of all relevant influencing factors, an independent comparison of buildings, structures, elements and materials is possible. For this reason, new, common definitions had to be specified within the study and made it possible, to define a grey energy benchmark.

The newly developed system shall be promoted through the initiation of case studies. Initiation of case studies could provide the possibility to collect substantial experience about the practicality and applicability of the developed systems. Any modification proved to be necessary at architectural and structural design stages may be reached as a result.

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A NOVEL APPROACH TO HIGH-RESOLUTION URBAN-LEVEL BUILDING ENERGY MODELING

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INTRODUCTION

New energy supply and management paradigms such as distributed power and heat generation, and grid-independent urban clusters have highlighted the necessity for accurate and high-resolution building-stock energy assessments. Such energy paradigms perceive the urban stock as an interconnected network of energy demand and supply nodes, allowing for more efficient allocation of resources and shared use of infrastructure, suited to the energy use patterns and sustainable energy harvest potentials of an assembly of buildings. For such planning, an overall understanding of the temporal and spatial distribution of energy demand and supply potential is essential. Realization of smart metering and large scale monitoring activities in near future are hindered by extensive investment costs and associated data privacy issues. In the meantime, computational methods which estimate the energy performance of the urban building stock based on available information seem promising to bridge the information gap. Bottom-up engineering models, EM, [1] are considered to be highly effective due to their independence from historical data and their capability to capture unprecedented changes. These models rely on building level performance assessment methods for the estimation of the energy demand of individual buildings. The precision and resolution of such models depend on the underlying computational engines. Presently, dynamic performance simulation is the most elaborate building energy assessment method available, which enables detailed investigation of occupant behavior, building's physical properties and boundary conditions with sub-hourly temporal resolution. However, they depend upon substantial amounts of data on buildings and extensive computational resources, hampering their implementation in large-scale inquiries. The present contribution reports on an ongoing research effort, which facilitates the employment of performance simulation for urban energy computing, by reducing the computational domain through automated GIS-based building sampling. Representation of the urban building stock through sample buildings or archetypes is not a new venture. However, a review of some contemporary energy assessment methods and their adopted sampling criteria revealed a frequent lack of explicitly stated arguments, evidence, or reasoning in support of the selected criteria. In most efforts, buildings are treated as isolated entities and their urban context is ignored [2].

METHOD

The ongoing research effort is concerned with the development of a bottom-up simulation supported urban energy model for the hourly estimation of heating demand in the city of Vienna, Austria. The case study involves a neighborhood in the city center including parts of the 1st, 4th, 6th and 7th districts of the city. The presented research project employs a well-known data mining method, Multivariate Cluster Analysis, MCA [3], for the identification of a set of buildings, reflecting the diversity of the area in terms of energy performance. The selected representatives are subjected to detailed performance assessments, the results of which are up-scaled to obtain the overall energy use patterns of the neighborhood. For the purpose of the MCA, a set of criteria was defined according to the main terms in the building's heat balance: Effective average envelope U-

value, effective window to wall ratio, thermal compactness, heated volume, effective floor height, daily area-related internal gains, daily air-change rate, ratio of annual daytime use hours to total annual use. Combined, these parameters cover various aspects of building geometry, operation and boundary conditions. Subsequently, available large scale data pertaining to the selected case study, including official and crowd sourced GIS data (e.g., [4]) as well as standards for the estimation of building heating demand (e.g., [5]) was collected. With the help of a plug-in, developed by the authors for the open source QGIS environment [6], the values of the above-mentioned variables were automatically computed. The resulting standardized data matrix was subjected to different MCA methods to identify groups of buildings with similar energy performance, from which a representative sample is selected. The plug-in is equipped with algorithms for geometric analysis and rule-based inferences based on standards and building properties, as well as methods for cluster analysis, optimal partitioning of buildings and selection of representatives. It will be made available on the open access QGIS plug-in repository upon finalization of the project. The representatives thus selected are to be simulated in view of their thermal performance. The results are then up-scaled to arrive at the energy profile of the neighborhood.

INTERIM RESULTS, DISCUSSION AND FUTURE RESEARCH

Three well-known MCA methods (K-means, hierarchical agglomerative, and model-based clustering) have been implemented on the data, which result in identification of 6, 7 and 12 building clusters respectively. As such the computational domain, initially including 750 buildings, has been drastically reduced, facilitating the employment of intricate performance simulation computations.

CONCLUSION AND FUTURE RESEARCH

The ongoing research effort presents a framework for the development of simulation-supported urban energy models. The developed GIS-based method allows for a systematic and automated selection of samples, representative of the diversity of the neighbourhood under investigation. The future research efforts involve performance simulation computations, upscaling of the results, and comparative analysis of the efficiency of the integrated MCA methods. Furthermore, a demonstration of the modelling capacities of the developed framework for the evaluation of the energy implications of various change and intervention scenarios, is planned. In this regard, potential collaborations with other doctoral researchers in the Department of Building Physics and Building Ecology, TU Vienna, in particular in the field of occupancy modelling [7] and micro-climate modeling are envisaged.

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INVESTIGATING THE 5TH FACADES IN VIENNA: A MODELISATION OF URBAN AGRICULTURE POTENTIALS

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INTRODUCTION

Increasing urbanization and the growth of the world population in the last 50 years generate important challenges for tomorrow. According to Dr. Dickson Despommier by the year 2050, the earth's human population will have increased by around 3 billion, and 80% will live in urban centers [1].

Our notion of green cities is not green enough. There's a necessity to readapt our consumption modes and rethink our urban spaces in order to ensure the long-term viability of our own environment. Urban agriculture could play a great role in this problematic.

Rooftop gardens provide a large range of benefits from enhancing biodiversity in the city to contributing to more sustainable processes including the ones necessary for food production and the improvement of quality of life [2]. The present work, focusing on the benefits of rooftop gardens in Vienna, analyses the existing surface opportunities within the city. The idea is to consider rooftop gardens as a key solution to convert linear city processes into a more sustainable and circular urban metabolism.

A SIMULATION OF INTENSIVE GREENING POTENTIALS

The investigation aims to develop a method using Geographic Information Systems (GIS) techniques and a parametric simulation that provides a responsive and effective planning strategy of the rooftop gardens network within the city. The research questions are: Where and in what conditions would rooftop gardens have the most significant influence on our existing urban system? How much profitable would it be (on a social and ecological point of view) and on what scale this analysis could be relevant?

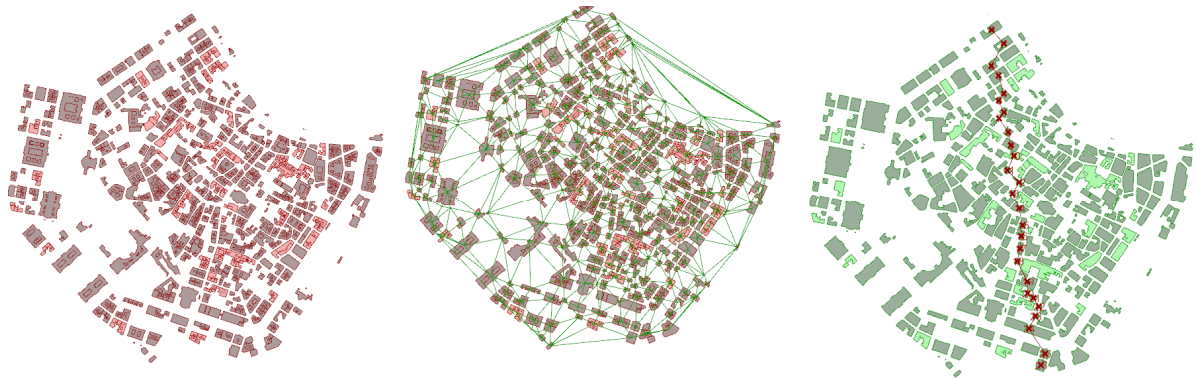
This interdisciplinary research is based on structural, ecological and social parameters: the rooftop lead angle of existing Viennese rooftops, the green corridors network expansion, the urban heat islands mitigation, the food and waste management and the social benefits. These different aspects will be analysed on different scales: the building block, the Viennese district and the city of Vienna.

To lead this study, the following method had been chosen: 1) Identification of all flat roofs and roof-terraces and quantification of the potential surfaces that could be converted into Rooftop gardens with Geographic Information Systems (GIS) techniques, 2) Implementation of the geofomation data into Grasshopper (a graphical algorithm editor tightly integrated with Rhino's 3-D modeling tools) in order to create a flexible modelisation of the Viennese rooftops, 3) Overlapping of the ecological and social parameters into the simulation model.

Last but not least, the last step of the study will be the identification of the green rooftops "Hotspots" and the quantification of their potential influence on our existing urban system (for this

purpose, prioritisation is based on the careful weighing up of the criteria such as priority needs and the potential parallel improvement of the benefits).

RESULTS



Picture 1: Green corridor analysis across the 1. District of Vienna connecting rooftops within 500 m [3]

The MA22 provides a first analysis of the rooftops, based on the lead angle of the surfaces (intensive greening is only possible when the surface lead angle is less than 5°). 1078,7 ha that is 21% of the entire rooftop surface in Vienna are adapted for intensive green roofs [4]. This potential is the equivalent of three times and a half the surface of the first district.

After importing the suitable rooftop surfaces into Grasshopper, the first step of the study was to identify the key surfaces capable to create large green corridor networks. Green corridors are designed to connect rooftop gardens located within 500 meters from each other. This represents the suitable distance for most common pollinators since their flight foraging distance is measured between 750 and 1500m [5]. The results show the shortest paths between each Viennese green nest and highlight the key spots.

CONCLUSIONS

These flying tracks constitute a significant element for ensuring long term security and resilience of urban biodiversity. This approach of the green rooftop corridors should be integrated in the context of the existing green spaces in Vienna. This would give a map of the biodiversity reservoirs and how they could be extended.

Defining the “hot rooftop spots” would contribute to a more efficient green urban strategy. It is now important to extend the study to other parameters: food production potential, urban heat islands mitigation, waste recycling capacity and social benefits.

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CORE BUILT

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IDEA

Core Built is an Idea that can make our Lifestyle more mobility. This can offer you a flat that you can deliver on every place where you will find a free cell in one of the Core Built. If you live in Boston and you would like to live in Vienna, you can order and reserve a place in one of the Core before your flight. Then you can transport your life block with truck, ship or plane. If you travel or make a trip this idea will give you a possibility to take your home with you. Also you will not even need to buy a parcel of land. You can stay there as much as you want.

APARTMENT

Each apartment will have an opportunity to get from 1 to 3 containers which are: 1B, 1BB, 1C, 1CC, 1D, 1E, 1F. Measurements showed in the schedule on this poster. Only types 1A and 1AA will not allow to put in, because the length is too big for building. The 12 meter size will make building wider and it is not necessary to reach this size. Core form is a box - 53.08x34.90m, plus two stair blocks - 8.00x6.00m.



Pic 1. Connection

PROCESS

When truck bring container a lifter will take it, then rotate in the direction where your spot was ordered. After that it will bring them up and drive it to reserved space. Then the wall, like a door, will open up and railings will open down. Container will get in and walls as also railings will close it. This system we need to make a good outside view. We do not need to install facade materials on the container, we will already have it on the facade of the Core Built and on the opened wall. With them we will protect our building.

TECHNOLOGY

The technology of this mobility and transportation type was already known by shipping and storing. Big container lifter trucks and cranes were used by them. Storages, like supermarkets storages, corn storages, medical storages and etc., were fully used a container system.

PORTABLE BUILDING

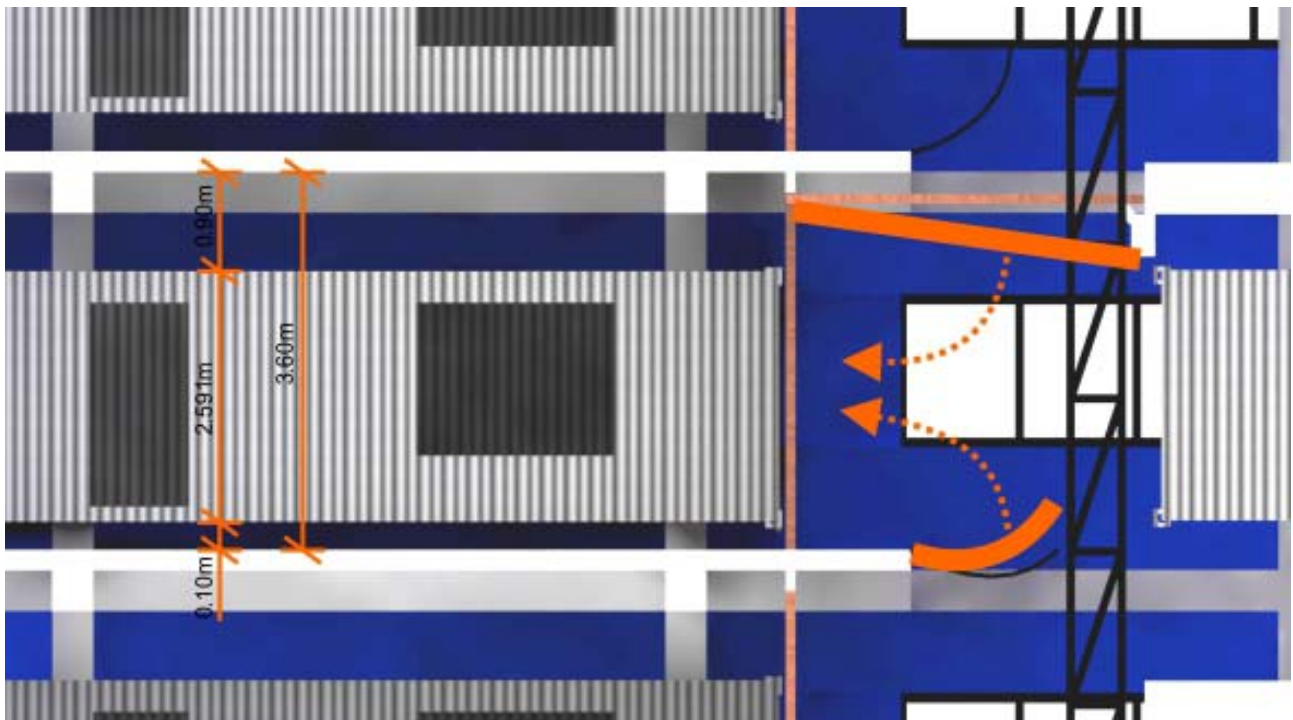
Portable building it is idea where you can move your home to the other place. This idea will move your home as a part of building to another building that will make easy transporting and cheaper homes. We will build one structure. The structure will stay for a long time and people will need only get theirs blocks inside. It is also will make easy a repair works. You will think more about interior then exterior. It is also a new step in portable buildings.

CORE BUILT

The Core Built can include 220 blocks. It means that it can be 220 homes by type 1 or 110 homes by type 2 or 73 homes by type 3. The good thing is that we will not give some priority of how many flats will we have with 1, 2, 3 types. Everybody will decide how much he need.



Pic 2. Lifter - photo from <http://www.poal.co.nz/>



Pic 3. Walls opening

URBAN GROWTH AND GREEN INFRASTRUCTURE IMPLEMENTATION: ASSESSING SPATIALLY AND SOCIALLY CONSCIOUS POLICIES

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INTRODUCTION

Direct impacts of climate change are environmental and physical with clear and strong repercussions on social and economic dimensions. Some of these impacts include increased heat temperatures (resulting in increased intense heat human mortalities and species migration), flooding due to extreme precipitation events (resulting in flooding with building and infrastructural damage as well as related mortalities), rising sea level (overflowing of developed coastal urban land resulting in lost property) and extreme variability of local and micro climates[1].

Urban and metropolitan populations will incur the financial, moral and temporal costs of these changes because, currently, more than fifty percent of the world population is residing in cities and mega-cities will to nearly 70% by 2050[2]. This results in expansion and/or densification of urbanized areas. As migration to urban areas is ongoing globally and the impacts of climate change are increasing, the need for resilient urban development is becoming increasingly important.

In the context of this research, green infrastructure (GI) is considered as important tool to enhance the resilience of the urban system in face of drivers of change - climate change and urban growth [3].

There is evidence that urban green space is under pressure due to densification processes such as infill and large scale projects developments[4]. Strategic green infrastructure planning and management can be very challenging under conditions of urban growth, since important ecosystem services are supposed to be delivered by limited green spaces. Green infrastructure planning can assist the traditional urban planning process, defining the lands for protection or restoration before and during expansion or the infill development takes place.

RESEARCH SUMMARY

In the first step the study areas of with the different types of urban growth are defined, and its vulnerabilities assessed. In the second, the limits of spatial resources and public understanding of GI elements and benefits are determined. The third step results in investigating appropriate GI strategies and proposing GI policies within the different types of urban growth (Figure 1).

Owing to GI's multi-functionality, there is no single science or discipline responsible for its implementation. GI relies on the theories and practices of several scientific and land planning professions, such as landscape ecology, social ecology, urban and regional planning, geographic analysis, information systems and economics.

EXPECTED RESULTS

The results from this research may identify where spatial opportunities for GI implementation under a urban growth process reside, what measures are socially applicable and what are the policy opportunities that are needed to advance the development of a vegetated green infrastructure network in the urban growth process.

There are different sorts of spatial opportunities expected to be find: surfaces that have a potential to become ecologically active vegetative surfaces but are threatened by current and projected urban

expansion, neglected vegetated surfaces across land uses not considered as part of an ecological system, surfaces within residential and commercial land uses and ecologically active tracts of land but with no protection for future services. Furthermore, green infrastructure elements and benefits evaluated by relevant stakeholders and groups of potential users will provide an understanding of what people will actually fund and use. Lastly, policy opportunities for implementing GI across different patterns of urban growth will be determined.

Framework	Topic	Results
Step 1: Initial conditions	Adaptation assessment	Vulnerability assessment in areas under different patterns of urban growth (urban infill, large scale projects) based on climate change impact and community character
Step 2: Limits of the system	Spatial assessment	Determining the spatial recourses in different areas of urban growth i.e. mapping of pervious surfaces and transformative impervious surfaces across the different land use classes
	GI values assessment	Relative values of GI benefits and GI spatial elements estimated by relevant stakeholders and users
Step 3: Enhancing the system	GI strategies and policies	Assessing the opportunities for socially and spatially appropriate strategies and policies for GI implementation in areas under different patterns of urban growth.

Figure 1: Research flow.

CONCLUSION

Framing GI planning through the systematic approach which conceptualizes a whole system of GI spatial elements, identifies coming climate and social challenges, and plans to integrate local policies with adaptation needs at the district scale is needed and proposed in the research. GI will be an effective adaptation policy when it is matched to the physical character of urban environments and the needs of communities they are intended to serve.

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GREENING IN AND ON BUILDINGS

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INTENTIONS

The worldwide projections show, that cities will grow within the next decades. In 2050 two of three human beings will live in cities. This causes increasing density of the buildings in urban areas. Green areas will decrease and be replaced by buildings. On one hand the advantages of dense cities are, that mobility can be reduced and infrastructure can be used more efficient. But on the other hand the liveability of big cities depend highly on green areas and plants. This causes a big challenge to planers and architects. Greened buildings can be a very good way to solve one of the biggest problems of growing cities in future. The area on roofs and facades can be used to increase plants and animals in dense cities.

This paper deals with the investigations carried out by a project in a school in Vienna which has been greened inside classrooms, the façade and the roof. The students and the teachers are involved into this research project. Different features of greened houses are measured and the project should explain the effects of plants on the buildings and its surrounding microclimate.



Figure 1: The green wall inside the biology classroom. Students setting plants.

CONTENT

The project is called “BRG7 Grün Plus Schule @ Ballungszentrum” and investigates the effects of plants on the buildings and its surrounding microclimate.

One standard classroom (Figure 2) and the biology room (Figure 1 and Figure 3) are greened inside. Also the



Figure 3: Students working on the green wall in the biology classroom.

façade of the building is greened outside (Figure 4) and the roof will be greened within the next weeks. The students and the teachers were involved into the project from the very first. They helped to set the plants and to classify them. There are several projects in the school that stimulate the children to be part of a scientific project.

In the greened classes the humidity, the temperature and the CO₂-concentrations of the air are measured. Also the demand of water and electricity, that is used by the green walls are measured. Before the plants



Figure 2: Working together on the green wall with students of the school.

were set, the noise inside the classrooms and in other areas of the school, which have been greened, had been measured. Also the dust was measured before the greening. Next measurements of the noise and the dust are planned in near future. Then it will be possible to compare the data from before the greening with the data which were measured in the greened rooms.



Figure 4: Greened Façade at the yard side of the school.

The greened façade is also investigated. Its heat flows and temperatures on its surfaces (inside and outside) are measured. The same parameters are measured on this façade on a not greened area. Based on this parameters the thermic insulation of the greened part of the façade can be compared with the not greened part.

RESULTS, DISCUSSION AND CONCLUSION

Concerning the noise it is expected, that the reverberant sound is getting shorter because of the plants. Especially leaves with a big surface should reduce the reverberant sound. As the influence of the plants on the noise depends very high on the leaves, the second noise measurements will be taken in spring, when all the plants have leaves again ^[1].

The CO₂-concentration is already measured frequently. First results show that the high concentration levels (above 2.000 ppm) can be reduced because of greening. It is important that the number of students in the classrooms are considered in the evaluations.

The thermic insulations of the façade raises because of greening systems. This can be said based on the measurements of the first winter. The benefit depends on the construction of the wall and the components of the greening system. In this case a benefit of the U-value around 20 % has been measured.

It is important to say, that the measuring period is very short yet. The measurements will continue within the next two years. This causes that the results of this project might change within the next weeks and months.

Acknowledgement: The project is GrünPlusSchule funded by BMVIT/FFG und BIG.

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**WHERE, WHO AND HOW MUCH:
EXPLAINING REGIONAL CHOICES FOR WIND POWER LOCATIONS**

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IDEA AND MOTIVATION

It has become urgent to not only decide on energy targets but to actually *reach* them. The Intergovernmental Panel on Climate Change warns of unforeseeable consequences of climate change. However, the realisation of climate and energy targets is delayed. This has been recently moved into the center of attention with the Paris Agreement from December 2015 that had pointed out the “*significant gap between pledges and results*” [1]. This again leads to lively discussions on the legitimate role of spatial planning as a supportive or restrictive influencing variable with respect to achieving climate and energy targets. Many doubt if existing planning systems and instruments have sufficient adaptability for the increasing demands of energy transition [2].

SUMMARY OF PHD RESEARCH

This PhD thesis enters this field of tension between introduction and realization of climate and energy targets by carrying out an institutional analysis on the subject of implementation of wind energy in European urban regions. Wind energy has developed from a niche technology to a globally successful industry within two decades [3]. Future expansion plans project unlimited growth until 2030. This development imports important practical experiences in dealing with emerging renewable energy technologies that are essential for planning purposes. The applicability of these experiences from wind energy to other renewable energy technologies has been discussed [4]. This work takes the position that organizational aspects are most important for renewable energy dispersion and less so the technology itself. In this context, planning for renewable energy is more than the territorial assignment of potential sites. It is rather the process-oriented task to realize energy targets by coordination of single actions of various actors in a specific environment over an extended period. Planning institutions cannot prescribe actions promoting renewable energy but rather propose directions. This guidance requires a strategy that goes beyond the formulation of a strategic energy target or “Leitbild” by a sufficient extent of governance capacity.

RESEARCH AIMS AND RESULTS

Aim of this thesis is therefore to explore the governance capacity of planning instruments together with their related decision structures in the implementation of wind energy targets. The research layout derived from actor-centered methods of the social sciences and from policy analyses. It is based on intensive multiple case study analysis. The unit of action is regional planning; the selected regions of analysis are situated in Austria, the Netherlands and Belgium. Conclusions are derived with respect to wind energy growth, resource-aware treatment of land and public support. To test the transferability of the results, a fourth region of analysis has been selected in Austria. In the last step, conclusions are compiled and put into relation to other emerging renewable energy technologies. The expected outcome of this thesis is practice-orientated by recommending fields of

actions for planning organizations relating to structures, processes and instruments of wind energy planning with results transferable to other emerging renewable energy technologies.

INTERFACES WITH OTHER TU-BASED RESEARCH ACTIVITIES

This doctorate is part of the doctoral college "Energy and Resource Awareness in Urban and Regional Development " (TUW) that aims at strategic planning for an energy-aware spatial development at different spatial levels (scales) by combining problem-based positive analysis and approaches with planning and normative conclusions. EWARD started March 2014 with 10 PhD students.

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PARIS POST-OIL: ENERGY CONSCIOUS URBAN INFILL DEVELOPMENT

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INTRODUCTION

The effects of climate change through energy consumption and emissions on urban life can no longer be ignored.^[1] Thus we are creating post oil scenarios using Paris as a case study to simulate the transition from fossil fuels to renewable energy as well as reduction of path distances (“city of short distances”) in order to find out more about how urban planning can influence developments incorporating the idea of reducing primary energy demand and emissions. These scenarios include actual urban development and master plans as well as detailed test planning for certain neighbourhoods.

Based on these scenarios we analyse the effects of urban planning on energy and environment by developing a combination of methods for creating a decision and planning support tool.

Scales, accessibility and morphology are inextricably interwoven. Only a well-functioning system across scales can be highly efficient. Consequently, we offer a multi-scalar approach on the city using the method of the geometric street network modelling in combination with a lifecycle assessment method.

Paris post-oil is as much about the future as it is about the past. We analyse the urban fabric starting from the baroque grid via Haussmann’s interventions until the implementation of high-ranked road networks installed for automobiles during the 20th century^[2] in order to learn more about the potential of robust and adaptive patterns and how to use them for creating highly efficient, walkable neighbourhoods for future developments – in the sense that every vision of the future is based on a vision of the past.

METHODS, DATA AND ANALYSIS FOR SCENARIO DEVELOPMENT

Our scientific work has the aim to synthesize on future potential development scenarios for big cities based on the case study of Paris. This is directly linked to energy conscious urban planning concepts: Which places have the potential for interventions and how to deal with existing urban structures being hierarchical ordered? We are focusing on walkability and, inter alia, energy efficiency. Taking Paris as an example, we analyse how its urban system has evolved and which structures have remained most robust and have stood the test of time (shifting centres, connectivity, accessibility).

Paris, *intra muros*, is the city with the highest density in Europe (21.289 citizens/km²) and its metropolitan region (*unite urbaine*) is the second biggest besides London. Paris’ population grows approx. 50.000 per year. Prognoses say that in 2050 it will reach 15 million.^[3]

There is almost no potential for urban infill development in the historic core (and the actual city in the administrative sense). The surrounding urban structure (*banlieus* = suburbs) in the inner ring (*petite couronne*) is characterized by high ranked street networks like motorways and railway structures. Significant for the situation in Paris is the *Boulevard Périphérique* – the cities ring motorway, which was installed in place of the city walls from the 1950’s till the 70’s. It is one of

the most frequented streets in Europe^[4] (1.1 to 1.2 million vehicles per day) and a major barrier between the city and its suburbs.

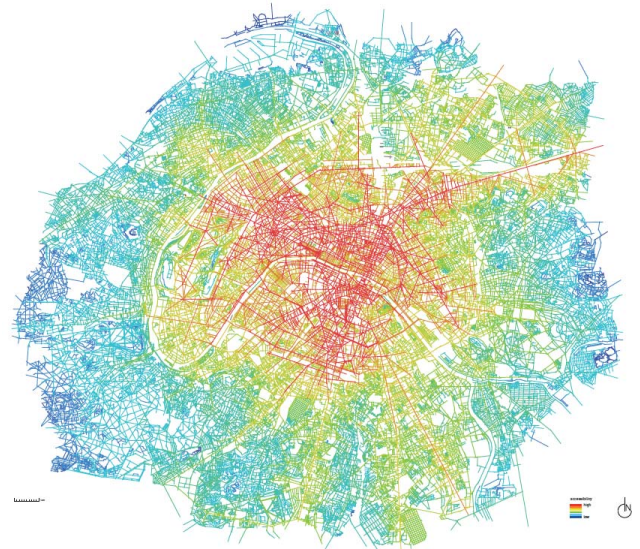
Our objective is to create a test scenario for potential urban infill developments based on the concept of emergence linked to walkability; post-oil strategies using the historic as well as the transformation potential of space-consuming structures in the centre of *Grand Paris* (the metropolitan region) designed by highway engineers^[5] during the 20th century. On a neighbourhood scale (local) the method of test planning (Scholl)^[6] will be applied. These very detailed urban scenarios can be extrapolated to other similar neighbourhoods and incorporated in the overall evaluation on a global scale (urban region). For the creation of the scenarios a detailed analysis of the status quo is essential. Thus we are analysing provided data (e.g. movement patterns, urban morphology, mobility and modal split, green space etc.) of the current status to preserve a multi-scalar approach.

In order to verify and compare the scenarios, different methodologies and special software will be applied: depthmapX (by Space Syntax) is a multi-platform software to perform different spatial network analyses. In the research-models it will be applied on a citywide and neighbourhood scale. urban scale. GaBi (by thinkstep) will be applied to compare and forecast energy consumption in various scenarios. For the first time we link the GaBi database with the Space Syntax model database in order to investigate, verify and understand parameters concerning: primary energy demand, CO² emissions, greenhouse effect potential, fine dust pollution, acidification potential, POCP. As one result a decision and planning support tool is to be developed.

This PhD research is supervised by Prof. Andreas Voigt and part of the EWARD doctoral college (Energy and Resource Awareness in Urban and Regional Development) and in close thematic consistency, not only with the members of the EWARD PhD college at TU Wien (Prof. Rudolf Giffinger) but also with UFR Géographie et Aménagement at Université Paris-Sorbonne IV, France (Prof. Anna Geppert) and the Faculty of Spatial Sciences at University of Groningen, the Netherlands (Prof. Claudia Yamu).

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Picture 1: Paris 2015 – Strategic pedestrian model, interaction global [INT N]

VISIONEERING THE LOW-CARBON FUTURES: THE CASE OF THE NORTHERN DOLOMITES

Chiara Andreotta

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INTRODUCTION

In order to implement public awareness and actions in face of Low-Carbon futures, spatial planning approaches oriented to communication and community building for actions are required. The intent of such approaches is to make communities act, also there where carbon emissions are not perceived as an urgent issue.

Strategic visions are potentially a solution as a comprehensive approach that transforms fragmentary information and ideas into meaningful messages and structured possible futures.

THE LOW-CARBON FUTURES AND THE DOLOMITIC ENVIRONMENT

The wide range of issues concerning the Low-Carbon future has been explored since several years ago. The output varies from global agreements, national and technical roadmaps or community handbooks ^[1-4]. Within the named documents the physical aspects of the spaces of the future, when mentioned, is the merely results of the physical asset of the technological aspects. Nonetheless how the spaces where we live our daily life may look like is rarely shown.

Exploring this characteristic of the future means envisioning the spatial setting of regions, city and territories to come. To meet this challenge, visionary planning approaches have not only a role in influencing the physical environment, but they can build civil support for possible futures. The discipline of strategic spatial planning enounces different possible future-oriented approaches among which the visioneering. Visioneering is a new methodology that has the purpose to combine the envisioning, hence imagining possible futures, and the engineering processes, hence the application of engineers' knowledge. The final intent is to draw strategic visions of the future and feasible path to support the walk toward it ^[5-11].

Concurrently decarbonizing the built environment requires to be conscious of the local contexts under which operate. The Dolomitic region (Italy) offers an interesting case study: is one of the most vulnerable spot to climate change in Europe due to the menace of natural hazard and, the threat at the economic system based on its geographical setting and natural resources ^[12,13].

Nonetheless, to which extent is visioneering effectively a methodology able to stimulate actions and improve awareness in the face of a Low-Carbon future in a remote mountain community?

VISIONEERING, A CHANCE FOR RESEARCH THROUGH DESIGN

The direct application of the visioneering methodology on the case study area of the Northern Dolomites, moves the research into a design practice. Hence work out territorial opportunities in form of design exercises bringing together the worlds of climate forecasting and energy analysis, with the world of creative envisioning.

The participatory events applied along the design practice are the devices with which evaluate the research. Namely the evaluation is based on the assessment of the social learning process happening during the events. The four dimension of social learning that are expected to evolve are: cognitive knowledge, mutual understanding, dealing with complexity, joint interactions.

RESULTS AND DISCUSSION

The first empirical results show that in this case study area a high social capital is available, together with natural resources for the production of renewable energy. Nonetheless a low degree of common actions for the implementation of a Low-Carbon energy system occurs. As a consequence the second part of the empirical research is focused on the implementation of a community building development, in order to stimulate common actions in the face of Low-Carbon futures.

CONCLUSION

The expected final result of the research is an adequate critique of the new spatial planning methodology visioning, elucidating its adequacy to the complex topic of Low-Carbon future. Therefore is expected a list of recommendations on the visioning that gives it a more efficient and clear application formula.

Nonetheless a possible future vision for the case study, and its applicability to similar realities, is the research output.

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MISCHUNG: POSSIBLE! CONTEMPORARY MIXED USE IN DENSELY BUILT URBAN QUARTERS

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The topic is based on the Smart City Demo-project “Mischung: Possible!”, funded by the Austrian Climate and Energy Fund (<http://www.smartcities.at/stadt-projekte/smart-cities>).

Mischung: Possible! The CHALLENGE of FLEXIBLE CAPACITIES

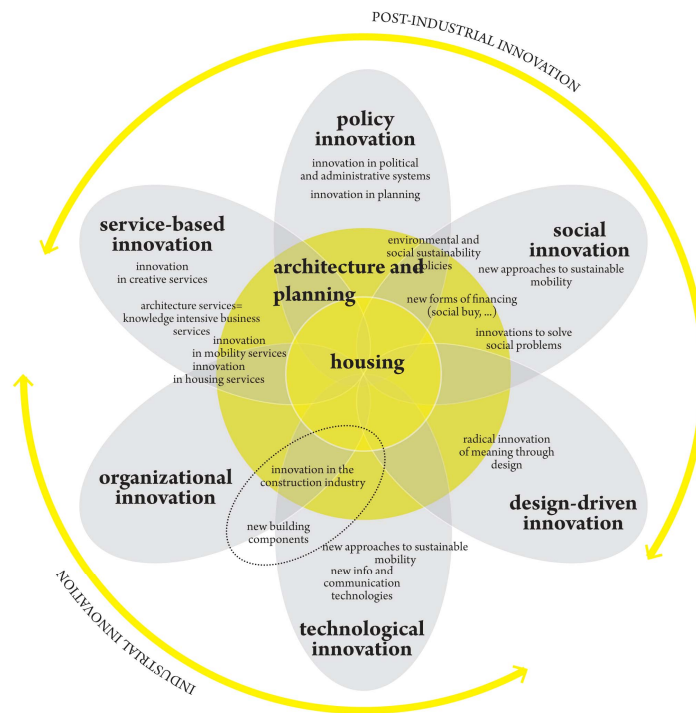
Flexible capacities cater for a wide range of uses and therefore potentially play an important role in urbanization processes, both in ecological and economical terms and from the point of view of the current societal challenges (demographic changes, new working conditions and spatial organization, real estate). Yet few measures are available to achieve flexible spatial qualities in new urban developments responding to the societal and technological differentiation. Though these qualities are aimed at in many urban concepts, their actual implementation is blocked by a variety of hardly researched barriers. In the context of the ‘Mischung: Possible!’ research, mixed-use has been understood as a basic condition for achieving flexibility of use at urban scale.

Mixed- use is not necessarily positive per se but much depends on the kind of mixed use and how the spatial and social components, mixed together, actually contribute to the long- term qualities of the urban environment and its capacity to adapt. Key terms like 'use' and 'work', cultivated by western modern societies over centuries, are shifting towards new destinations today. There is uncertainty about the real future of work and the figure of the user in a more and more global, commodified and technological world. There is uncertainty as well about the future political forces and the future public opinion. What we see for now is, that both the growth and the technological paradigm, as the predominant orientations at the macro level are failing apparently at steering society towards a sustainable way of life. In this perspective, the aspect of affordability in the context of mixed use and its flexible capacities represents a core area of research. Affordability is essential with regard to the mixed-use development process as well as to the phase of use and re-use of the spatial capacities. In combination with accessibility, affordability is important for the distribution and redistribution of opportunities in the city and is therefore substantially responsible for the spatial arrangements as an expression of the cities social structure.

Mixed use: which innovations?

To come into play with implementation, the contemporary framework of mixed-use urban development needs to be presented as an environment where the planning of the physical structure (the 'hardware' of mixed use) more and more becomes intertwined with the need for the development of appropriate soft tools and processes (the 'software' of mixed use). Good ideas about flexible housing and building design are available, yet until now their implementation remains highly unsatisfactory. Especially immaterial aspects connected to flexibility and mixed-use, of institutional, instrumental and process-based nature, tends to be disregarded. These immaterial aspects include contractual aspects, right of use, planning use categories and regulations such as parking requirements, as well as formal and informal aspects related to communication and participation. It is therefore important to understand innovation in the framework of mixed-use urban development both in relation to these material and immaterial dimensions, moving beyond industrial notions of innovation, related to the technological and organizational dimension of

production towards post-industrial notions of innovation, related therefore to planning processes, social innovations, service-based innovations as well as the development of new meanings and interpretations of building typologies in relation to contemporary extended notions of 'use' and 'work'.



A further important perspective is the already mentioned differentiation between the potential of fine- versus large grained mixes. Fine- grained mixed-use, ensuring the provision of affordable workspaces, has been recognized as particularly important for ensuring the existence and development of small and middle enterprises as well as a relevant factor for the residential use quality and use-value, as well as in urban contexts. This differentiation, embedded in spatial and typological configurations as well as in economical set-ups related to affordability , relevantly contributes to the range of flexible capacities of these quarters.

Especially for these kind of mixed- uses, the project Mischung: Possible! is developing a series of **innovative models based on combinations of incremental and radical innovations both for what concerns spatial configurations as well as soft tools and processes.**

Research Field *Information and Communication Technology*

Chair and Reviewer:



Mecklenbräuer, Christoph
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Introduction

Physical "real-world" objects and devices, like sensors and actuators, are to be connected in large scale by the Internet of Things. Such objects and devices will gain new features and functionalities by large-scale networking. This development will profoundly affect many sectors of our society: health, urban planning, transport, telecommunications, government, as well as the arts, to name a few.

The technical challenges of the Internet of Things demand fundamentally new approaches to the processing of information in space and time:

Key aspects include the generation, compression, coding, transmission, dependability, archiving, storing, addressing, processing, search, and interpretation of information in the Internet of Things.

The diversity of the submitted abstracts highlights the broad scope and importance and its potential of application.

The topics under discussion range from the analysis of micro-electro mechanical systems to the characterisation of fading in millimetre wave channels and from three-dimensional scene reconstruction to smartphone-based crowdsourcing for performance benchmarking in mobile networks. They exemplify the creativity which thrives the design and developments towards the Internet of Things.

EFFICIENT SHAPE OPTIMIZATION FOR CONSUMER-LEVEL 3D PRINTINGPrzemyslaw Musialski^a, Christian Hafner^a, Leif Kobbelt^b^aE186/2 – Institute of Computer Graphics and Algorithms, TU Wien^bVisual Computing Institute, RWTH Aachen, Germany**INTRODUCTION**

Traditionally, 3d modelling in computer graphics deals with the geometric and visual aspects of 3d shapes. On the other hand, due to the growing capabilities of personal digital fabrication technology and its spread into offices and homes, 3d models are increasingly entering the physical world. Therefore, the physical properties of 3d models come into focus. For example, 3d-printed models should be able to stand balanced in a desired pose without toppling over, or should react in certain ways when external forces are applied, like spinning the object. It is thus desirable to have a method that allows the user to specify the intended physical properties of an object in addition to its 3d geometry, and which automatically takes these properties into account when generating a specification for a 3d printer.

FUNDAMENTAL OF THE PROBLEM

Our research aims at the development of novel methods for efficient shape optimization in order to allow everyday users to design desired 3d-printable geometric shapes in commodity software and hardware. For instance, in our last year's project we developed a method which optimizes a given geometric object in order to make it fulfil desired physical mass properties. In particular, the target functionality can be to make the object stand, spin, or even float. We solve the problem by adjusting the physical mass properties of solid bodies by slightly deforming their surface in their interior and possibly also exterior.

RESULTS AND DISCUSSION

The result of our work is an algorithm which efficiently optimizes mass properties of 3d shapes. For instance, Figure 1 depicts a 3d printed fish model whose interiors has been optimized in such a way that the fish floats beneath the surface of water in a controlled orientations. Our method is an elegant mathematical formulation which is very flexible and efficient. The details of the method have been accepted as full technical paper to the ACM SIGGRAPH 2015 conference, and it has been published in the ACM TOG journal [1]. More results of our method can be found on the project web page [2], and further it has been further mentioned in Austrian press [3, 4].



Figure 1: 3D fish model optimized for controlled floating.

CONCLUSION AND FUTURE WORK

The aim of our work is to investigate how shape optimization algorithms can be combined with computational design in order to enable everyday users to create their own 3d printable objects.

Currently we are working on further improvements of our method in order to extend its applicability to more than mass properties. We aim at an approach that can be utilized for various shape optimization tasks using varying shape parameterizations. In particular, we want to efficiently optimize natural frequencies, mass properties, as well as the structural aspects of solid body in a unified and efficient computational framework.

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GILBERT-TYPE VEHICLE-TO-VEHICLE PERFORMANCE MODELLING

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INTRODUCTION

We expect Intelligent Transport Systems (ITS) to have a strong beneficial effect on road safety. This potential stems from the ability to communicate informations about hazards, such as icy conditions or emergency braking maneuvers. Furthermore, such systems navigate dense traffic at higher speeds and fluidity than human drivers, which brings a positive impact on travelling times and fuel efficiency. A thorough understanding of the communication link performance is essential, as system failure in these applications can pose a direct threat to humans.

Our goal is to accurately model the packet-level performance of Vehicle-to-Vehicle (V2V) transmission, while retaining a manageable complexity of the model. Our model is validated using extensive real-world measurements conducted on a highway east of Vienna. A similar approach for the Vehicle-to-Infrastructure channel has been demonstrated in [1].

METHOD

The probability of the success of a packet transmission depends strongly on the instantaneous Signal-to-Noise Ratio (SNR) during transmission. Accurate modelling of the signal strength requires intricate knowledge about multipath propagation and the associated doppler shifts, which results in complex models that are highly specific to the given situations. Instead, we restrict our modelling approach to the measured packet-error traces and per-second mean SNR.

Within one second, the instantaneous SNR oscillates about the mean, and the packet-error behavior changes accordingly (see Fig. 1). We model this using the Gilbert model [2], which is a special case of a Hidden Markov Model (HMM). The Gilbert model allows to model a burst error process that alternates between error-free bursts and error-prone burts, using three parameters (see Fig. 2). P_{GB} and P_{BG} are transition probabilities that govern transitions between good and bad, while P_e defines the error probability in bad state. Using this model, we are able to abstract the underlying physical processes into three parameters, while retaining the important information about Packet Delivery Rate (PDR) and burst error length.

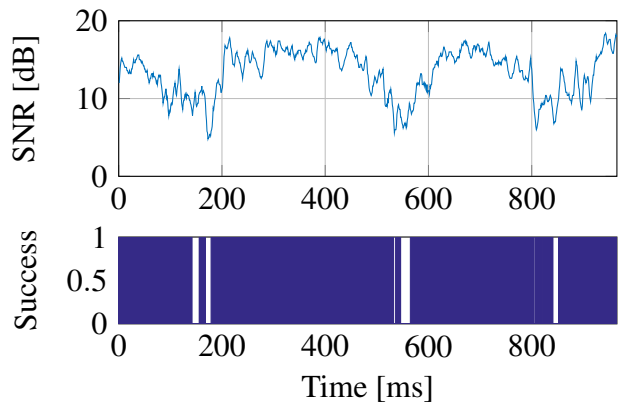


Figure 1: Instantaneous SNR and transmission success indicator for one second.

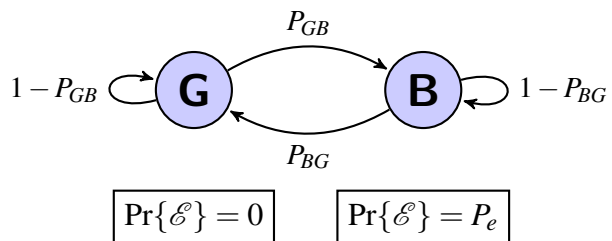


Figure 2: The Gilbert model has two states, good and bad. Transitions between the states as well as the packet errors are governed by the probabilities P_{BG} , P_{GB} and P_e .

From the parameters of the model, the PDR can be expressed as

$$\text{PDR} = 1 - \frac{P_{GB}}{P_{GB} + P_{BG}} P_e, \quad (1)$$

while the transition probabilities P_{GB} and P_{BG} govern the burst behavior. The parameters for a given mean SNR can be found by using the Viterbi algorithm [3] on the packet-error traces for all times with the corresponding mean SNR.

RESULTS AND DISCUSSION

Figure 3 depicts the results of the modelling approach, compared to the measurements. The average PDR is plotted against the mean SNR in the leftmost graph. The burst behavior is described by the probabilities of a correct transmission given the previous transmission was correct $P(C|C)$, and the probability of an error given an error $P(E|E)$. Both error and error-free transmissions are shown to be in fact bursty in their behavior, and the model we derived is able to capture this behavior.

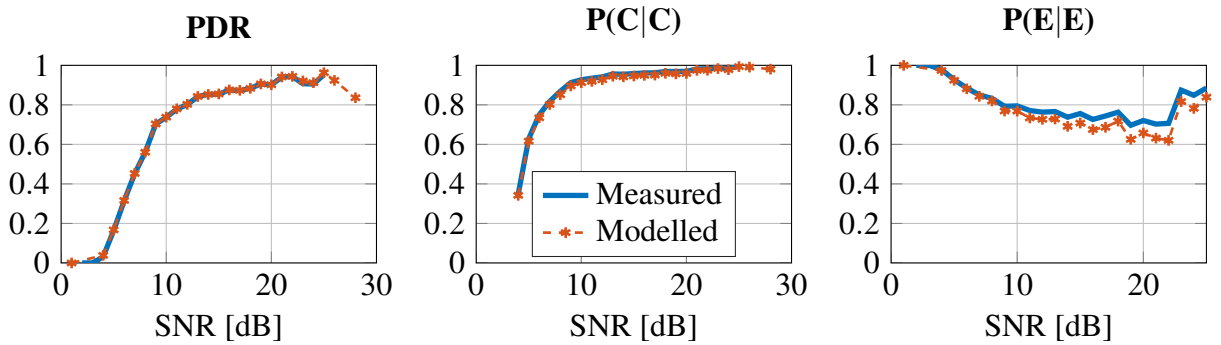


Figure 3: Results of the performance modelling. The figures show the average PDR vs SNR, the probability of a correct transmission given the previous was correct $P(C|C)$, and the probability of an error given the previous transmission failed $P(E|E)$.

CONCLUSION

Transmission over the vehicular channel shows bursty behavior, due to the time-varying nature of the scenario. Intelligent transport systems will have to account for delays due to temporarily unfavorable channel conditions. In this work we provide a low-complexity model that is able to provide this behavior based on real-world measurements, allowing reproduction in simulations.

In ongoing work, we look further into the time variance of the model parameters to capture more effects on the system.

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DESIGN OF INDUCTIVELY COUPLED BOOSTER FOR HF RFID CARDS

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INTRODUCTION

The market for Radio Frequency Identification (RFID) technology has extensively grown in the recent years due to its various applications and capabilities. High Frequency (HF) RFID cards operate at 13.56 MHz where communication is based on inductive coupling between a reader coil and card. The card is conventionally composed of a spiral coil which is galvanically connected to a chip. This galvanic connection increases the costs of card’s manufacturing in addition to reducing the card’s robustness against mechanical stress. In order to counteract these disadvantages, a module is used instead of the normal chip. The module contains a small coil and chip. Its manufacturing costs are considerably low, however, the coil’s dimensions are too small to operate on its own at the same performance limits as the conventional cards. Therefore, we propose the use of an additional circuit (booster) to efficiently transfer power from the reader coil to the chip on the module [1], as proposed in Fig. 1.

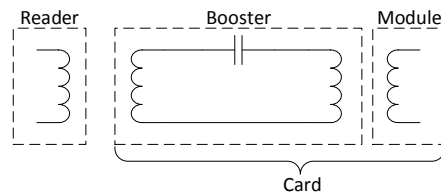


Figure 1: Overview of an RFID system with an inductively coupled booster.

BOOSTER DESIGN

We propose a booster composed of a capacitor and two coils; namely primary and secondary coils. Fig. 2 shows the structure of the booster, where points “1” and “2” are connected using a different layer. The module containing the module coil and chip is placed directly on top of the secondary coil. The booster has two main functions: Firstly, to increase the power harvested from the reader coil and secondly, to efficiently deliver this power to the chip. The first part is achieved through the primary coil which is the main contributor for the coupling between the reader coil and card. The secondary coil transmits the power efficiently to the chip because of its location directly below the module coil. The capacitor in between the two coils enhances the power delivered to the chip, since it creates a series resonance circuit.

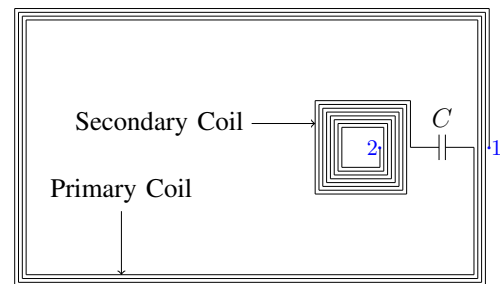


Figure 2: Booster: composed of primary, secondary coils and a capacitor.

SIMULATIONS AND MEASUREMENTS

To verify our design, simulations and measurements were carried out for a card with a 2 turn primary coil and dimensions 75 × 44 mm. The secondary and module coils are identical with 8 turns and 15 × 15 mm, in addition to a 100 pF lumped capacitor. The chip is not included in the

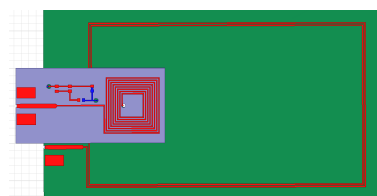


Figure 3: Non-galvanic HF RFID card created in HFSS.

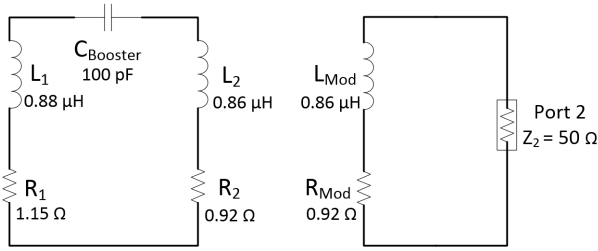


Figure 4: Circuit model for non-galvanic card.

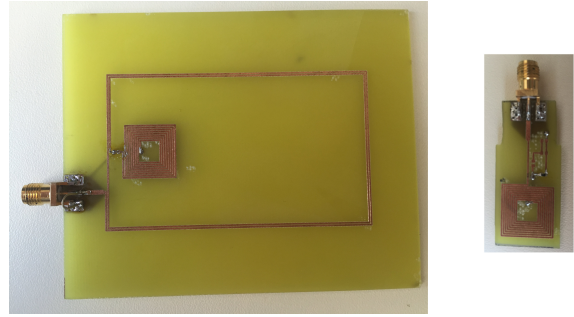


Figure 5: Manufactured booster and module coil.

current work. Two types of simulations were carried out: 3D electromagnetic field simulations using High Frequency Structural Simulator (HFSS) and circuit simulations by Advanced Design System (ADS). Fig. 3 shows the non-galvanic card containing primary, secondary and module coils, implemented in HFSS.

Furthermore, we created the equivalent circuit for the card as shown in Fig. 4, where all the resistances, inductances and mutual inductances are calculated by FastHenry [2]. The elements R_1 and L_1 are the equivalent model for the primary coil. Similarly, R_2 , L_2 , R_{Mod} and L_{Mod} are the elements for the secondary and module coils. The parasitic capacitances of the coils are not considered in this model, as they would have a low effect on the performance compared to the 100 pF capacitor.

The card was manufactured as shown in Fig. 5 and is tested through the use of a vector network analyzer. Port 1 is connected to the reader and port 2 is attached to the module. The distance between the reader coil and card is 37.5 mm. Since the goal is to maximize the power transferred from the reader to the card, S_{21} parameters are shown in Fig. 6, where there is a good alignment between the simulations and measurement. In order to highlight the improvement in performance due to the lumped capacitor $C_{Booster}$, we carried another HFSS simulation for the same design without this capacitor and it showed that the performance is decreased by almost 15 dB.

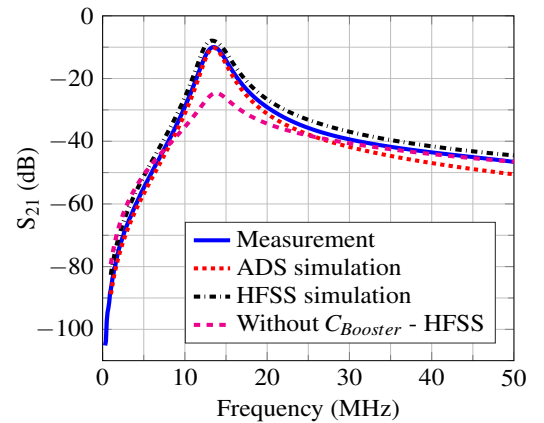


Figure 6: Magnitude of the transmission coefficient between the reader coil (Port 1) and card (Port 2).

CONCLUSION

The presented design provides good performance for non-galvanic HF RFID cards. The performance has been verified through circuit simulations, electromagnetic field simulations and measurements. The use of lumped capacitor in the booster enhances the power transfer (S_{21}) to the card by almost 15 dB.

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3D SCENE RECONSTRUCTION VIA HIERARCHICAL STEREO MATCHING

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INTRODUCTION

The reconstruction of 3D scenes from a pair of stereo images/videos that were captured from slightly displaced camera view points presents an important computer vision task for a variety of applications, including human motion capture and novel view synthesis, robotics, autonomously moving cars and drones, or 3D city reconstruction. In the context of the Internet of Things, networks of smart cameras can capture and exchange information on the observed 3D scene content. A key problem in stereo analysis is the determination of dense point correspondences in the input stereo pair, in order to generate a disparity (or depth) map as illustrated in Figure 1. High resolution images acquired by modern cameras impose special difficulties for stereo matching such as computational complexity and matching ambiguities, affecting both run-time and 3D reconstruction quality. In our work, we investigate hierarchical stereo matching to resolve the aforementioned difficulties by using image pyramids and simple but effective disparity propagation techniques.

EXPERIMENTS

We have developed a hierarchical cost volume filtering framework to enable both accurate and fast stereo matching. To this end, we have combined (i) an adapted cost volume filtering framework previously developed by us in [2] and (ii) a hierarchical matching scheme within a unified framework.

Stereo Algorithm. Our stereo algorithm consists of four basic steps: First, a cost volume is derived by computing the dissimilarities between both views for each pixel at each allowed disparity level. Second, we use a fast edge preserving filter [1] to align disparities of the cost volume with edges of the input stereo views. Third, we select the disparity with the lowest cost for each pixel, which gives us an initial disparity map. Fourth, we refine the disparity maps similar to [2] by (i) detecting invalid disparities via cross-checking (ii), filling these invalid disparities with valid disparities located on the same horizontal scan-line, and (iii) applying a weighted median filter to the infilled disparities.

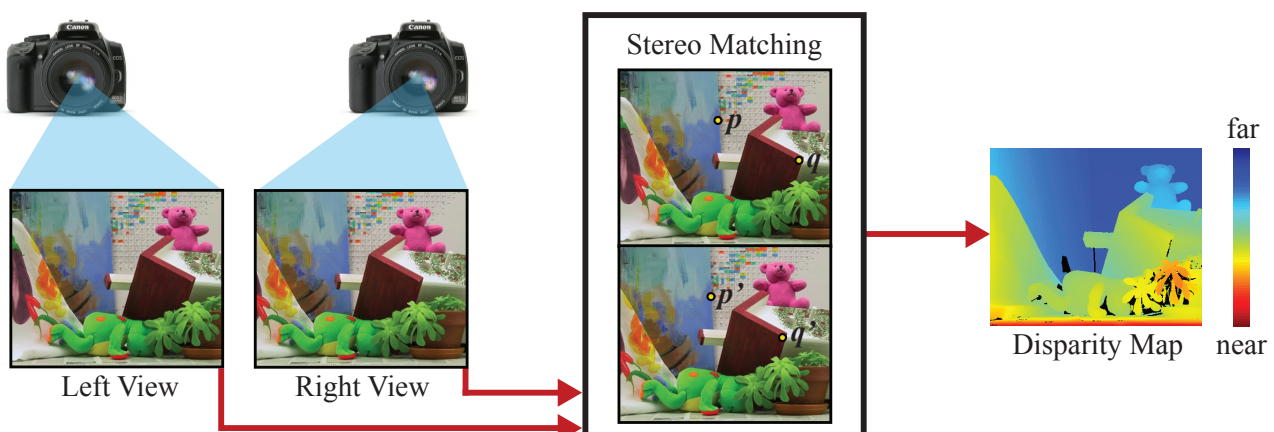


Figure 1: Basic concepts of stereo matching: The stereo matching module takes both left and right views and encodes the correspondences for every pixel (e.g., points p and p' and point q and q') in a disparity map.

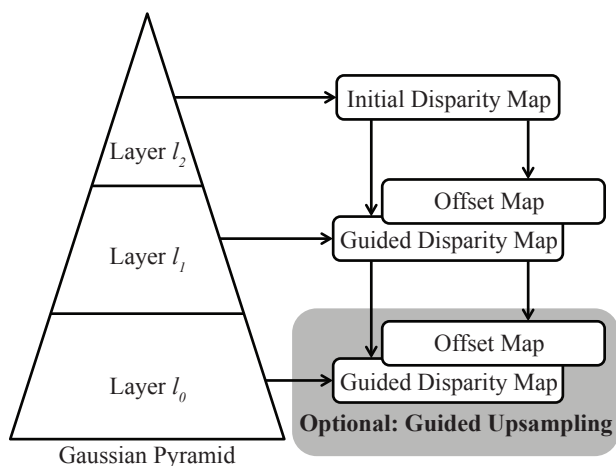


Figure 2: Schematic concept of our hierarchical matching framework.

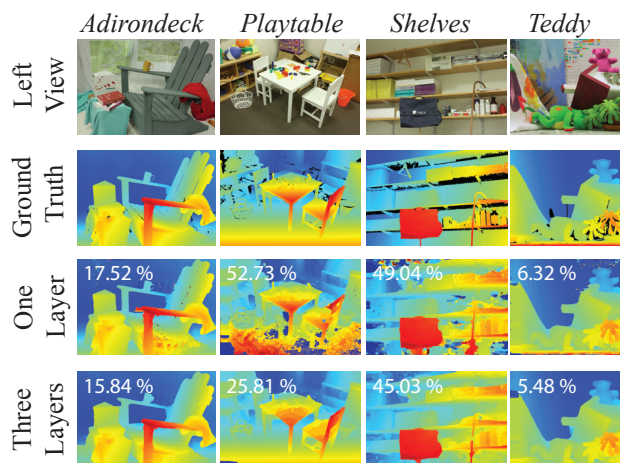


Figure 3: Disparity maps and error rates of four datasets with known ground truth^[3].

Hierarchical Matching. Figure 2 illustrates our hierarchical matching framework which relies on Gaussian pyramids built with 3 layers of successively lower resolutions (with a reduction factor of 2 in both resolution and disparity range between layers). After computing an initial disparity map for the coarsest layer l_2 , we use a derived offset map to guide the disparity estimation at the next finer resolution. The restrictions imposed on disparity d_p of pixel p at the finer resolution are derived from the disparity d_q of the corresponding pixel q at the coarser resolution according to $d_p \in [2 \times d_q - \Delta_d; 2 \times d_q + \Delta_d]$, with $\Delta_d = 4$. The process is iterated until we reach the final layer l_0 . Alternatively, we can obtain a disparity map of final layer l_0 via guided upsampling^[1] of layer's l_1 disparity map.

RESULTS AND DISCUSSION

Figure 3 compares the disparity maps of four datasets with known ground truth^[3]. It can be seen that our hierarchical approach using three layers outperforms the standard stereo approach using one layer in both visual quality as well as matching accuracy. Concerning the former, wrong disparity assignments especially in low textured areas are visibly reduced. Concerning the latter, lower error rates are obtained. Moreover, we found that when both hierarchical matching and guided upsampling are used, a speed-up of about 5 times with a marginal decrease in matching accuracy can be achieved.

CONCLUSION AND ACKNOWLEDGEMENT

We have presented a hierarchical cost volume filtering framework based on image pyramids and a simple but effective disparity propagation technique. For future work, we plan to support temporally consistent disparity map computation and to port our implementation to the GPU.

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SMARTPHONE-BASED CROWDSOURCING FOR MOBILE NETWORK BENCHMARKING

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INTRODUCTION

Crowdsourcing is a neologism coined as a portmanteau of *crowd* and *outsourcing* by Howe and defined as "outsourcing a job traditionally performed by a designated agent to an undefined, generally large group of people in the form of an open call" [1]. The crowdsourcing paradigm is introduced to a plethora of disciplines, but its potential applications in telecommunications, in particular for the performance evaluation and benchmarking of mobile networks has not yet been fully explored. This research is specifically targeting at establishing such a framework.

MOBILE NETWORK BENCHMARKING

The state of the art in mobile network benchmarking is designated drive tests, for which the disadvantages are: consumption of significant amount of time and human effort, large operation expenditure, geographically limited data acquisition, and the requirement of off-line analysis. Smartphone-based crowdsourcing makes a viable alternative to conventional drive tests. The idea is for smartphones to operate as geo-localized sensors capable of monitoring the state of the access network (*passive*), along with serving as measurement probes (*active*). The common practice is for the devices to run a mobile application which, besides coordination with a designated server, can provide measurements of network-related properties such as data rate and delay. Figure 1 presents the generic structure of such a system.

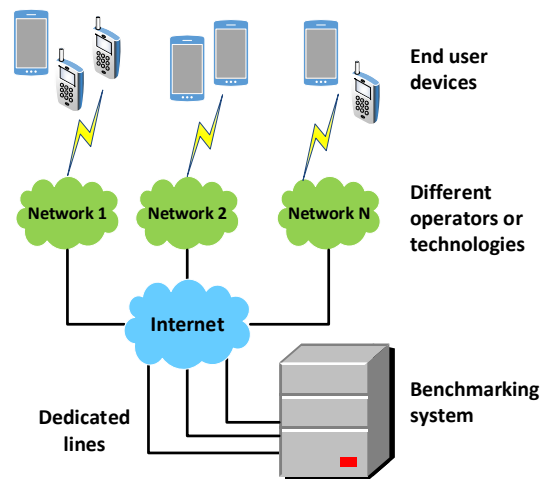


Figure 1: Crowdsourcing-based mobile network benchmarking system

RESULTS AND DISCUSSION

We focus on three main aspects: identification of the opportunities and challenges of crowdsourcing mobile network performance measurements, determining the necessary signal processing approaches and relevant metrics for translating user experience into an overall network performance, and identifying the properties of an ideal benchmarking system for accurate, fair and repeatable benchmarking.

Opportunities and Challenges

We identify the opportunities inherent to crowdsourcing as "*Power of the Crowds*" (simplification in operation), *Mobility and Ubiquity* (pervasiveness of smartphones), *Real-Time Operation*, *Cost Reduction*, and *Representation of Realistic User Performance*, where the challenges are *End-Device Related Issues* (unavailable parameters, unknown properties and personal usage), *Resource Consumption*, *Privacy versus Reliability*, *Incentive Mechanisms*, *Inaccuracy of Measurement Algorithms*, and

the challenges associated with determining *Network Performance from User Performance* [2].

User Performance to Network Performance

For fair benchmarking, it is essential to estimate the overall network performance from a large number of potentially tariff-limited users. This includes: a) employing machine learning algorithms to detect user profiles ("which users are tariff-limited, which are not?) from plots similar to Figure 2 through clustering, b) identifying measurement bottlenecks ("is there a tariff-limitation, network bottleneck, or server bottleneck?") [4], and c) finding the relevant metrics for baselining ("according to what reference value should the results be compared?").

Benchmarking System Requirements

We investigate the necessary design principles for crowdsourced benchmarking systems. For instance, Figure 3 shows the use of cumulative sum (CUMSUM) average as a time series analysis method to estimate a "good" average capable of discarding the ramp-up phase for TCP-based measurements, increasing the accuracy of the system's available data rate estimate. Similarly, conducting bottleneck analysis on an existing system, we show that appropriate request scheduling is of key importance for fair benchmarking [4].

CONCLUSION

We investigate the possibility of replacing conventional drive tests with crowdsourced network benchmarking and show that although there is a big potential, data collection has to be complemented with appropriate signal processing for fairness and accuracy. Future work includes cluster analysis and time series forecasting for estimating mobile network performance.

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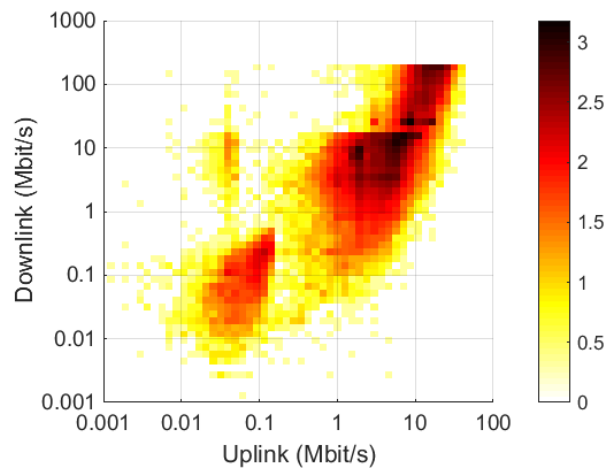


Figure 2: Reported data rates for all measurements in RTR Open Data [3] (one operator, 2014-2015, log10) [4]

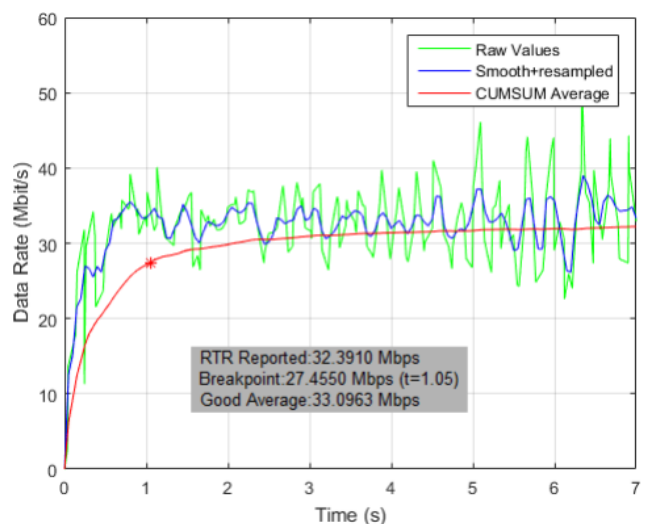


Figure 3: Time series for downlink data rate from a single measurement in RTR Open Data [2,3]

INVESTIGATION OF MILLIMETRE WAVE WIRELESS CHANNEL FADING PARAMETERS FOR THE FUTURE "INTERNET OF THINGS"

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INTRODUCTION

Access to enough spectrum is essential for high transmission rates in wireless communications. Since there are hardly any free frequencies at today's frequencies (< 6 GHz), future generations of wireless communication systems are forced to operate in the millimetre wave band (30 – 300 GHz). Fading parameters at these frequencies are investigated scantily. We determine the Rician K factor - a fitting parameter for the amplitude's distribution of the fading channel - and the root mean square delay spread (RMS-DS) - a measure for multipath richness - based on scalar power measurements.

EXPERIMENTAL SETUP AND RESULTS

For the generation of millimetre wave signals we use Pasternack models which serve as up/down-converter from baseband to 60 GHz, operating built-in Phase-Locked Loops (PLLs), cf. Fig 1. The common reference signal for the PLLs is at 278.514 MHz. Thus, the more than 30 fold increased mixer-frequency is subject to strong phase noise. Although we measure the S_{21} parameter with an R&S ZVA24 vector network analyser, we disregard the phases and work with the scalar power measurements $|S_{21}|$, only. The transmitter is an open ended waveguide. The receive site uses a 20 dBi horn antenna.

The first objective is to determine the Rician K-factor. As we perform measurements in static environments, we cannot evaluate the amplitude statistics to obtain it, instead we use ergodicity and derive the Rician K-factor from the transfer function [1].

The second objective is to make use of the frequency domain level crossing rate (FD-LCR) to obtain the RMS-DS from the directional power measurements [2]. Analogous to the relation of mobile speed and time domain level crossing rate (or average duration of fade), there is a direct proportional relationship between the FD-LCR and the RMS-DS. The larger the RMS-DS,

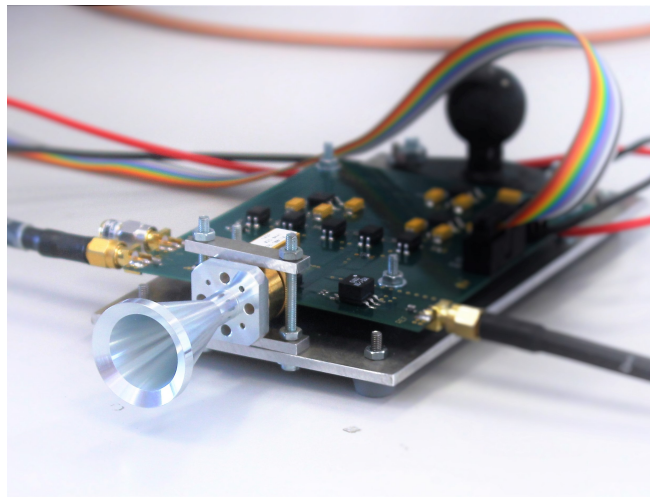


Figure 1: A picture of the measurement setup. The millimetre wave modules are connected through a flange to the horn antenna.

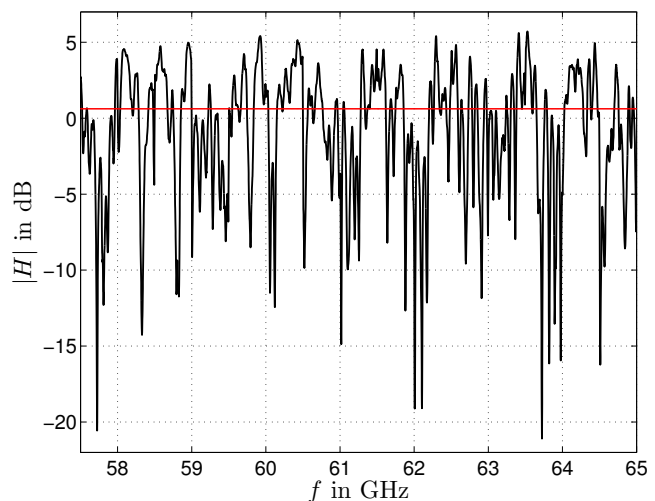


Figure 2: Exemplary transfer function for a NLOS measurement.

the higher the FD-LCR. In Fig. 2, we illustrate an exemplary transfer function measurement. The level crossings, through the RMS amplitude level, are indicated. This method is very suitable for static indoor scenarios and continuous wave frequency sweeping methods.

For the exemplary transfer function, the receiver and transmitter were facing in opposite direction, so that a none-line-of-sight (NLOS) connection was established. The parameters of interest were found to be

$$K = 2.0842, \quad \tau_{\text{RMS}} = 3.0758 \text{ ns} \quad (1)$$

The RMS-DS is in agreement with reported measurements [3] [4].

CONCLUSION

Through measurements of millimetre wave wireless channels, we are able to study the propagation conditions at higher frequency bands. Initial measurements indicate that millimetre wave channels are less reverberant (have lower RMS-DS values) than its centimetre wave counterparts. Reliable reception might be only possible through specular reflections [5], where Rician fading distributions ($K > 0$) are seen.

For our future work we measure the Rician K factor and the RMS-DS on a sphere to evaluate those parameters for every possible impinging direction. Further, we will apply directional statics on those measurements to look for correlation of these parameters at various receiver positions within our laboratory.

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EVALUATION OF WIRELESS REPEATER PERFORMANCE ON-BOARD AUSTRIAN RAILWAY TRAINS BY MEASUREMENTS

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INTRODUCTION

The commuting trips using public transportation systems such as trams, busses, and railways have become part of the daily routine for those living in metropolitan areas. This short-hour journey would be more productive for passengers if mobile communication quality onboard trains were satisfactory. This work adds efforts to change that situation.

EXPERIMENTS / FUNDAMENTAL OF THE PROBLEM / EXAMINATIONS

There are solutions to improve signal quality inside trains, technical and economical reasons restrict choices, leaving few feasible options. Deployment of wireless repeater has been used as an option to enhance signal onboard trains. However, providing satisfactory wireless communication inside trains using wireless repeater remains challenging, due to the high cellular signal attenuation of state-of-the-art thermally insulating windows, particularities of the mobility and the variety of propagation scenarios. This work evaluates the performance of an on-board wireless repeater. In this solution, the repeater's donor antenna is mounted on the rooftop of the train carriage. The service antenna is connected to a coaxial leak cable that crosses the carriage roof longitudinally. The repeater performs Frequency Division Duplex (FDD) and amplifies selected signal bands bidirectionally.

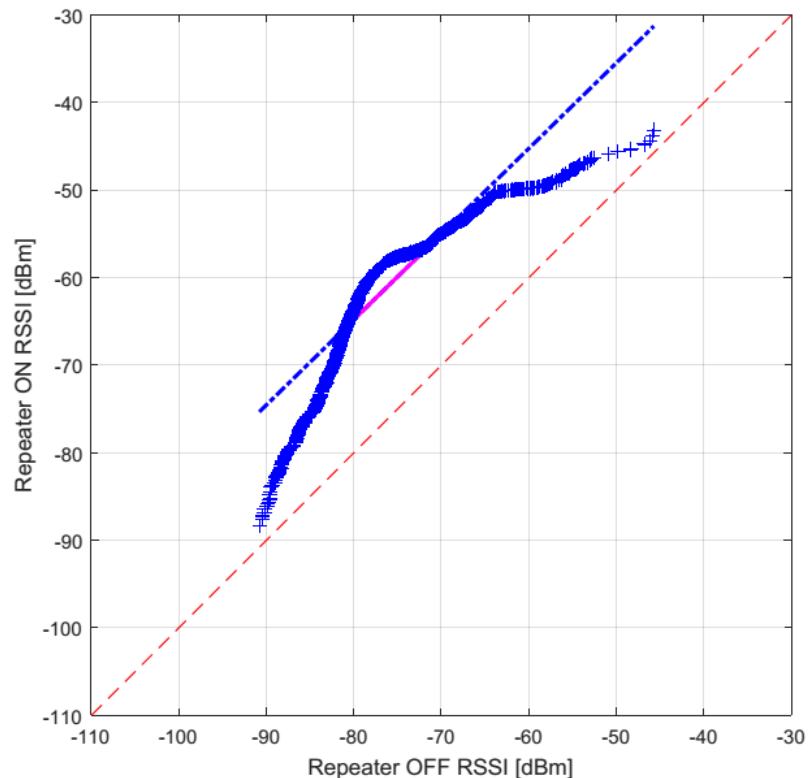


Figure 1 – A quantile-quantile plot comparing signal strength (RSSI) with and without on-board repeater.

This contribution reports on real-world mobile telecommunications quality of service measurements on-board RailJet and CityJet trains with and without on-board multiband amplify-and-forward repeater. Onboard measurement is performed with Anite's Nemo Walker Air. This tool consists of a group of six smart phones with software that allows pre-configuration to produce voice and data service demands, as well as data logging of signal strength and events from all ISO layers. It will be considered a scenario with multi-operators, various mobile systems - GSM 900MHz, GSM

1800MHz, UMTS 2100MHz LTE 800MHz and LTE 2600. The assessment will cover physical layer - signal strength inside and outside, propagation scenario, handover- as well as service layer- data and voice quality service. The results would be useful for academics, professionals and institutions interested in robust and structured methodology to assess mobile repeater performance onboard trains.

There are various important researches on providing cellular coverage and Internet onboard public transportations ^{[1], [6]}. Additionally, general literature addresses this topic and important considerations on mobile infrastructure to deal with handover issues ^[3]. Nonetheless, there is a gap for work assessing performance of voice and data inside trains by measurement.

In order to challenge the general status quo, we question whether the observed measurements support the statement that the on-board repeater improves mobile voice and data coverage onboard trains. The suggested hypothesis states that deploying repeater onboard train does not improve mobile/wireless communication performance under some external conditions (topology and coverage), it even degrades the network performance in some scenarios. Measurements are performed with and without repeater for comparison. Received Signal Strength Indicator (RSSI), SNR (signal to noise ratio), Received Signal Quality (RSRQ), Call Drop Events, and call failure, data connection and throughput will be submitted to parametric hypothesis testing, e.g. Z-test, and Non-parametric hypothesis testing, e.g. Wilcoxon-Mann-Whitney-Test.

PRELIMINARY RESULTS AND DISCUSSION

Preliminary analysis using descriptive statistics showed that the repeater increases signal strength and coverage onboard under certain conditions. That is illustrated in Figure 1, in which the maximum difference between conditions with and without repeater is approximately 20dB. However, high data throughput, LTE-users performance appear to be negatively affected. Measurements analysis has raised more questions, reinforcing the need for a more in-depth assessment. These questions will be addressed with methodological adjustment and a more statistically robust evaluation.

ACKNOWLEDGMENTS

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LIGHTWEIGHT ANTENNA MATERIALS FOR THE INTERNET OF THINGS

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INTRODUCTION

The Internet of Things (IoT) aims at making a variety of devices accessible in networks. The most flexible way to connect such devices to a network is via wireless communication, such as wireless LAN or data services from mobile telephony. As part of their communication system IoT-devices must include antennas that allow reliable reception and transmission of electromagnetic waves.

Composite materials provide the mechanical stability for lightweight construction needed in many industrial and consumer devices. Carbon-fiber-reinforced polymers (CFRP) are increasingly used by mechanical engineers. Because the carbon-fibers are electrically conductive they are especially suited for lightweight antenna design.

Antennas for consumer devices and sensor networks in the IoT should be small. A process called Laser Direct Structuring (LDS) allows the metallization of plastic components and therefore conformal antennas as part of a polymer chassis.

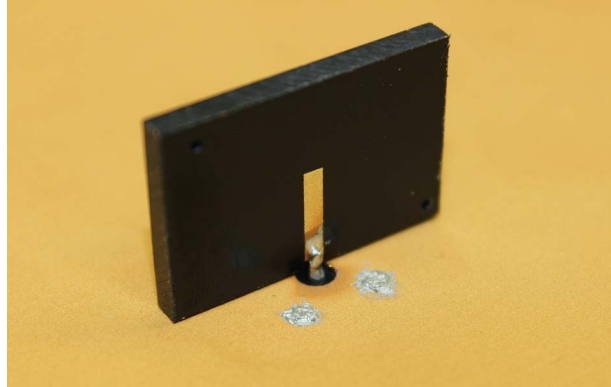


Fig. 1: Monopole antenna in LDS technology on a PC/ABS substrate mounted on an LDS ground plane.

MEASUREMENT OF ANTENNAS ON CFRP AND LDS GROUND PLANES

The availability of an electrically conductive sheet such as a CFRP chassis can be utilized as the ground plane for antennas in monopole or patch antennas.

A monopole antenna (Fig. 1) for intelligent transportation systems was fabricated with the LDS process. The radiating element for 5.9 GHz is a ~10 μm thick layer of copper, nickel and gold on a XANTAR LDS3720 PC/ABS substrate.

Three monopole antennas are mounted on rectangular ground planes made of aluminium, CFRP and one manufactured with the LDS, each with a side length of 150 mm. The antennas are measured inside the institutes' anechoic chamber (Fig. 2). To further reduce the influence of the measurement environment, the antenna under test is placed on a column of Rohacell. This material has a permittivity similar to air, even at high frequencies. Results are obtained with a near-to-far-field transformation.

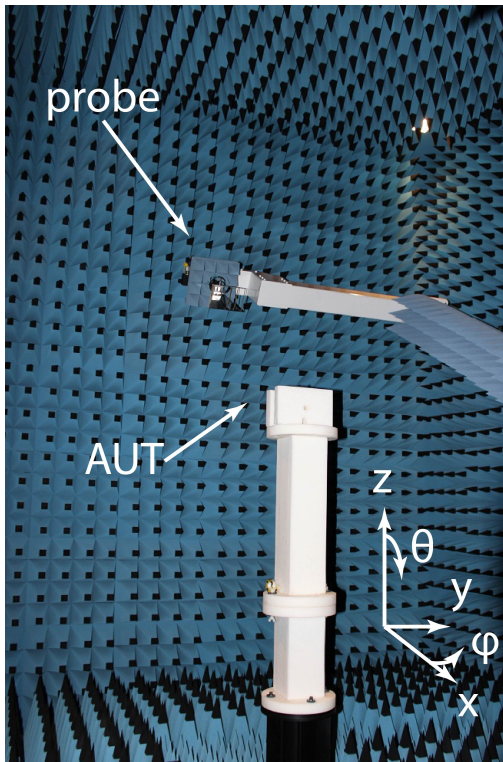


Fig. 2: Antenna under test (AUT) inside the institutes' anechoic measurement chamber.

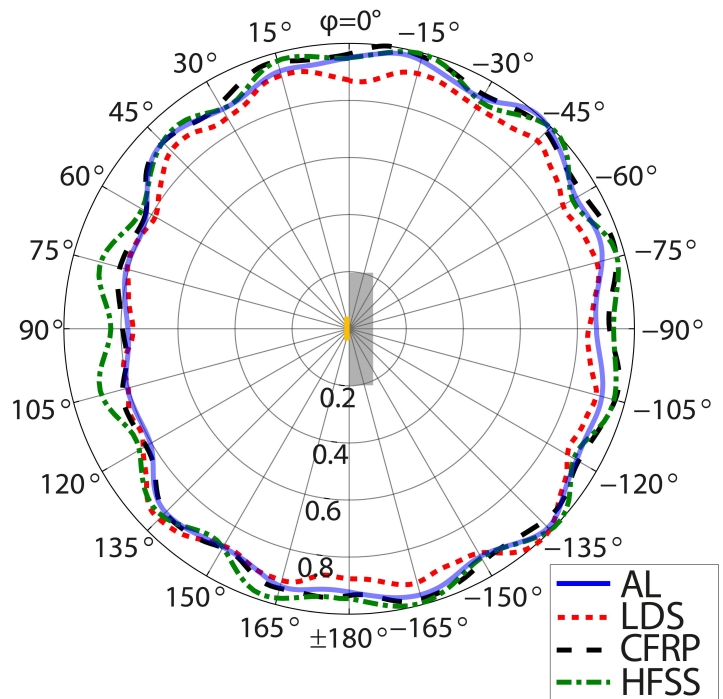


Fig. 3: Radiation pattern of LDS monopole antenna on aluminium (Al), laser direct structuring (LDS) and carbon-fiber-reinforced polymer (CFRP) ground plane; simulation in HFSS with perfect conductive ground plane. ^[1]

A horizontal cut of the antennas radiation pattern on different ground plane materials is depicted in Fig. 3. The LDS and CFRP ground planes are compared to aluminium, as it is a good electrical conductor and widely used as construction material for IoT devices. Additionally, simulation results for a perfect conductive ground plane obtained with Ansoft HFSS are shown. The radiation patterns of the antenna are similar for all considered materials.

Measurements have shown that on the CFRP ground plane the radiation efficiency is about 80 % relative to the efficiency on an aluminium ground plane.^[2] On a polymer ground plane metallized with LDS 96 % efficiency relative to aluminium can be achieved.

CONCLUSION

Carbon-fiber-reinforced polymers (CFRP) are a suitable material for antenna ground planes and offer high mechanical strength for lightweight construction. Radiation efficiency can be increased with metallized polymers. Lightweight construction of devices and their antennas can substantially increase the number of devices that can be connected in the Internet of Things.

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TRANSFORMING IOT STREAMING DATA AND BIG DATA INTO A SMART DATA

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INTRODUCTION

Internet of Things (IoT) in smart cities are continuously producing tremendous amount of dynamic and heterogeneous data in the form of IoT streams to which we call IoT Streaming data. To integrate, analyze and make effective use of that data are the key challenges faced by experts. IoT is driven by two initiatives of IT: Cloud computing and big data^[1]. Data is considered as Big Data if it meet the requirement of “five V’s”. These are Volume, Variety, Velocity, Veracity and Value^[2]. IoT generally have less memory and processing power, also, they are scattered in remote locations. Therefore, it is important to store data in a secure location which is accessible from everywhere and from where it is easy to integrate, develop, deploy and analyze data for an end user application. Now a days, cloud computing is providing these services. The purpose of this work is to develop a model which can acquire data from IoT which are geographically-dispersed, integrate, store and provide real-time data analysis to the end-user. In this work an attention will be given to three main IoT Streaming and Big data issues discussed below.

1) Heterogeneous data

Data produced by IoT can be structured, semi structured and unstructured. Almost 80% of the data produced by organization is unstructured^[3]. Structured data has very sophisticate integration with database, it is organized in a well manner and it is easy to interpret and manage. The great deal is to manage unstructured data which is completely raw and unorganized. This data is highly dynamic and does not follow any particular format. It may exist in the form of word processing document, spreadsheets, email attachments, images, pdf documents, medical records, X rays, voice mails, graphics, video, audio etc. and they cannot be stored in row/ column format as structured data. The very first step after data acquisition is to structured data in a careful way^{[4] [5] [3]}. Hadoop and MapReduce are used to address this issue.

2) Scalable data

Large and rapidly increasing volumes of data is a big challenge now a days. Scalability in Big data can be measured in two dimension: vertical and horizontal. 1) Vertical scalability is related to storage and 2) horizontal scalability refers to processing [2]. Scalability arises many other challenges, such as data analysis, organization, retrieval and modeling [3]. [6] Proposed a modified method of discovery and composition algorithm to address the challenge of scalability.

3) Integration of data

Integration of heterogeneous data is a big challenge. Seamless data integration is required not only to define a uniform data representation, but also to keep the integrity and consistency of the heterogeneous data without violating the autonomy of the data resources.

SCANARIO

To test our designed model, we propose following scenario. In tested scenario, a vehicle will be equipped with OBDII to collect speed, rpm, acceleration, fuel consumption, gear position, engine load, distance travelled and engine coolant temperature and driver’s smart phone will be used to get current location, video and weather data. The data produced by vehicle can be seen as streaming

and big data, as it is generated continually and not only big in volume but also varies in format, representation and effected by dynamicity of the environment. This data is transmitted to database server with the help of web service for data analysis. Data analysis techniques will be used to provide assistance to driver for attentive driving and guide him in driving behavior to achieve fuel efficiency.

METHODOLOGY

Methodology will follow data acquisition, data storage, data analysis and data presentation step. Unstructured data will be accessed using web service based on RESTful API and sent to database over the 3G/LTE network. Data storage will be done in a way that it combines heterogeneous sets of data streams and provide a unified view of all the data with the help of data aggregation and federation process. Pattern recognition and machine learning algorithms based on statistical methods will be used to analyze data.

INTERFACE BETWEEN MY RESEARCH AND RESEARCH PRIORITIES OF GROUP

Institute for Software Technology and interactive system is highly motivated towards working on cloud computing, big data and data analysis and this work is one of the initiative to address the big data issues and provide real-time solution to facilitate citizens.

CONCLUSION

Model developed in this work will help in real-time analysis of heterogeneous data produced by heterogeneous intelligent devices and will show how the IoT streaming data can be seamlessly integrated and processed to devise information and actionable-knowledge (smart data) that can be used by end-users to improve their behavior and decision making.

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USE OF MAGNETIC FIELDS IN COMBINATION WITH WIFI AND RFID FOR INDOOR POSITIONING

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INTRODUCTION

The earth's magnetic field needs no positioning infrastructure and can be measured everywhere. Therefore its use for indoor-positioning and navigation is feasible. In the employed fingerprinting approach the magnetic induction of the earth's magnetic field - or the signal strength from Wi-Fi or RFID - is measured at certain known locations. These measurements and their corresponding point coordinates are stored in a so-called radio map. If the magnetic induction of the earth's magnetic field is measured at an unknown location, the coordinates of this position can be retrieved by comparing the current measurements with the data from the radio map.

EXPERIMENTS / FUNDAMENTALS OF THE PROBLEM / EXAMINATIONS

Existing positioning systems which are using the fingerprinting approach with magnetic fields are discussed e.g. in [1], [2]. With these systems positioning accuracies of a few metres can be achieved. The problem, however, is that positioning errors of more than 50m can also occur. Other investigations in the context of magnetic field fingerprinting^[3] have shown that by combination with other signal sources, higher positioning accuracies can be achieved. For example, by using Wi-Fi fingerprinting an approximate positioning solution can be firstly obtained. Afterwards magnetic field fingerprinting is used to refine this approximate solution.

In this study measurements are carried out by the user in two selected test areas, whereby a mobile robot is additionally used in one of these (Figure 1). Two sensors, a smartphone and a low-cost-IMU ("Inertial Measurement Unit"), are employed in the test. In first preliminary investigations the influences of the user's body and the electric motor of the robot on the magnetometer measurements are examined. Furthermore the measurements to create the radio maps and static and kinematic test measurements are carried out. To determine the position of the user respectively the robot, the magnetic field fingerprinting is used in combination with Wi-Fi and RFID fingerprinting. To analyse the short term- and long term-variations of the earth's magnetic field, continuous 24-hour-observations and epoch by epoch measurements are carried out additionally.



Figure 1: User with smartphone and IMU (left) and location of the sensors on the robot (right)

RESULTS AND DISCUSSION

An influence of the electric motor of the robot is only present while driving. To minimize the influence of the user's body, the measurements to create the radio maps are carried out in four orientations. By analysing the radio maps hardly any spatial variations of the earth's magnetic field

could be seen; a circumstance which affects the positioning phase in a negative way. In the evaluation of the static test measurements, positioning errors of more than 50m can occur if only the earth's magnetic field is used in the fingerprinting approach. If the result of Wi-Fi-fingerprinting is used as an approximate solution for the magnetic field fingerprinting and if these two solutions are averaged out afterwards, the medium positioning errors range from about 2.0 to 4.5m. When the RFID-fingerprinting-solution is additionally used, the average positioning errors show the same results. The results are also compared according to the distance criteria which were used in fingerprinting. Those retrieved by using the Mahalanobis-distance are slightly better than the ones retrieved by using the most commonly employed Euclidean-distance. Thus in the kinematic test measurements the combination of Wi-Fi and magnetic field-fingerprinting and the Mahalanobis-distance are used for localization. The results of the fingerprinting approach are then used as observations in a Kalman filter. To predict positions in the Kalman filter a motion model was developed. In one of the two test areas the trajectories are determined quite well. The average lateral deviation is only about 1.0m and the positioning error does not exceed 6.0m. In the other test area, however, the positioning algorithm fails for kinematic positioning of the robot.

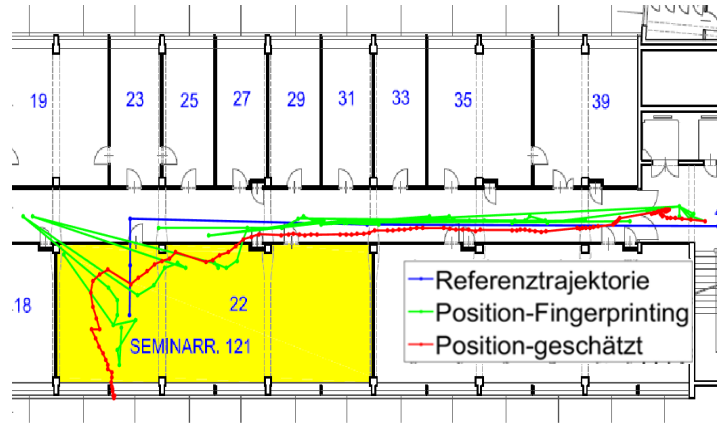


Figure 2: Result of the kinematic positioning of the user

In the evaluation of the variations of the magnetic field it could be seen that in the short-term the magnetic field is reasonably stable whereas in the long-term variations of several micro tesla can be observed. Therefore the radio map has been updated by using repeated measurements at certain points. This update, however, has not improved positioning accuracy significantly.

CONCLUSIONS

As the positioning accuracy by using magnetic field fingerprinting in combination with Wi-Fi fingerprinting for the static test measurements results in quite the same as with Wi-Fi fingerprinting alone, one might conclude that the use of magnetic field fingerprinting is not beneficial. On the other hand, for kinematic measurements it could be proven that the use of magnetic fields is advantageous, because of the faster measurement data recording in comparison to Wi-Fi. However, there are still problems in kinematic positioning with magnetic fields and Wi-Fi fingerprinting (see green trajectory in Figure 2), which have to be investigated more in detail. A closer look at the update of radio maps and the integration of PDR (“Pedestrian Dead Reckoning”) seem to be promising possibilities to increase the positioning accuracy and reliability.

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A DATA-BASED APPROACH TOWARDS MODELLING, SIMULATION AND OPTIMIZATION OF THE OPERATION OF PRODUCTION PLANTS

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INTRODUCTION

The goal of the research project BaMa (Balanced Manufacturing)¹ is to increase energy efficiency of industrial production sites. A toolchain, consisting of the three main parts monitoring, simulation and optimization, is developed to optimize the operation strategy and production plan of a given production facility. Additionally to usual parameters such as production time and delivery reliability, energy consumption and CO₂-emissions are taken into consideration. [1, 2].

In order to illustrate the method, the development of an energy-optimized operation strategy for a refrigeration plant, consisting of four electric chillers, supplying a semiconductor production plant is presented. Several different methods for modelling, as well as optimization were identified and applied to the problem. Without any additional measurement equipment or interruption in the operation of the plant, it was possible to build sufficient models. The results of the application are propitious and indicate the feasibility of the BaMa-method in general.

DESCRIPTION OF MODELLING APPROACH

By measuring relevant input- and output signals, a model can be parameterized. This model makes the prediction of the behaviour of the electric chillers possible. [3]. The generation, preprocessing and aggregation of data results in models that can be used to optimize the underlying plant's operation.

Figure 1 shows how an electric chiller is modelled according to the BaMa-method. Relevant input parameters are electrical power P_{el} , the cooling demand $\dot{Q}_{c,d}$ and condenser and evaporator return temperatures T_{con} and T_{eva} . Based on those inputs, the cooling power \dot{Q}_c and the electrical power demand $P_{el,d}$ is calculated. A model proposed by Monfet and Zmeureanu [5] which is based on the work of Hyde-man et al [4] was used.

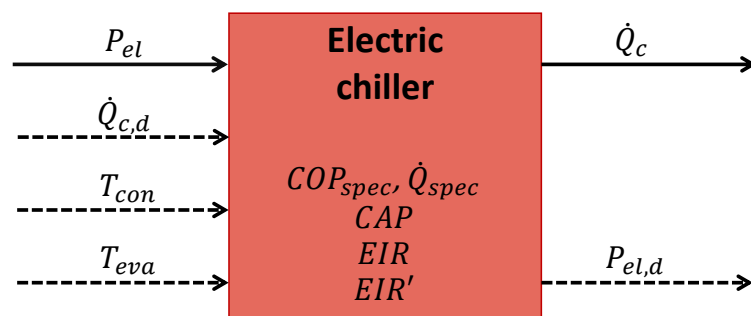


Figure 1: In- and outputs of chiller cube (energy and information)

¹bama.ift.tuwien.ac.at

The behaviour is described using the following mathematical model:

$$\begin{aligned}\dot{Q}_{avail} &= \dot{Q}_{spec} \cdot CAP & PLR &= \frac{\dot{Q}_c}{\dot{Q}_{avail}} \\ \dot{Q}_c &= \min(\dot{Q}_{avail}, \dot{Q}_{c,d}) & P_{el,d} &= \frac{\dot{Q}_{avail}}{COP_{spec}} \cdot EIR \cdot EIR' \\ CAP &= f(T_{con}, T_{eva}) = a_1 + a_2 T_{con} + a_3 T_{eva} + a_4 T_{con}^2 + a_5 T_{con} T_{eva} + a_6 T_{eva}^2 \\ EIR &= g(T_{con}, T_{eva}) = b_1 + b_2 T_{con} + b_3 T_{eva} + b_4 T_{con}^2 + b_5 T_{con} T_{eva} + b_6 T_{eva}^2 \\ EIR' &= h(T_{con}, PLR) = c_1 + c_2 T_{con} + c_3 T_{con}^2 + c_4 PLR + c_5 PLR^2 + c_6 T_{con} PLR + c_7 PLR^3\end{aligned}$$

For each individual chiller unit, the values for \dot{Q}_{spec} , COP_{spec} , as well as the coefficients a_i , b_i and c_i were determined based on the available monitoring data. The root mean square model prediction errors for the electrical energy demand of the four electric chillers are 11.8%, 4.7%, 5.3% and 3.3%, respectively. Apart from the first value, those errors are in the same order of magnitude as those presented by Monfet and Zmeureanu.

SIMULATION AND OPTIMIZATION

Using the chiller models, a simulation of the underlying chiller plant consisting of four electric chillers was set up. As a baseline for the assessment of the optimized operation strategy, chiller operation states for a period of 80 days in 2015 were used. Together with the information about the corresponding temperature signals T_{con} and T_{eva} in that period, alternative chiller operation states were found by choosing the, optimal chiller unit (i.e. the one with the lowest electrical energy demand at a given time). According to the simulation, the saving potential amounts to 10-15% of the baseline energy consumption.

DISCUSSION AND CONCLUSION

The presented approach demonstrates that considering energy efficiency in the operation of existing refrigeration plants can reduce overall energy demand significantly. As a next step, the developed model will be combined with other cubes in order to locate optima in a broader set of possible states. Furthermore, the optimized operation strategy should be adapted in order to validate the predicted saving potential. For additional improvements of the model and the optimization results, the existing monitoring system needs to be expanded to the remaining chillers.

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SIMULATIONS ON RESILIENCE AND MALWARE CONTAINMENT IN SMART GRID COMMUNICATION ARCHITECTURES

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INTRODUCTION

Smart grids utilize Information & Communication Technology (ICT) to increase efficiency and reliability, by managing dynamics in power grids. However, ICT opens additional vulnerabilities affecting critical infrastructures, by increasing their attack surface. According to Ijure et al. [1] legacy control systems experience an increasing number of attacks, as they were developed for good performance and with emphasis on features that meet network constraints, without security concerns. They argue that almost 70% of the current incidents are attacks originating from outside the network. Smart grids must be designed with security features in mind. Systemic resilience in critical infrastructures is of key importance. It therefore must include attacks, aside from technical failure.

PROBLEM STATEMENT

Malware poses a serious threat to communication networks, as it propagates with the goal of infecting vulnerable hosts. It can exploit several attack vectors to destabilize the power grid e.g. manipulating control events in power-switching equipment or denial of service attacks similar to the events described by Christiner [2]. Therefore, it is important to develop methods that employ security by architecture among other features. Considering that software vulnerabilities are discovered over time, a number of hosts in a network may be vulnerable before security patches are available.

METHODOLOGY

Several scenarios were developed for simulating malware propagation in the simulation environment ns-3. Figure 1 illustrates three types of malware attacking four types of ICT-topologies with the goal of infecting all nodes. Resilience criteria are derived from the containment properties of each topology. The architecture of communication networks can provide security features and disrupt the propagation of malicious code.

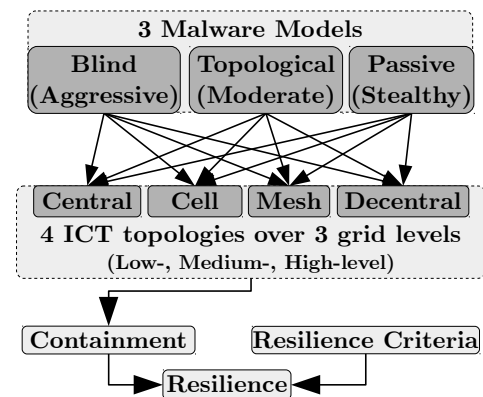


Figure 1: Scenarios: 3 malware models over 4 ICT typologies

RESULTS AND DISCUSSION

Four different topologies are instigated with the goal of improving resilience, security, and malware containment. Figure 2 illustrates a fully centralized approach, dedicated cells, mesh networks, and a fully decentralized approach. [3]

The fully centralized topology (Figure 2.a) provides situational awareness and resource control, due to a single control node. It lacks resilience because failure of the central node can result in catastrophic failure. Furthermore, malware can infect the control center and lead to a similar result.

Cell structures (Figure 2.b) allow decentralized control features, resource control, and resilience on low-level nodes. The high-level ICT is connected via uplinks, yet the cells act autonomously. This

approach provides security because propagation is inhibited by warning adjacent cells of anomalies.

Mesh networks (Figure 2.c) on the low- and medium-level provide good resilience features against failures because alternative communication paths exist. However, malware may use these paths to propagate quickly through such a network, infecting nodes in other hierarchy levels.

The fully decentralized topology (Figure 2.d) provides a mesh network throughout all levels of the hierarchy. This approach promises increased resilience against failure, at the drawback of ideal conditions for malware propagation and decreased situational awareness.

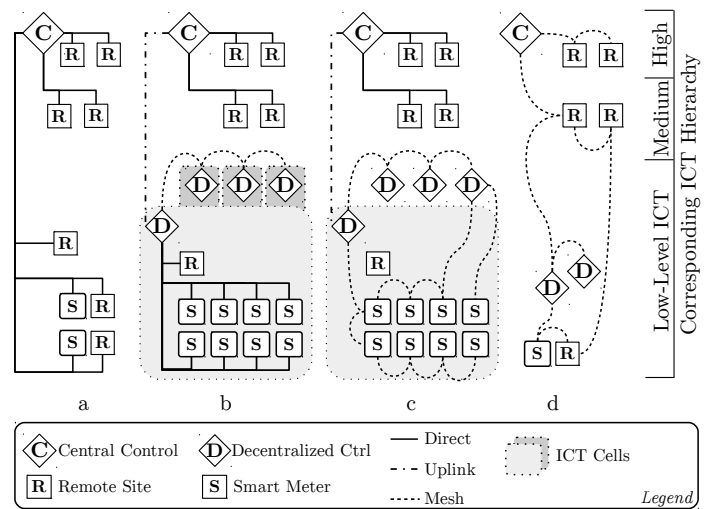


Figure 2: Control scheme with ICT cells connected via a mesh network for added resilience on the medium ICT-level

CONCLUSION & OUTLOOK

Smart grids can be secured with proactive measures such as the logical separation of networks, physical security of critical nodes, penetration testing, white-listing, regular updates or access management. Alternatively, reactive security measures allow anomaly- and intrusion-detection of unknown adversaries. Disaster recovery plans and fall-back systems can support seamless operation and recovery.

In future work the impact of three malware models on the architectures above will be simulated and appropriate defense strategies derived from the simulations. The malware features are as follows:

An aggressive "blind scan" malware aims to infect as many hosts in the shortest time possible. It employs horizontal scanning of the IPv4 address space and therefore, produces conspicuous traffic. On successful connection with a host, the payload is transferred via TCP.

Another type uses a moderate strategy which employs a "topological scan" of the home subnet. This approach does not produce failed connection attempts outside its subnet. Furthermore, it informs other instances of failed attempts and immune nodes. Such a partitioning of the address space allows more stealthy behavior, which makes it harder to detect.

The "passive scan" malware spreads only to such nodes initiating a connection. It therefore generates no failed attempts. This even more stealthy behavior comes at the cost of propagation-speed.

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Research Field *Mathematics Sciences*

Chair and Reviewer:



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Introduction

The famous mathematician Carl Friedrich Gauß (1777-1855) referred to mathematics as the Königin der Wissenschaften ("Queen of the Sciences"). One need not

subscribe to this statement. Nevertheless, mathematics is undisputable very important in our modern world. It is an indispensable tool in many sciences, most notably in the natural sciences, engineering, physics, medicine, and economics. For these fields, mathematics provides a common language to describe many phenomena through mathematical models. It provides tools to analyze these models and thereby helps to better understand these phenomena. Additionally, it has techniques in store to make predictions based on these models.

At TU Wien, mathematics is a very active research field. The faculty of “mathematics and geoinformation” comprises three large mathematics institutes: the Institute of Analysis and Scientific Computing, the Institute of Discrete Mathematics and Geometry, and the Institute of Statistics and Mathematical Methods in Economics. Together, these three institutes cover a broad spectrum of branches of mathematics, ranging from many fields of pure mathematics to application-oriented areas. This breadth of research of these three mathematics institutes is also a reflection of TU Wien’s dedication to promote interdisciplinary and application-oriented research as well as basic research at the highest international level.

The distinction between pure and applied mathematics is not as strict as it may appear. In fact, quite a few mathematical theories were initiated by questions arising from applications. Conversely, pure mathematics has often been able to reveal deeper underlying structures in applications. Many famous mathematicians, for example, Carl Friedrich Gauß have made fundamental contributions in both pure and applied mathematics.

A research area in which the connection between pure and applied mathematics is very visible is the field of partial differential equations, in which Vienna has a long tradition. A classical example of a partial differential equation is the system of the Navier-Stokes equations that describe a fluid. These equations postulate a relationship between physical state variables (e.g., velocity, pressure) and their derivatives with respect to time and location. More generally, differential equations are a fundamental tool in modern science and technology to model complex scientific and technical processes. Such differential equations can be analyzed mathematically and information about the model can be extracted. Natural questions of interest may, for example, be qualitative information such as the long-time behavior of the system. Differential equations can also be quantitatively analyzed with the aid of numerical simulations. These tools can be used to improve our scientific understanding of fundamental principles. Furthermore they provide an alternative to time and cost-intensive experiments.

MODELLING THE INTERACTION BETWEEN FLOODING EVENTS AND ECONOMIC GROWTH

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INTRODUCTION

The proposed abstract is not only part of an interdisciplinary program, but also interdisciplinary in itself. Built on recent models in socio-hydrology we introduce a dynamic optimization framework that allows to optimally decide between investments in productive capital fostering economic growth and investment into flood defense measures.

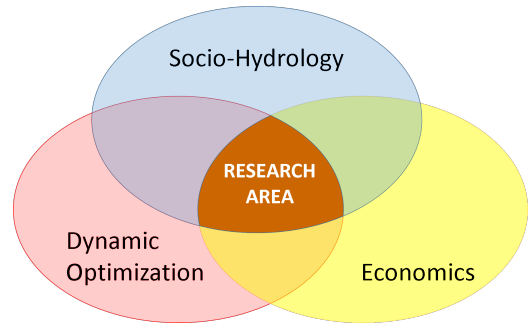


Figure 1: Combining research areas

THE MODEL

Socio-hydrology describes the interaction between the socio-economy, water and population dynamics. Di Baldassarre (2013) ^[1] and Viglione (2014) ^[2] developed a descriptive model to investigate in the feedbacks of a society living close to a river and flooding events. Based on their model we developed an economic growth model in Grames (2016) ^[3], where an economic agent decides on investment and consumption for the society facing floods. Complementary to the descriptive model by Di Baldassarre (2013) ^[1] we apply dynamic optimization. In order to solve that model analytically all functions have to be continuously differentiable and we therefore introduce a new flood damage function.

We assume a damage function $d(k_d(t), W(t))$ analogous to Viglione (2014) ^[2] and a recovery rate based on the economic capital, the prevailing technology and the optimal consumption behavior. Since the recovery is endogenous in our optimization framework, we can describe the optimal consumption and investment behavior given an exogenous forcing of the water level $W(t)$.

The amount of damage is related to the flood intensity $W_{eff}(W(t), k_d(t)) = W(t) + \xi_d k_d(t)$ which is a function of the water level $W(t)$ and the additional amount of water $\xi_d k_d(t)$. This additional amount of water occurs due to existing defence capital $k_d(t)$ such as levees: Levees at one place protect this area from flooding, but increase water levels further down the river due to loss of flood plain retention ^[1]. If the flood intensity $W_{eff}(W(t), k_d(t)) = W(t) + \xi_d k_d(t)$ exceeds the flood defence capital $k_d(t)$ and the levees spill over, a damage of the overall capital stock occurs. The higher the effective water level $W_{eff}(W(t), k_d(t))$, the higher the direct damage of the flooding ^[4]. The damage rate $d(k_d(t), W(t)) \in [0, 1]$ gives the relative damage of the capital stocks. Beyond $k_d(t)$, the damage of the flood is proportional to the effective water level of the flood W_{eff} and, also, to the flood duration, which is the time interval when $W_{eff}(W(t), k_d(t)) > k_d(t)$ holds. This assumption reflects the common situation that structural damage is related to the water level, while damage to industry production and stocks is related to the duration of the inundation. The damage rate $d(k_d(t), W(t))$ is then

$1 - \exp(-W_{eff}(t))$ if $W_{eff}(W(t), k_d(t)) > k_d(t)$ and 0 otherwise.

For ease of obtaining a numerical solution of the optimization model, we approximate the damage with a continuous function. Still, damage ($d(k_d(t), W(t)) > \varepsilon$ with a positive ε close to zero) only occurs if $W_{eff}(W(t), k_d(t)) > k_d(t)$. We choose the signum-approximation function and base it on the following four assumptions: First, the minimum value is 0 for the water level $W \leq 0$. Second, if $W_{eff}(W(t), k_d(t)) = W + \xi_d k_d > k_d$ and $W \rightarrow \infty$ we reach the maximum value 1. Third, the inflection point is at $W + \xi_d k_d = k_d$. Fourth, the gradient at the inflection point is chosen such as to approach infinity to approximate the jump between 0 and the relative damage $d > 0$. Furthermore, we add a multiplicative term $(1 - \frac{1}{1+W(t)^\eta})$ that is increasing in the water level $W(t)$ and bounded by the interval $[0,1]$. This term ensures that the damage is higher for a more intense flooding.

$$d(k_d(t), W(t)) = \frac{1}{2} \left(\tau_3 + \frac{\tau_2 + W(t) - (1 - \xi_d)k_d(t)}{\sqrt{(W(t) - (1 - \xi_d)k_d(t))^2 + \tau_1}} \right) \left(1 - \frac{1}{1 + W(t)^\eta} \right) \quad (1)$$

The coefficients τ_i adjust the accuracy of the approximation. If the defence capital is higher than the water level, the damage is closer to zero (no damage) until the inflection point $W(t) = (1 - \xi_d)k_d(t)$ and then close to one (total damage).

RESULTS AND DISCUSSION

The specific damage function and the exogenous forcing of the non-autonomous water level described in Games (2015)^[5] lead to interesting behavior of the long-term solution explained in Games (2016)^[3]. We obtain limit cycles, where paths are different to autonomous systems. Not only the initial conditions are relevant for the long-term solution, but also the starting time in respect to the exogenous forcing.

CONCLUSION

Combining disciplines allows new insights for every field. We did not only develop a new socio-hydrology model, but also found interesting phenomena in the non-autonomous optimal control problem. In further research we will include stochasticity in the model framework and therefore use Impulse Control Theory.

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**NONLINEARITY IN COLLABORATIVE APPLICATIONS
INCORPORATING HUMANS AND MACHINES: IDENTIFICATION AND MODELLING**

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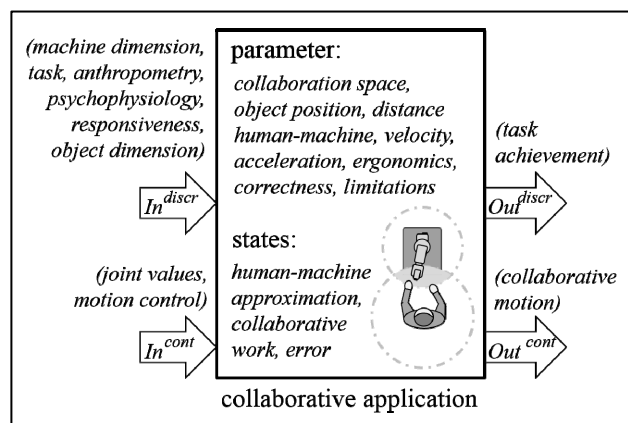
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INTRODUCTION

Collaborative applications defining the concept of humans working together with machines are becoming increasingly important in terms of enhancing productivity. However, the lack of safety regulations and validation tools despite of the proximity between workers and machines make it crucial to provide a safe and reliable working environment. By implementing models of collaborative work into a simulation environment, human-machine interactions, collaborative tasks and risk assessments can be easily tested and evaluated without a physical prototype. In this work, parameters for modelling collaborative applications are identified while also defining nonlinearities in terms of specified physical and ergonomic limitations. Based on a methodical system formalism for describing hybrid models, a simulation model for collaborative applications is presented.

EXPERIMENTS / FUNDAMENTAL OF THE PROBLEM / EXAMINATIONS

Research regarding human-machine collaboration dates back several decades now and focuses mainly on developing safe robots^[1]. Comparatively little attention is given to the development of simulation models in order to validate intended collaborative tasks or system behaviour in error conditions, respectively. Although, valid simulation models already exist for machines as well as for human workers, a simulation environment or rather model for combining these two systems is still missing. Thus, it is necessary to identify a system formalism for describing collaborative applications incorporating humans and machines by answering the following research questions: How can the dynamic behaviour of collaborative systems be efficiently described within a system formalism including nonlinearities? Is the model valid regarding the real physical system and is it integrable in existing simulation environments? A risk analysis of collaborative tasks shows, that humans are mostly exposed to mechanical risks when collaborating with machines^[2]. Hence, parameters for monitoring collaborative applications include mutual distances, velocities, accelerations and forces but also process parameters of the control program such as correctness of the program sequence (Picture 1). In comparison to state-of-the-art simulation models, work envelope monitoring, control program monitoring as well as psychophysiological monitoring needs to be integrated in a hybrid model for collaborative applications. Additionally, nonlinearities describing physical and ergonomic limitations need to be identified and integrated. Work envelope monitoring is dependent on the size, velocity and responsiveness of the machine and the human, respectively. These factors can be described in the form of differential equations as a function of



Picture 1: Illustration of a hybrid collaborative system. Human works on objects that are moved by a machine.

time and joint parameters. Ergonomic limitations for collaborative applications can be adopted from guidelines specifying ergonomic working environments for workers. Already specified parameters include for example an ergonomic working height or an ergonomic free space around the human co-worker. Physical limitations, however, need to be identified by conducting research experiments - for example, for identifying the maximum velocity where a human worker is still able to operate on an object moved by a robot.

Having those parameters specified, the dynamic interoperability of a collaborative system needs to be validly mapped by the hybrid model formalism. In this sense, the system specification formalism of DEV&DESS (Discrete Event and Differential Equation Systems) introduced by Zeigler^[3] is used for describing the hybrid system of collaborative work. Hybrid systems specify systems consisting of both a discrete and a continuous part and can be described by an 11-tuple including a set of possible discrete and continuous inputs and outputs, a set of possible states, external and internal state transition functions, discrete and continuous output functions, a rate of change function as well as a state event condition function. As DEV&DESS describes only a method for formally specifying the behaviour of a system, a simulation-ready model is presented at the end of this work. Furthermore, the reliability of the implemented simulation model is evaluated as a human, for example, needs to be able to fulfil his required task during the movement of the robot or a robot may not harm a human worker during error conditions. This leads to a required predictability of the simulation model regarding physical feasibility and in particular safety.

RESULTS AND DISCUSSION

This work examines the impact of simulation on validating complex dynamic systems, especially in terms of identifying nonlinearities in human-machine collaborations. Collaborative work may not be implemented in industrial applications as long as the feasibility and reliability of the system is not evaluated with the help of simulation. This work has several implications for the research of human-machine collaboration. Above all, it identifies parameters influencing the safety of collaborative work. Furthermore, it shows a simulation model that is capable of validly mapping a physical collaborative system.

CONCLUSION

The process of designing safe collaborative machines that can co-work with humans has been mainly focused on mechanical capabilities of the machine. However, the reliability of a collaborative application needs to be validated by simulation prior to physical application. With the introduction of a mathematical valid simulation model for hybrid collaborative systems, a simulation-based evaluation of the system behaviour can be conducted. Although, digital human modelling has certain limitations, for example numerical model of psychophysiological behaviour, this work established a proof of concept concerning the validity of the proposed model.

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**CONVERGENT NUMERICAL METHODS FOR MICROMAGNETIC SIMULATIONS
OF SPINTRONIC DEVICES**

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INTRODUCTION

The classical micromagnetic theory models the behavior of ferromagnetic materials in the absence of electric currents and for constant temperature far below the Curie point. However, important scientific findings, e.g., the discovery of the giant magnetoresistance in magnetic multilayers, have suggested that there is a strong interplay, usually referred to as *spin transfer*, between spin-polarized currents and the local magnetization. Such theoretical findings provided the scientific background for the development of new spintronic devices, e.g., sensors, storage devices, and frequency generators. As their size decreases, testing and development become more and more involved, so that the need for reliable and stable simulation tools rises. In this work, we numerically compare different extensions of the micromagnetic model which include interaction with spin-polarized currents. We focus on mathematically reliable numerical integrators that are proven to be convergent towards a weak solution of the problem.

MATHEMATICAL MODELS

To take the interactions between magnetization and spin-polarized currents into account, several extensions of the micromagnetic model based on the concept of spin-transfer have been proposed. Most of them are based on augmented forms of the Landau-Lifshitz-Gilbert (LLG) equation, where the classical equation of motion governing the magnetization dynamics is enriched by a spin-transfer torque term. This additional term describes the mutual exchange of magnetic moment between the flowing itinerant conduction electrons and the localized magnetic electrons responsible for the magnetization of the material. We compare the model of Zhang and Li^[5], the coupling of the LLG equation with a quasilinear diffusion equation for the spin accumulation^[1–3], and a self-consistent model which consists of the LLG equation, an elliptic equation to model the spin accumulation in the stationary regime, and an equation for the electric potential derived from the Maxwell equations^[4].

NUMERICAL TREATMENT

As for the discretization of the LLG equation, numerical challenges arise from the strong nonlinearities, a nonconvex pointwise constraint which enforces length preservation, and the possible nonlinear coupling to other PDEs. We discuss numerical integrators, which combine lowest-order finite elements and boundary elements in space, that are proven to be (unconditionally) convergent towards a weak solution of the problem. Emphasis is put on an effective numerical treatment, where the time-marching schemes decouples the numerical integration of the LLG equation and the coupled equation.

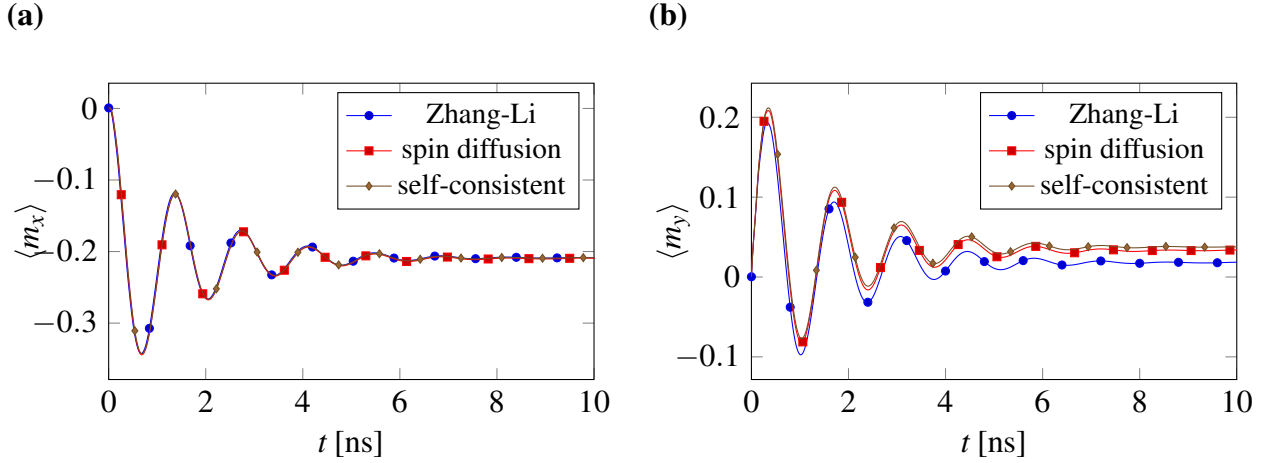


Figure 1: A suitable benchmark for current-driven domain wall motion is the micromagnetic standard problem #5 proposed by the μ MAG group. We compare the results for different micromagnetic models. Time evolution of the averaged magnetization components: (a) x -component, (b) y -component.

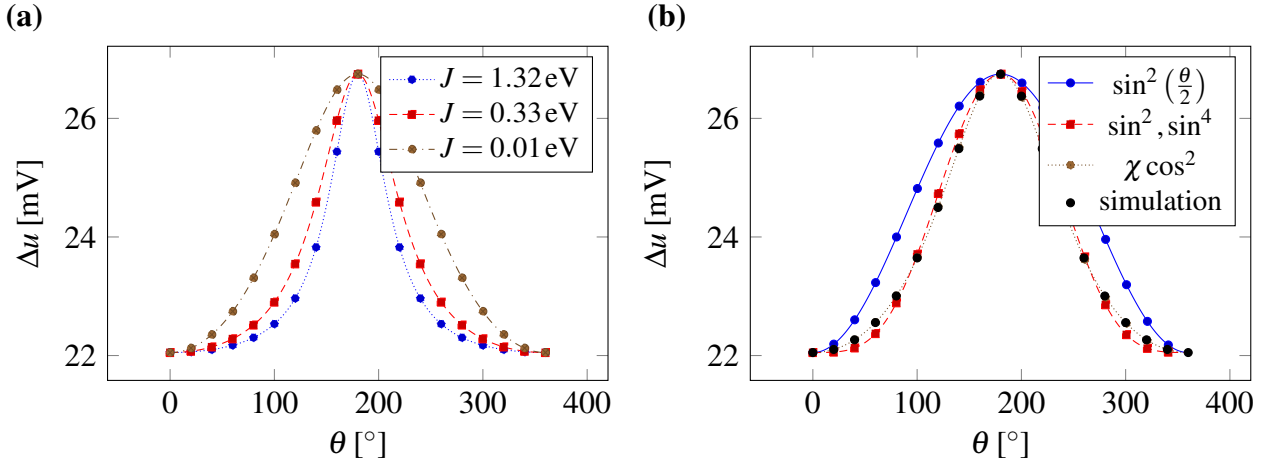


Figure 2: GMR computation using the self-consistent model. Potential difference Δu between top and bottom contact of a magnetic multilayer required to generate an average current density of 10^{12} A/m² as a function of the tilting angle of the magnetization in the free and fixed layer. (a) Variation of the exchange integral J , (b) Comparison of different GMR models.

ACKNOWLEDGEMENTS

The authors acknowledge support from the Vienna Science and Technology Fund (WWTF) under grant MA14-44, from the Austrian Science Fund (FWF) under grant W1245, from TU Wien through the *Innovative Projekte* initiative, from the Austrian Federal Ministry of Science, Research and Economy and the National Foundation for Research, Technology and Development, through the EPSRC grant EP/K008412/1, from the Royal Society under grant UF080837.

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THE REFLECTION-ABSORPTION MODEL FOR DIRECTED LATTICE PATHS

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INTRODUCTION

In this abstract we analyze *directed lattice paths*, when a boundary reflecting or absorbing condition is added to the classical models. The lattice paths are characterized by two time-independent sets of rules (also called steps) which have a privileged direction of increase. Depending on the spatial coordinate, one of the two sets of rules applies, namely one for altitude 0 and one for altitude bigger than 0. The abscissa $y = 0$ thus acts as a border which either absorbs or reflects steps. The absorption model extends the model analyzed by Banderier and Flajolet ^[1], while the reflection model leads to a more complicated situation. More details are given in ^[2], and a full version is in preparation.

Definition 1. A *step set* $\mathcal{S} \subset \mathbb{Z}^2$, is a finite set of vectors $\{(1, b_1), \dots, (1, b_m)\}$. An *n-step lattice path* is a sequence of vectors (v_1, \dots, v_n) , such that v_j is in \mathcal{S} . Geometrically, it is a sequence of points $(\omega_0, \omega_1, \dots, \omega_n)$ where $\omega_i \in \mathbb{Z}^2$, $\omega_0 = (0, 0)$ and $\omega_i - \omega_{i-1} = v_i$ for $i = 1, \dots, n$. The elements of \mathcal{S} are called *steps* or *jumps*. The *length* $|\omega|$ of a lattice path is its number n of jumps.

These walks constantly move one step to the right. We introduce the abbreviation $\mathcal{S} = \{b_1, \dots, b_m\}$.

Definition 2. For a given step set $\mathcal{S} = \{b_1, \dots, b_m\}$, we define the respective *system of probabilistic weights* as $\{p_1, \dots, p_m\}$ with $p_j > 0$, and $\sum_{j=1}^m p_j = 1$. For $b_j \in \mathcal{S}$ the associated weight is given by p_j . The

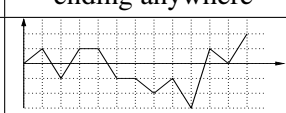
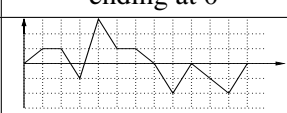
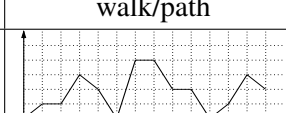
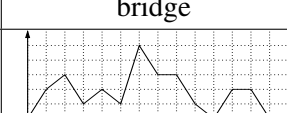
	ending anywhere	ending at 0
unconstrained (on \mathbb{Z})		
	walk/path	bridge
constrained (on \mathbb{N})		
	meander	excursion

Table 1: The four types: walks, bridges, meanders and excursions.

THE REFLECTION-ABSORPTION MODEL

Let us consider directed walks on \mathbb{N}^2 , with a weighted step set \mathcal{S} , starting at the origin, confined to the upper half plane, and which have another weighted step set \mathcal{S}_0 on the boundary $y = 0$. This walk model is encoded by two *jump polynomials*: $P(u)$ and $P_0(u)$. These are Laurent polynomials describing the allowed jumps when the walk is at altitude $k > 0$, or $k = 0$, respectively. We fix $c, d, c_0, d_0 \in \mathbb{N}$ and introduce:

$$P(u) = \sum_{i=-c}^d p_i u^i, \quad P_0(u) = \sum_{i=-c_0}^{d_0} p_{0,i} u^i, \quad P_0^{\geq}(u) = \sum_{i=0}^{d_0} p_{0,i} u^i.$$

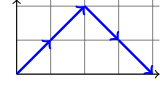
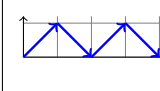
models		
absolute value	$\frac{1}{1+p_0/p+q_0/q}$	$\frac{p_0/p+q_0/q}{1+p_0/p+q_0/q}$
reflection model	$\frac{p}{1+p}$	$\frac{1}{1+p}$
absorption model	$\frac{p}{p+p_0}$	$\frac{p_0}{p+p_0}$

Table 2: Probabilities of paths restricted to excursions with $\mathcal{S} = \{-1, 1\}$ of length 4 in the absolute value ^[2], reflection, and absorption model. The jump polynomials are $P(u) = pu + qu^{-1}$, as well as $P_0(u) = u$ in the reflection, or $P_0(u) = p_0u$, $p_0 < 1$ in the absorption model.

In order to exclude trivial cases we require $p_c, p_d \neq 0$. These weights are probabilities, which means that $P(1) = P_0(1) = 1$. These step polynomials characterize the *reflection-absorption model*: depending on the chosen weights, the boundary behaves like a reflecting or an absorbing wall. We talk about a *reflection model* if $P_0^\geq(u) = P_0(u)$, while we talk about an *absorption model* if $P_0^\geq(u) \neq P_0(u)$.

RESULTS AND DISCUSSION

We will analyze excursions in the reflection-absorption model. The used methods are generating functions and singularity analysis [3]. Due to its analytic nature we will encounter several constants. Note that these constants seem artificial, however they are explicit.

Let τ be the structural constant given by $P'(\tau) = 0$, $\tau > 0$, let $\rho = 1/P(\tau)$ be the structural radius.

Lemma 3. *Let $u_1(z)$ be the unique small branch of the kernel equation $1 - zP(u) = 0$. Then the equation $1 - zP_0^\geq(u_1(z)) = 0$ has at most one solution in $z \in (0, \rho]$, which we denote by ρ_1 .*

Additionally, we define the constants $\alpha = (P_0^\geq(u_1(z)))'|_{z=\rho_1}$, $\alpha_2 = (P_0^\geq(u_1(z)))''|_{z=\rho_1}$, $\gamma = \frac{1}{\alpha\rho_1^2+1}$, and $\kappa = \rho \sqrt{2P(\tau)/P''(\tau)}(P_0^\geq)'(\tau)$.

Theorem 4 (Asymptotics of excursions). *The number of excursions in the reflection-absorption model possesses the following asymptotic expansion for $n \rightarrow \infty$:*

$$\begin{cases} \gamma\rho_1^{-n} \left(1 + \mathcal{O}\left(\frac{1}{n}\right)\right), & \text{supercritical case: } P(\tau) < P_0^\geq(\tau), \\ \frac{1}{\kappa\sqrt{\pi}} \frac{\rho^{-n}}{n^{1/2}} \left(1 + \mathcal{O}\left(\frac{1}{n}\right)\right), & \text{critical case: } P(\tau) = P_0^\geq(\tau), \\ \frac{\kappa}{2\sqrt{\pi}(1-\rho P_0^\geq(\tau))^2} \frac{\rho^{-n}}{n^{3/2}} \left(1 + \mathcal{O}\left(\frac{1}{n}\right)\right), & \text{subcritical case: } P(\tau) > P_0^\geq(\tau). \end{cases}$$

Theorem 5 (Limit laws for returns to zero). *The number X_n of returns to zero of a random excursion of size n admits a limit distribution:*

1. *In the supercritical case, i.e. $P(\tau) < P_0^\geq(\tau)$, $\frac{X_n - \mu n}{\sigma\sqrt{n}}$ with $\mu = \gamma, \sigma = \alpha_2(\rho_1\gamma)^3 - \gamma + \gamma^2(\rho_1 + 2) - 2\gamma^3$, converges in law to a standard Gaussian variable $N(0, 1)$.*
2. *In the critical case, i.e. $P(\tau) = P_0^\geq(\tau)$, the normalized random variable $\frac{\kappa}{\sqrt{2\pi}}(X_n - 1)$, converges in law to a Rayleigh distribution defined by the density $xe^{-x^2/2}$.*
3. *In the subcritical case, i.e. $P(\tau) > P_0^\geq(\tau)$, the limit distribution of $X_n - 1$ is a negative binomial distribution $\text{NegBin}(2, \lambda)$, with $\lambda = P_0^\geq(\tau)/P(\tau)$: $\mathbb{P}(X_n - 1 = k) = (k+1)\lambda^k(1-\lambda)^2$.*

CONCLUSION

Similar results hold for the asymptotics of meanders, and the limit law for the final altitude of meanders [2]. Furthermore, these results can also be extended to bridges and their returns to zero.

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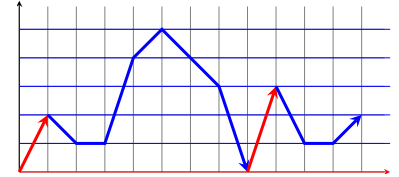


Figure 1: A walk in the reflection-absorption model. Different steps for altitudes $k = 0$, and $k > 0$.

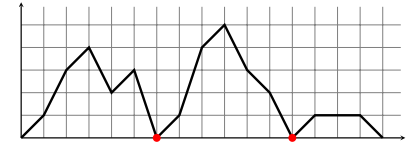


Figure 2: An excursion with 2 returns to zero.

3D LASER SCANNING AND PALEONTOLOGY

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INTRODUCTION

The purpose of this study is to illustrate the potential of 3D laser scanning technology in the context of paleontology. This is demonstrated by addressing a particular research question, the extraction of fossilized oyster shell central lines, in a dataset collected from the world's largest fossilized oyster reef whose age is 16.500.000 years. Laser scanning techniques provide a precise and objective methodology to digitally document and study paleontological objects *in situ* in a non-destructive manner. Analysis of high resolution laser scanning data (1 mm) offers a distinction between geometrical features and therefore supports the interpretation of surrounding topography. The visualization and detection of shell surfaces within the complex surroundings of the oyster reef provide a new room to test and study possibilities of using geometrical features in analysis. The reef's high resolution digital surface model helps to develop new algorithms for object extraction and analysis, such as reliable computations of shell size, orientation and volume. 3D laser scanning is an ideal candidate for multidisciplinary studies. Its results can be combined with those of other disciplines such as photogrammetry, geographic information systems (GIS) or biology and paleontology.

MATERIAL AND METHOD

Data collection

The world's largest fossilized oyster reef is located in Stetten, Lower Austria. A laser scanning and photogrammetric campaign was organized at the reef in 2014. The large and complex site was digitally documented using a remotely controlled high-speed FARO Focus3D laser scanner and a Canon 60D camera with a Canon EF 20 mm f 2.8 lens. The 3D point clouds and high resolution images from this field campaign were processed with photogrammetric methods into a digital surface model (DSM, 1 mm resolution) and orthophoto (0.5 mm resolution) to support the paleontological interpretation of data.

Mathematical method to extract individual 3D central lines of oyster shells: In this study, high resolution orthophoto and the DSM were used to define fossil boundaries. These are then used as an input for an automatic extraction of fossil central lines to provide information of their length. Central line calculation included: i) Constrained Delaunay triangulation between the fossil shell boundary points and formation of the Voronoi diagram; ii) extraction of Voronoi vertices within a shell and construction of a connected graph tree between them; iii) reduction of the graph to the longest possible central line via Dijkstra's algorithm; iv) extension of longest central line to the shell boundary and smoothing it with a cubic spline curve; and v) integration of the central line into the corresponding 3D point cloud.

RESULTS AND DISCUSSION

In the test set, 1121 complete oyster shell sizes and their orientation were derived from their 3D central line lengths and attitudes. The largest specimen attains 60.1 cm in length. The mean central-line length is 23.7 cm ($\sigma = 9$ cm); the interquartile range is from 17 cm to 30 cm. The orientation data provided direction of shells per tile [1]. Shell volumes were automatically derived from closed mesh models created from 9 individual shells extracted from the reef. These were used as volume estimates for shells with corresponding shell area in the reef as only their upper surface areas were known. Analysed specimens had a mean shell volume of 350.8 cm^3 ($\sigma = 313.7$) and age less than 10 years, growing up to about 30 cm in length [2]. Also, our results showed that the automatic central line calculation overestimated the manually collected reference length by 1.5%. This was deemed sufficient for shell age determination and indication of potential hydrodynamic currents. Volume calculations yielded a carbonate production estimate of $15 \text{ kgm}^{-2} \text{ yr}^{-1}$.

CONCLUSION

The resulting longest path estimate for the 3D central line is a size parameter that can be applied in oyster shell age determination both in paleontological and biological applications [2]. Our investigation evaluated that the proposed method was successful in measuring shell lengths based on a comparison between automatically extracted central lines and manually collected reference data.

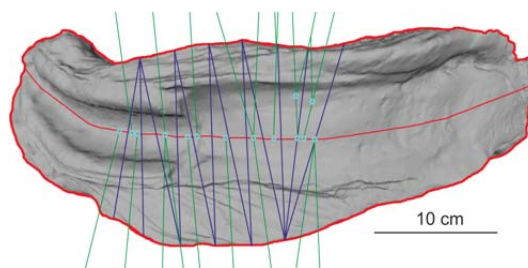
Despite the numerous publications that deal with the lower Miocene strata of the investigation area, virtually nothing was known about the geometry of the shell bed. This study provided a novel paleontological context about size, orientation, and volume of the fossil shells which are now included in a GIS database. Moreover, extracted central lines support 3D object matching by finding similar or identical objects in the database. In future, our work will aim to use point cloud and central line information to better describe relations between them in order to find shell pairs. These will provide a digital documentation of the current status of the fossils. Considering the case of natural disasters or deliberate destruction, the highly detailed digital model enables future interpretation and analysis based on not yet known scientific experiences.

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Picture 1: Oblique view of the orthophoto overlain with a shaded digital surface model derived from 3D point cloud (2 m x 1.6 m).



Picture 2: High-resolution 3D model of single oyster shell overlapped with illustration of Delaunay triangulation, Voronoi vertices and extracted central line.

MATHEMATICAL MODELING OF IRREGULAR FIRING IN THE ELECTRICALLY STIMULATED RETINA

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INTRODUCTION

Using inner eye prostheses, the restoration of vision to the blind has achieved a low level which hopefully will be enhanced in the future. Patients suffering from degeneration of their photoreceptors, cells which modulate light input to neuronal output, can regain visual perceptions by electrically stimulating the remaining retinal neurons. The aim of the investigated modeling approach was to contribute to the understanding of the responses of extracellularly stimulated retinal ganglion cells (GCs) which generate artificial vision in the visual cortex.

METHODS

The modeled response of GCs to extracellular electrical stimulation can be computed with multi-compartment models. Our modeling discretizes a given 3-D cell geometry in space, generating cylindrical and spherical compartments. Current flow between compartments and across the cell membrane leads to a system of ordinary differential equations (Fig. 1^[1]). The cell membrane is modeled as a resistor-capacitor circuit, thus, three currents in each compartment can be discerned: i) a capacitive current charging up the membrane; ii) an ionic current through ion channels embedded in the membrane; iii) an ohmic current in axial fiber direction. Ionic currents are computed with a Hodgkin-Huxley-like model approach^[2]. Additionally, random fluctuations of the transmembrane currents were included^[3]. The extracellular field generated by a stimulating electrode is computed by a simple analytical solution for point sources in homogeneous media.

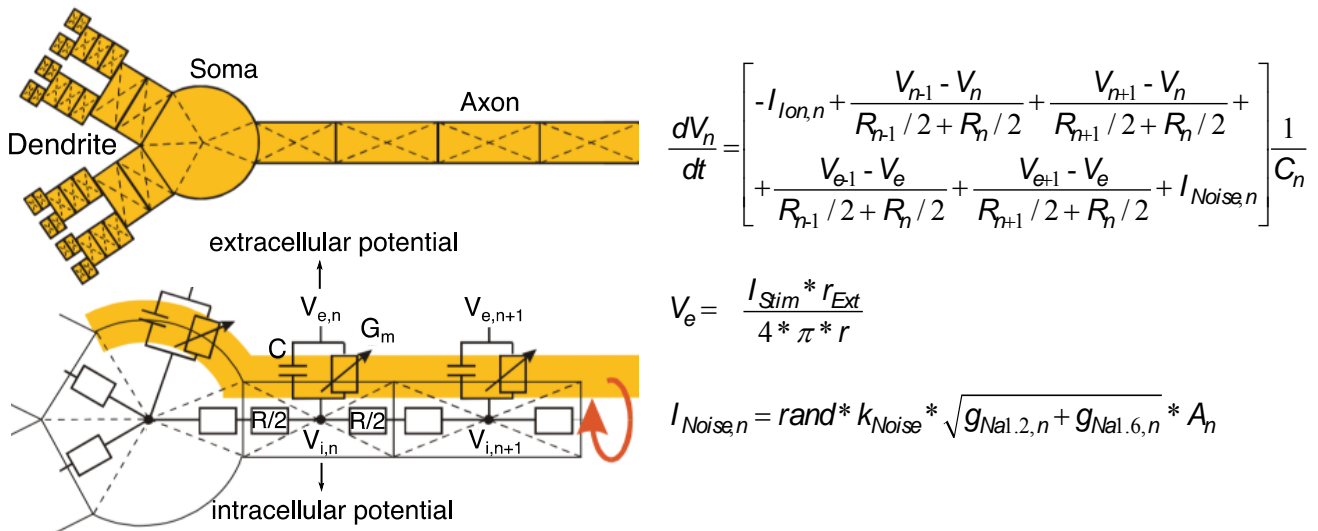


Figure 1: Mathematical model of nerve cell response to extracellular stimulation - (Left) A simple neuron geometry (top) and its equivalent electrical circuit (bottom). (Right) Governing equation for the multi-compartment model and equations used for the computation of extracellular electric fields and random membrane currents, respectively. For details see^[1].

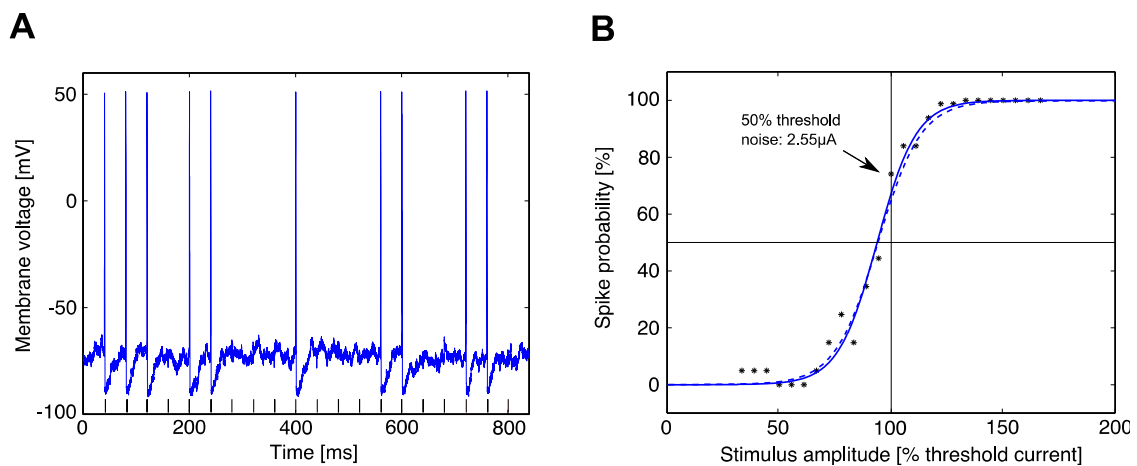


Figure 2. Irregular spiking response of an electrically stimulated GC and recruitment curve for stimulation - (A) Response of the model neuron to 20 pulses (indicated at the bottom) at $2.55\mu\text{A}$. 10 spikes were initiated which corresponds to a 50% spike probability. (B) Recruitment curve describing spiking probability as function of stimulus amplitudes. The solid trace denotes a fitted sigmoid (Boltzmann) function. Data from experimental work is shown as dashed line [4]. Threshold amplitude was determined at $2.55\mu\text{A}$ which led to more than 50% spike probability.

RESULTS AND DISCUSSION

Modeled noise led to variable results in repetitive simulations even when the same input parameters were used. Recruitment curves of neuronal responses could be computed by introducing a probability for spiking at distinct amplitudes. Figure 2A shows a spike train at the 50% spiking probability of the model neuron. Twenty 0.1ms stimulus pulses were applied to the model neuron with an inter-stimulus interval of 39.9ms (25Hz). Baseline noise could be seen in the voltage trace throughout the whole simulation. When an AP was initiated the membrane voltage trace becomes smoother because currents during a spike are immense higher than the small noisy currents.

Running this simulation for different amplitudes resulted in recruitment curves as shown in figure 2B. When the stimulus amplitude was increased stepwise ($0.05\mu\text{A}$) spike probability increased from 0-100%. Each stimulus was presented twenty times. Until a stimulus amplitude of approximately 60% of threshold current no spikes were observed and amplitudes above 140% threshold current led to spikes all the time.

CONCLUSION

Introduction of random fluctuations to a mathematical model of GCs describes physiological behavior in *in-vitro* stimulated GCs quite well [4].

ACKNOWLEDGMENT

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MODEL OF PARTICLE DEGRADATION OF CALCIUM SORBENT USED IN FLUIDIZED BED BOILERS FOR COAL COMBUSTION

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INTRODUCTION

Fluidization is one out of many process technologies that are widely used in fossil fuel energy industry. Its mechanism concentrates on oxidant gas lifting of solid fuel particulate material in order to occupy whole volume of given reactor^[1]. The process is well known for high mixing conditions and high conversion rates. Fluidization also allows for performing desulfurization inside of reactor by adding sorbent, in most of cases calcium carbonate inside of the reactor to fluidize along with the fuel.

The main aim of work was development of model for product particle degradation with emphasis on calcium sorbent usage in the of flue gas desulphurization process for coal-fired boilers. The project started with proper literature models selection and their further optimization basing on data analysis. The results gave insight on several process improvement possibilities for the one of coal-fired power plants in Southern Poland.

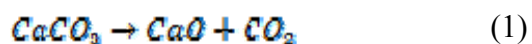
FUNDAMENTALS OF THE PROBLEM AND EXAMINATIONS

Due to complexity of the processes that needs to be modelled, the project was broken down into three stages that addressed different aspects of the phenomenon and general combustion process:

Fluid bed characterization: this part comprised of calculations based on data and sample gathering form one of hard coal power plants in Southern Poland. The process parameters were gathered and analysed for elemental constituents and their basic properties.

Particle size distribution: in fluidization particle size is a key parameter in fluidization control and gas sorption. The challenging aspect of the problem lies in particle size change during the process caused by high mixing conditions^[2]. The authors suggested the size change function as exponential equation.

Kinetics desulphurization process: the main reactions that govern this process are thermal decarbonisation of calcium carbonate (1) and chemisorption of sulphur trioxide (2):



To simulate this two stage process with consideration of particle pore structure and structure a Shrinking Core Model (SCM) developed by Hu and Watanabe^[3] was adapted.

RESULTS AND DISCUSSION

Gathered based data analysis resulted in full process characterization along with complete mass balance in the reactor and average residence time of the particles calculation. Additional mass flow analysis on the other hand discovered plug flow reactor conditions, an unfavourable fluidization regime. Analysis of size distribution when optimized with least square function gave the parameters

for a size change function. When compared with gathered data on feed particles a function that closely follows the experimental results with error no bigger than 5%, was obtained.

The application of SCM model resulted in very low conversion rates that in addition were poorly matched to experimental results. In order to fix the issue a correction (3) for particle size was applied as the result showed clear dependency for this variable.

$$\frac{d d_p}{d t} = 10^{-4} d_p \quad (3)$$

The result for reaction kinetics, changes in particle size during process and general conversion efficiency were then recalculated. For comparison, the actual reactor particles conversion was compared with experimental conversion of 83%. The final calculated conversion equal to 81% gave a good match as shown on Fig 1.

CONCLUSION

The project succeeded in creation of model capable of dry desulfonation simulation with emphasis on sorbent conversion and its diameter size. The kinetic SCM-based model that utilized speed of diameter change as a correction to normal SCM model gave satisfying results that matches the literature data [5]. Moreover the function created for particle size description also were in good

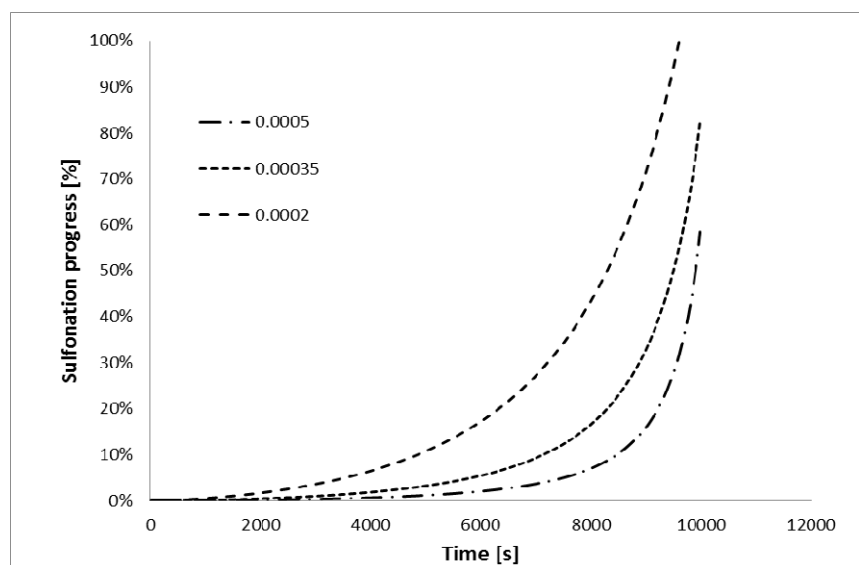


Figure 1 Reaction kinetics after adjustments for different particle diameters: 0.2mm, 0.35mm 0.5mm

agreement in experimental results. The next stage of the project should include the test of reactor under different conditions to practically assess its potential for further calcium sorbent usage optimisation. Before then it is important to address unfavourable flow regime in the reactor and decide if any countermeasures should be applied. The Authors of this paper suggest recirculation of fly ash as the easiest way to increase the conversion.

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GEOMETRIC ANALYSIS OF ELECTROSTATIC MICRO-ELECTRO MECHANICAL SYSTEMS (MEMS)

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INTRODUCTION

Micro-Electro Mechanical Systems (MEMS) are very small structures that combine electrical and mechanical components on a common substrate to perform a variety of tasks. Due to their importance in various fields such as medicine, transport industry and technology MEMS have been studied intensively. Mathematical modeling and analysis have been successfully employed in the design and improvement of these devices. The aim of this contribution is to present our results concerning a second-order PDE modeling electrostatic-elastic devices.

EXPERIMENTS/FUNDAMENTAL OF THE PROBLEM/EXAMINATIONS

In the standard model, the dynamics of a thin membrane under the influence of elastic and electrical forces is described by a parabolic PDE with a particular nonlinear source term [1]. Special attention is given to the so-called “touchdown phenomenon”, leading to unbounded electric field. Mathematically, touchdown causes non existence of steady states and/or finite time blow-up of solutions.

Our starting point is a recent more detailed model depending on a small “regularization” parameter ε in which the singularities are avoided by considering additional insulating effects [2]. Its interesting dynamics and bifurcation structure have been studied numerically and by formal asymptotic methods. The main difficulty is that close to touchdown the problem depends singularly on two parameters.

RESULTS AND DISCUSSION

Geometric singular perturbation theory and blow-up techniques can provide more detailed information about the dynamics of the model as the two main parameters tend to zero. In particular, this approach leads to a better understanding of the singular perturbation nature of the problem and to identify the source of a logarithmic switchback phenomenon.

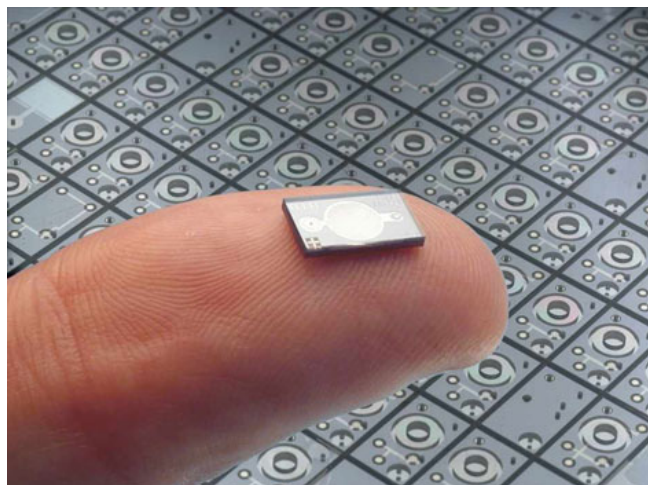


Figure 1: Electrostatic-elastic MEMS prototype.

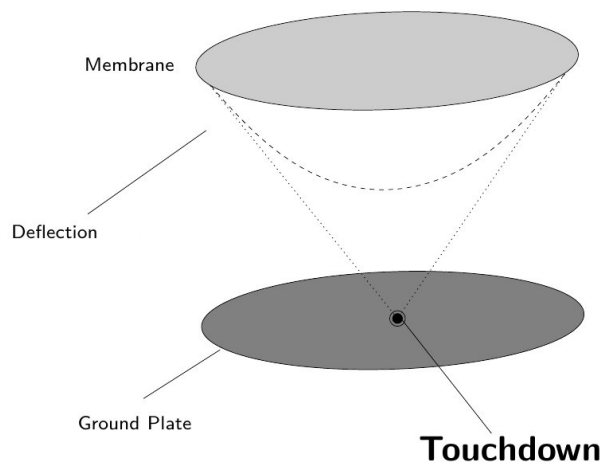


Figure 2: Schematic description of an electrostatic-elastic device; the deformation is due to the application of a potential V .

CONCLUSION

Our future goal is to extend these studies to an analogous model considering a bi-Laplacian term.

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Introduction

Quantum mechanics describes nature on the microscopic scale of individual atoms and molecules. Its laws lead to baffling, sometimes even disturbing phenomena, such as a fundamental uncertainty of physical quantities, superpositions of contradicting measurement results (see Schrödinger's cat), and the entanglement of the properties of spatially separated particles. Quantum mechanics has fundamentally changed our understanding of the predictive power of physical theories and the role of the measurement process or the observer.

Currently, essentially all devices and technologies we use in everyday life are dictated by the laws of classical physics. The laws of quantum physics provide an entirely different toolbox for constructing a "quantum technology". Conceptually new approaches to topics like the storage and processing of information (quantum computers), the encrypted transmission of data (quantum communications), and precision measurement instruments such as atomic clocks and interferometers (quantum metrology) are investigated. Such quantum devices have the potential to outperform their "classical" counterparts or solve problems that are fundamentally untraceable by current classical technology.

Research groups at the TU Wien are seeking to observe quantum effects in a variety of physical systems like photons, neutrons, atoms, molecules and solid-state systems. Our aim is to develop robust implementations of quantum physics as the basis for future quantum technologies. Quantum physics and quantum technology is one of the five research focus areas of the TU Wien.

DYNAMICS OF A DRIVEN BOSONIC JOSEPHSON JUNCTION: INTERACTING BOSE-EINSTEIN CONDENSATES IN A DOUBLE-WELL POTENTIAL

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INTRODUCTION

At temperatures very close to absolute zero, a gas of atoms undergoes a phase transition into a new state of matter, where all atoms can be described by a single collective quantum-mechanical wave function. This so-called Bose-Einstein condensate was theoretically predicted in 1925 and experimentally realized exactly 70 years later, yielding two Nobel prizes in 1997 and 2001. Bose-Einstein condensates are interesting for a broad variety of studies such as ultra-precise measurements or quantum simulations. They are characterized by a high level of control over the experimental parameters (interaction sign and magnitude, controlled introduction of defects, dimensionality), making them of particular interest as an analogue to condensed matter systems.

We present a bosonic Josephson junction, realized by a Bose-Einstein condensate magnetically trapped in a double-well potential. This system bears a strong analogy with a superconducting Josephson junction, in which two superconductors are separated by a thin layer of insulating material. In condensed matter, the Josephson effect allows the tunneling of electrons pairs and the circulation of supercurrent through the junction despite the insulating layer. In a bosonic Josephson junction, atoms will tunnel under the effect of inter-atomic interactions. These introduce an intrinsic non-linearity, making a bosonic Josephson junction richer than their condensed matter analogue.

EXPERIMENTS / FUNDAMENTAL OF THE PROBLEM / EXAMINATIONS

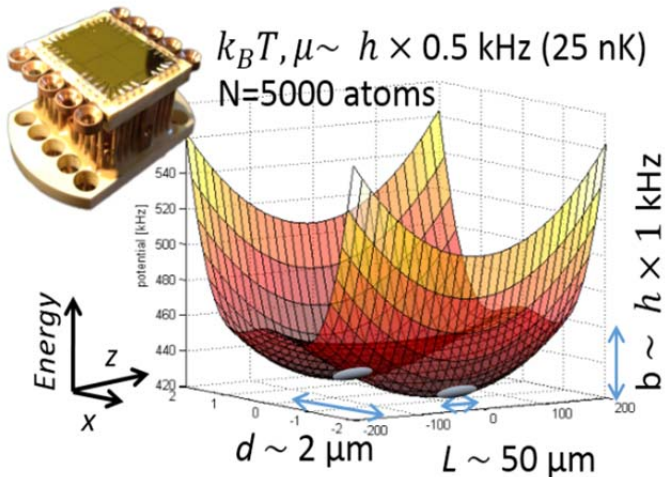


Figure 1: Atom chip and simulation of the double-well potential with typical experimental parameters

We study the effects of particle interactions on the tunneling dynamics of an elongated Bose-Einstein condensate in a magnetic double-well potential, realized on an atom chip.

In contrast to Josephson junctions in solid state physics, the tunnel barrier can be dynamically adjusted, using a method known as radio-frequency dressing^[1]. It enables a deformation of the trap and a splitting of the Bose-Einstein condensate wave-function into the left and right sites. Atomic clouds are then separated by a potential barrier through which atoms will tunnel.

The tunneling dynamic translates into a time evolution of two experimentally accessible quantities: the atom number difference and the relative phase between the two clouds. The controlled tuning of the potential barrier and the presence of inter-atomic interactions allow the investigation of various tunneling regimes such as Josephson (plasma) oscillations and macroscopic quantum self-trapping.

RESULTS AND DISCUSSION

In all of these regimes, we observe that the tunneling dynamics is accompanied by a fast relaxation towards a phase-locked equilibrium state. The observed relaxed state is identical regardless of the experimental parameters and initial state of the system. This relaxation was not expected, as it does not occur in the Josephson junction in condensed matter.

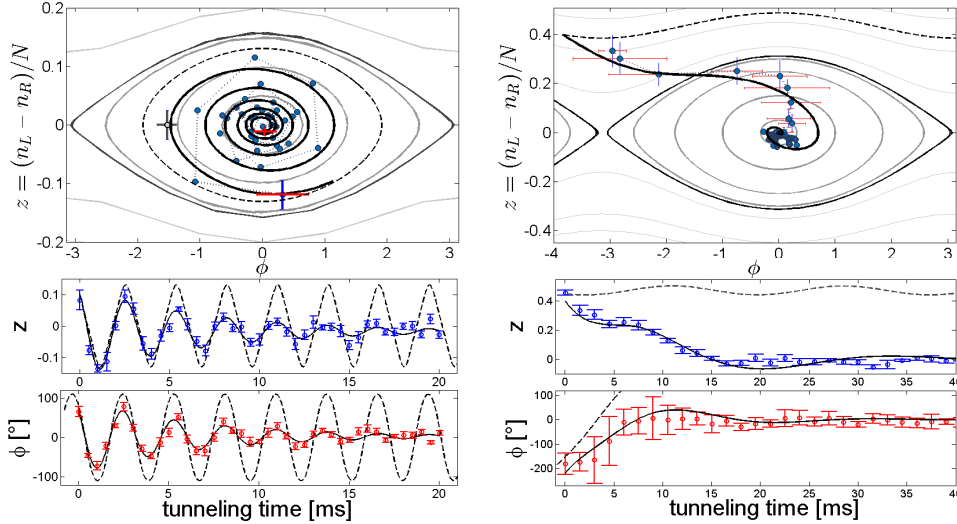


Figure 2: Relaxation of the tunneling dynamic in the oscillating regime (left) and in the self-trapping regime (right). Top to bottom: phase portrait representation, time evolution of the number difference, time evolution of the relative phase. Dashed lines are the undamped trajectories.

The tunneling dynamic of our system can be modelled by a Bose-Hubbard Hamiltonian. One can derive from it the equations of motion, which predict the time evolution of the relative phase and number difference. In order to reduce the complexity of the problem, we adopt a mean-field approach, in which each atom experiences the presence of the other atoms as a single average effect, hence reducing a many-body problem to a one-body problem. The equations of motion in this description are similar to those of a pendulum, whose length would vary with its velocity. Using this analogy, we include the observed damping to the mean-field model as an empirical viscosity, analogue to the friction term damping a classical pendulum^[2]. This empirical description allows a better understanding of the damping mechanism, as we can deduce from it the dependence of the damping magnitude with our experimental parameters. We observe no dependence of the damping on the tunnel coupling strength but a dependence on the atom number.

CONCLUSION

In this study, we observe that coupled elongated Bose-Einstein condensates will undergo a tunnel dynamic when driven out of equilibrium. In addition to the expected periodic dynamic, we observed a fast relaxation of the system not contained in the existing descriptions. This relaxation happens regardless of the initial state and experimental conditions. In particular, it does not depend on the strength of tunnel coupling and varies with the atom number.

Work is currently done on analysing the effect of the temperature, initial phase, initial imbalance, as well as the effect of the initial fluctuations. Knowing the effect of these parameters will help determining the physical origin of the damping. The analysis of the fluctuations will also provide a better understanding of the relaxed state. In particular, we would like to compare the equilibrium state reached after relaxation to the ground state of the system at equilibrium.

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QUANTUM TUNNELING OF LARGE MECHANICAL OBJECTS

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INTRODUCTION

Since the advent of quantum physics in the beginning of the last century we know that physics on much smaller scales than our everyday world exhibits completely different and sometimes counterintuitive behavior. One of these being that objects are only allowed to have certain discrete quanta of energy which motivated the name for the physics on these scales: Quantum physics. For the founding fathers who explored this new physics most ideas remained mere thought experiments. Only for the last few decades due to a tremendous advances in technology and a vast amount of effort experimental physicists were able to prepare systems this small and fragile.

QUANTUM TUNNELING

Among the many strange phenomena of quantum physics the "tunnel effect" is particularly simple to grasp. From classical mechanics we know that in order to pass a barrier an object (e.g. a tennis ball) needs at least enough energy as the barrier is high to leap over it. In quantum physics objects (e.g. electrons and atoms) which have much less than the classically required energy, have a chance to clear the barrier by tunneling through it. This phenomenon is at the heart of many modern technological devices such as microscopes and memories. In these devices however only very small objects like electrons, which are considered completely in the realm of quantum physics, exhibit this tunneling. For decades scientist wondered whether also "larger" objects exhibit the same behavior [1]. This is also relevant for the long standing question how our well known classical world as we know it emerges from this underlying strange quantum world. If tunneling or the absence of it was observed for objects of increasing mass, we were able to determine whether mass drives the crossover between classical and the quantum physics.

RESULTS AND DISCUSSION

Building on the recent work of [2] we propose a protocol to prepare a large mechanical object (e.g. levitated nanometer scale beads or a thin membranes) such that they tunnel through an engineered potential barrier. Furthermore we identify a measurement signature which ensures that actual tunneling and not classical leaping over the barrier has occurred. By bouncing off light pulses on these objects in a controlled way we can prepare them as well as infer their position. Controlling the position of mechanical objects by light go by the name "optomechanics".

CONCLUSION

We have proposed an experimentally feasible way to observe tunneling for macroscopic objects using optomechanics paving the way towards observing the quantum or classical nature of increasingly massive objects. This might help shed new light on the transition between quantum and classical world.

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ANDERSON LOCALIZATION OF A ONE-DIMENSIONAL BOSE-EINSTEIN CONDENSATE AFTER LONG-TIME EXPANSION

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INTRODUCTION

Anderson localization is an interference effect of non-interacting particles in disordered systems which leads to suppression of transport^[1]. It is still an open question whether Anderson localization occurs in interacting systems. In recent experiments Bose-Einstein condensates were used to investigate Anderson localization in a highly controllable setup^[2]. A Bose-Einstein condensate initially trapped in a harmonic potential was released and its expansion in a weak disorder potential was monitored. The observed suppression of its expansion was explained assuming that the initially interacting system becomes non-interacting for long expansion times^[3]. We investigate this assumption and examine the long-time influence of pair interactions by calculating the expansion with and without inter-particle interaction. We evaluate at which times the two scenarios can be distinguished from each other.

THEORETICAL BACKGROUND

Anderson localization originates from destructive interference of all partial waves in a disorder potential leading to suppression of transport and "freezing" of the wave function. For non-interacting one and two-dimensional disordered systems Anderson localization is a general feature and independent of the properties of the disorder potential^[4]. In the experiment^[2], a Bose-Einstein condensate was formed out of a cloud of ultra-cold atoms (in the present case ⁸⁷Rb atoms) that interact with each other via van der Waals interactions. At very low temperatures these interactions can be described as point-like interactions. The many-body dynamics can be described on the mean-field level within the Gross-Pitaevskii equation

$$i\hbar \frac{\partial}{\partial t} \Psi(x,t) = \left[-\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2} + V(x) + g |\Psi(x,t)|^2 \right] \Psi(x,t), \tag{1}$$

which assumes that the motion of all atoms is fully coherent at all times and can be described effectively by one wavefunction with self-interaction (Eq. 1).

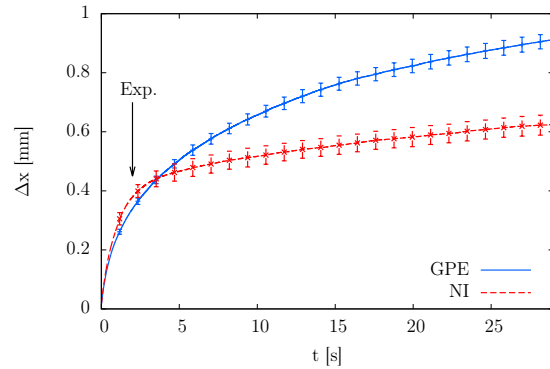


Figure 1: Comparison of the width Δx of a Bose-Einstein condensate that is interacting throughout the simulation (solid line - GPE) with the case where interactions are turned off after an initial expansion period where most of the interaction energy is converted into kinetic energy (dashed line - NI). We show the mean value and the standard deviation over 30 different realizations of the disorder potential. The arrow denotes the experimentally investigated time span^[2].

RESULTS AND DISCUSSION

We compare the proposed scenario ^[2,3](NI) with a calculation in which the condensate is interacting at all times (GPE). In the first case (NI), we switch off interactions when most of the initial interaction energy is converted into kinetic energy. Monitoring the width Δx of the Bose-Einstein condensate for the two scenarios we observe a difference for $t > 5$ s (Fig. 1). This is a long time scale compared to the experiment where observations stopped at $t \approx 2$ s ^[2]. Looking at the condensate wave function we observe that for the interacting condensate the central part keeps broadening at all times (Fig. 2). For the initially interacting condensate where we switch off the interaction after a given time interval we observe saturation of the wave function (Fig. 3). The shape of the wave function was predicted theoretically ^[3].

CONCLUSION

Within this work we revisited the problem of Anderson localization of Bose-Einstein condensates in disordered systems. We performed long time simulations and were able to show that the difference between an interacting Bose-Einstein condensate (GPE) and the case where interactions are assumed to be negligible for the long-time behavior and therefore switched off after a certain time (NI) is clearly visible after 5 s which is considerably longer than the experimentally investigated time ^[2]. In contrast to the interpretation of the experiment that the condensate dilutes during the propagation and can therefore be treated as if non-interacting we show that the effect of interactions becomes visible only after long propagation times. We propose to revisit this problem experimentally and are confident that today's experimental setups can clarify the question how interactions influence Anderson localization.

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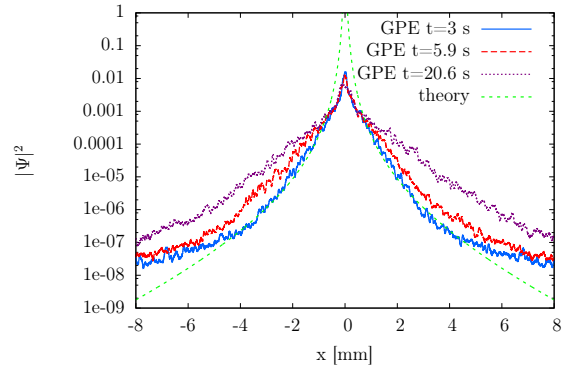


Figure 2: Smoothed wave function of the interacting condensate for different times.

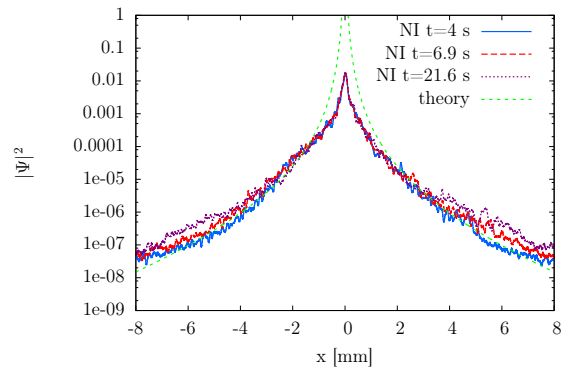


Figure 3: Smoothed wave function of the only initially interacting condensate for different times. Typical switch-off times for the interaction are $t \approx 1.3$ seconds.

INHIBITION OF GROUND-STATE SUPERRADIANCE AND LIGHT-MATTER DECOUPLING IN CIRCUIT QED

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INTRODUCTION

The Dicke model is frequently used in atomic and solid-state systems as a minimal model to describe phenomena related to the collective coupling of many emitters to a single radiation mode^[1]. When extended to the ultrastrong coupling regime, the ground state of the Dicke model undergoes a phase transition into a superradiant state^[2], where the atoms are polarized and the field mode exhibits a non-vanishing expectation value.

The existence of a superradiant phase transition (SRT) in the ground state of equilibrium cavity quantum electrodynamics (QED) systems is still subject of ongoing debate^[3]. The so-called A^2 -term, originally neglected by Dicke, supposedly prevents the SRT in these atomic systems.

The question of the SRT has regained considerable interest with the development of circuit QED systems, where ultrastrong light-matter interaction between superconducting two-level systems and microwave photons has recently been implemented. In particular, it has been argued^[4] that the A^2 -term does not play a crucial role in these artificial devices.

FUNDAMENTAL OF THE PROBLEM

In this work we investigate a circuit QED system, depicted in Fig. 1, where N identical two-level systems (charge qubits) are coupled symmetrically to a single microwave mode, such that in the limit of weak couplings the system reduces to the standard Dicke model. We show from first principles that the full description of such a system necessarily contains additional direct interactions between the two-level systems, which have been ignored in many previous studies, but become non-negligible as one approaches the ultrastrong coupling regime.

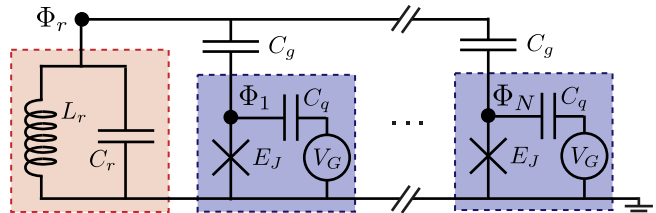


Figure 1: The setup of our system. The leftmost shaded box describes the microwave degree of freedom and the boxes to the right of it constitute the two-level systems. All of the two-level systems are identical and symmetrically coupled to the microwave mode.

We study the ground state of the circuit QED system both numerically and analytically. Based on the insight obtained from the numerical simulations, we develop a simple and intuitive theoretical description to explain the interesting properties of such interacting light-matter systems in the ultrastrong coupling regime.

RESULTS AND DISCUSSION

We find that the interactions between the two-level systems, rather than an A^2 -like term, prevent the occurrence of the conventional SRT in our circuit QED system. Instead, with increasing coupling the

system gradually evolves into a hybridized state. Surprisingly, at even higher interaction strengths, an opposite effect can take place, where the microwave component of the ground state completely decouples, while the two-level systems collapse into a highly entangled state with vanishing dipole moment.

CONCLUSION

In summary, we have analysed collective interactions in circuit QED systems in the ultrastrong coupling regime. We have shown that the interactions between the two-level systems prevent a SRT in such systems and lead instead to light-matter decoupling and highly entangled ground states at very strong interactions.

These findings are experimentally accessible with state-of-the-art superconducting devices^[5,6], and it should be possible to test our predictions for $N = 2$ or more two-level systems, but also provide new insights for closely related effects discussed in the optical or THz regime^[7-9].

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QUANTUM INTERFERENCE EFFECTS IN COHERENT ELECTRON TRANSPORT THROUGH SINGLE MOLECULE JUNCTION WITH BRANCHED COMPOUNDS CONTAINING FERROCENE

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INTRODUCTION

Molecular electronics has become an active field of research in recent decades, since it holds the promise to maintain a continuous progress in the miniaturization of digital devices, thereby overcoming the limitations of semiconductor technology^[1,2].

Quantum interference (QI) effects have been found to significantly reduce the conductance in some conjugated π systems where graphical rules could be derived to predict their occurrence from the molecular structure^[3,4]. QI effects could be applied for logical gates^[5] and data storage^[6] in single molecule electronics, and have been suggested as a general tool for the implementation of various single molecule devices. In this contribution, the emphasis is on investigating QI effects in branched molecules containing Ferrocene (Figure 1), where the transmission functions describing coherent electron transport through the junction (Figure 2) were calculated from density functional theory in combination with a non-equilibrium Green's function approach (NEGF-DFT).

QUANTUM INTERFERENCE EFFECTS IN JUNCTIONS WITH SINGLE- AND DOUBLE-BRANCHED COMPOUNDS

We designed molecular compounds with one and two branches each containing Ferrocene (Figure 1), where from the transmission functions (Figure 2) we could identify QI induced minima (dips) in the energy region at the lower and upper borders of the HOMO-LUMO gap, where both occur for structure A, only the lower one for structure B and only the upper one for structure C, respectively. We interpreted the findings in terms of simplified tight binding (TB) models. In these TB models we found that with a few frontier molecular orbitals (MOs) we could reproduce the main interference characteristics from the DFT calculations for each studied system, where the sign of the product of the couplings between the respective MOs and the contact gold atoms at the left and right electrodes plays a critical role. For this type of analysis we needed to derive the couplings of each relevant MO to the s- state of the gold contact atoms because the surface states of the leads with s- symmetry dominate the transmission function around the Fermi level. As long as we obtained the correct signs for these couplings, we could use Larsson's formula^[7,8] to analyze the

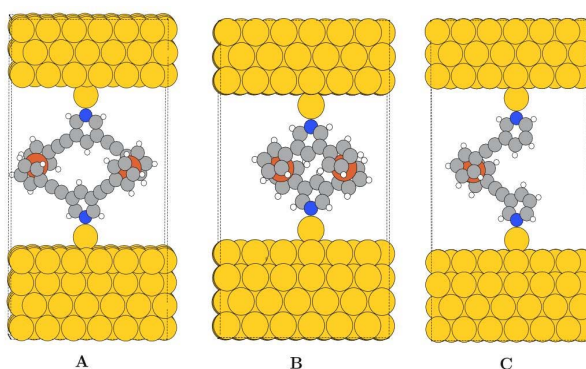


Figure 1: Junction geometries for the ferrocene branched compounds we investigated.

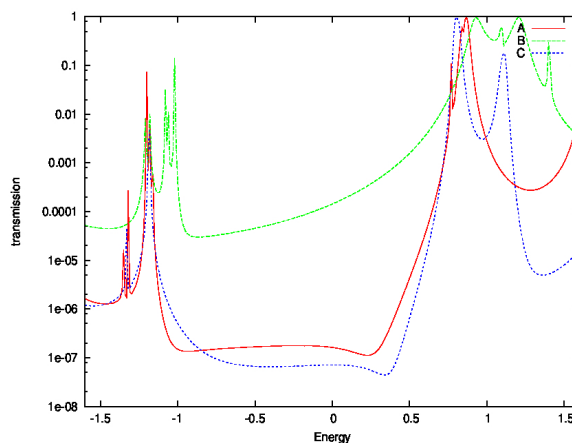


Figure 2: Transmission functions for the three ferrocene junctions calculated from NEGF-DFT.

cause of the respective interference effects and further interpret the sources in the respective molecular and electronic structures for them to occur.

ADJUSTING THE OXIDATION STATE OF ONE OF THE TWO REDOX-ACTIVE CENTERS

Furthermore, we adjusted the redox state of one of the metal centers for the double-branched compounds by adding a Chlorine atom into the junction which obtained an electron from the junction due to its high electronegativity, leaving it open for the resulting positive charge to distribute itself across the complex and gold electrodes, where the Chlorine counterions ensure charge neutrality within the unit cell of the device region. We achieved an asymmetry of the two branches regarding their respective partial charges to different degrees by gradually changing the distance between the Chlorine atom and one of the two Ferrocene groups. By comparing the transmission functions of the neutral compounds with the corresponding charged systems described in this way, we could investigate the influence of the asymmetry induced by a difference in the partial charging of the two branches for structures A and B on the occurrence and characteristics of the observed QI effects.

CONCLUSION

In summary, we focused on interpreting the sources of QI effects in coherent electron transport through a set of molecular compounds containing Ferrocene in one or two branches. In our analysis, we tried to distinguish the contributions to these observed QI effects coming from several structural features of the investigated compounds: i) the meta-connections to the pyridil anchor groups; ii) the large number of Ferrocene states; iii) paths through two different branches. In our study, we considered all these possibilities and their respective role. For the QI effects observed in the transmission functions from NEGF-DFT (Figure 2) for structures A, B and C (Figure 1), where we used simplified TB models and Larsson's formula applied to the frontier MOs of the compounds as our main tools for this analysis. Our study opens a way for the systematic design of branched metal-organic compounds. For molecular devices, where the ON and OFF states of a molecular transistor would differ in their conductance due to QI effects, and the switching between the two states can be triggered by a redox reaction.

ACKNOWLEDGEMENTS

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**THE FALICOV-KIMBALL MODEL:
ANALYTICAL RESULTS ON ELECTRONIC CORRELATION**

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INTRODUCTION

Correlated electrons are of great interest, both for experimental and theoretical solid state physics. Interactions between electrons give rise to a plethora of fascinating and potentially useful phenomena, including superconductivity and quantum criticality. The well-known Hubbard model is believed to contain the fundamental physics which cause high temperature superconductivity, but while it can be treated numerically, exact results are scarce. The Falicov-Kimball model ^[1] (FKM) cuts away some degrees of freedom but remains an interacting system. The reduced complexity suddenly allows for an analytical solution, at least for some quantities.

PROBLEM AND METHOD

The FKM is a model for interacting electrons of two types, mobile *c*-electrons and stationary *f*-electrons on a lattice, which repel each other: This is defined by the Hamiltonian

$$\mathcal{H} = \sum_{\langle i,j \rangle} t c_i^\dagger c_j + \sum_i \left[U c_i^\dagger c_i f_i^\dagger f_i - \mu \left(c_i^\dagger c_i + f_i^\dagger f_i \right) \right], \quad (1)$$

with the summation over *i* including all lattice sites and $\langle i, j \rangle$ summing over all pairs of nearest neighbours. Despite its simple appearance, the solutions of this model are non-trivial.

Dynamical mean field theory ^[2] (DMFT) provides a well established method of describing all purely local correlations of such electrons systems by mapping the problem to a single impurity site embedded in a bath and self-consistent solution of the impurity problem. Assuming a converged DMFT calculation is available, two-particle scattering amplitudes (vertices) for the *c*-electrons can be expressed in closed form, depending only on the DMFT results. These vertices can then be used to systematically include non-local correlations to the system as well.

One method of including non-local effects in a Feynman-diagrammatic fashion is the one-particle-irreducible approach ^[3] (1PI), which uses vertices from the DMFT calculation. The system is divided into local and non-local degrees of freedom. The local degrees of freedom are treated as a DMFT problem and the vertices provide the interaction for the purely non-local degrees of freedom.

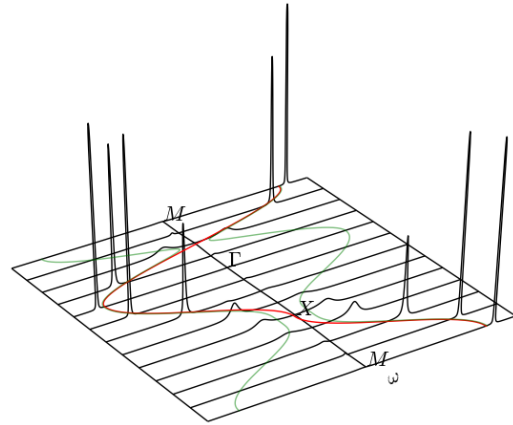


Figure 1: Spectral functions for different *k*-points following a path through the Brillouin zone. Calculated from a combination of DMFT and 1PI for a quadratic lattice and using the parameters $U = 1, t = 0.25, \mu = 0.5$ for a temperature $T = 0.08$.

RESULTS AND DISCUSSION

Analytic results were obtained for the vertices, including irreducible ones, of the FKM and used to include non-local correlations, resulting in increased scattering rates of impurities for mobile c -electrons due to the interaction with f electrons. The interaction between c and f electrons leads to an indirect interaction between the f electrons themselves, influencing their relative distribution on the lattice which in turn causes coherent scattering and increased resistivity for the c -electrons.

The results can also be used as a benchmark for numeric algorithms developed for solving similar systems. In this application, the numerical cost of determining high-precision results for the FKM is low due to the availability of analytical expressions.

This work opens the opportunity to study the localization of particles due to coherent backscattering, the so-called Anderson localization [4].

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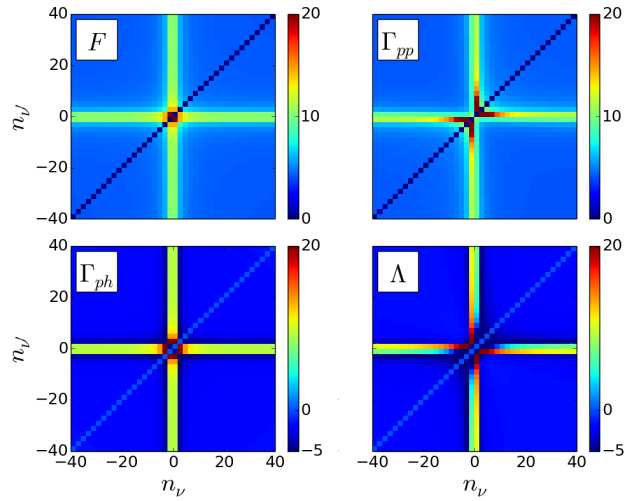


Figure 2: Plots of the DMFT vertices for values of $U = 1$, $\mu = U/2$ and $t = 0.25$ on a quadratic lattice at temperature $T = 0.06$

FLUCTUATION DIAGNOSTICS OF ELECTRONIC SPECTRA

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INTRODUCTION

Many of the fascinating phenomena in condensed matter systems occur when strong electronic correlations are present. Valuable information about these systems can be gained from photoemission and scanning tunneling microscopy [1] by spectral measurements experiments. However, identifying unambiguously the physics leading to these spectra can be very challenging due to the accented many-body nature of strong correlations. This is prototypically the case for the so-called pseudogap phase in the single-particle spectrum of the high-temperature superconductors of the cuprate class. This phase has been attributed to spin fluctuations, preformed Cooper pairs, the Mott-insulating nature of the parent compound, and, recently, to charge-fluctuations. On the experimental side, spectral measurements are often supplemented by techniques at the so-called two-particle level. These techniques exploit the access to generalized susceptibilities of the systems, e.g. neutron scattering, pump-probe or infrared and optical spectroscopy and muon-spin relaxation. This additional (two-particle or scattering) information is used to get insight into which physical process is determining the (one-particle) spectral function of the system. Exactly the same path was chosen by us to shed light onto this question on the theoretical side by means of the Fluctuation Diagnostics [1].

THE FLUCTUATION DIAGNOSTICS METHOD

The general idea of the Fluctuation Diagnostics approach is to **rewrite** the equation which connects the one-particle level (spectrum or self-energy Σ) with the two-particle level (scattering amplitude or vertex F), i.e. the Dyson-Schwinger **equation of motion**, in different but equivalent representations (spin-, charge- and Cooper-pair (particle-particle) representation) and doing partial summations over (K, ω) or (K, \vec{q}) , respectively (see Fig. 1).

$$\Sigma(k) = \sum_{k', q} F_{\uparrow\downarrow}(k, k', q) g g$$

$$q = (\bar{Q}, \omega), k = (\bar{K}, \nu)$$

$$F_{ch}(k, k', q) = F_{\uparrow\uparrow}(k, k', q) + F_{\uparrow\downarrow}(k, k', q) \quad \text{charge}$$

$$F_{sp}(k, k', q) = F_{\uparrow\uparrow}(k, k', q) - F_{\uparrow\downarrow}(k, k', q) \quad \text{spin}$$

$$F_{pp}(k, k', q) = F_{\uparrow\downarrow}(k, k', q - k - k') \quad \text{particle-particle}$$

Identical results after all k - and ω -summations
But: significant info by performing partial summations

Figure 1: Dyson-Schwinger equation of motion in different equivalent representations.

RESULTS AND DISCUSSION

The Fluctuation Diagnostics is applied to the simplest modelization of the cuprates, the one-band **Hubbard model** on a simple square lattice. This model considers only the kinetic energy of the electrons hopping between the lattice sites and the Coulomb interaction between them which is

assumed to be purely local.

Both the self-energy and the vertex are calculated in the so-called dynamical cluster approximation (DCA)^[1] for a parameter set of intermediate Coulomb-interaction and small hole-doping, which leads to a pseudogapped self-energy (see upper panel of Fig. 2). Performing firstly a partial summation excepting the transfer momentum Q results in the bar charts in the middle panel of Fig. 2. The different representations are grouped for the different momenta Q and are color-coded (from left to right) in spin (red), charge (blue) and particle-particle (green). One can immediately see that for both Brillouin-points at which the self-energy is shown ($K = (0, \pi)$ and $K = (\pi/2, \pi/2)$), the only peaked representation is the spin-representation at $Q = (\pi, \pi)$, whereas the weights of charge as well as particle-particle representation are equally distributed over all momenta. This means that the physically **dominant** representation (the “correct” representation) is the **spin representation**. The question of whether these spin fluctuations are long-lived can be answered by performing a partial summation excepting the transfer frequency ω (pie charts in lower panel of Fig. 2).

In the spin representation the dominant frequency is $\omega = 0$, determining the **spin fluctuations** (left pie) to be **long-lived** in contrast to, e.g., particle-particle fluctuations (right pie) for which one obtains an equal distribution over the first several frequencies.

CONCLUSION

We have shown that it is possible to identify unambiguously the impact of different types of fluctuations on the spectrum of correlated electron systems by means of a new technique called Fluctuation Diagnostics. The main idea of this technique is to perform partial summations in the Dyson-Schwinger equation of motion. For the simplest modelization of the cuprates, the one-band Hubbard model, we showed that the **pseudogap** in the one-particle spectrum is **opened due to antiferromagnetic spin fluctuations**. The progress in computer-power, especially in calculating the vertex F will allow for an application of our method to more complex systems, e.g. Hubbard models with spatially extended interactions or multiorbital models as more realistic modelizations of the cuprates^[1].

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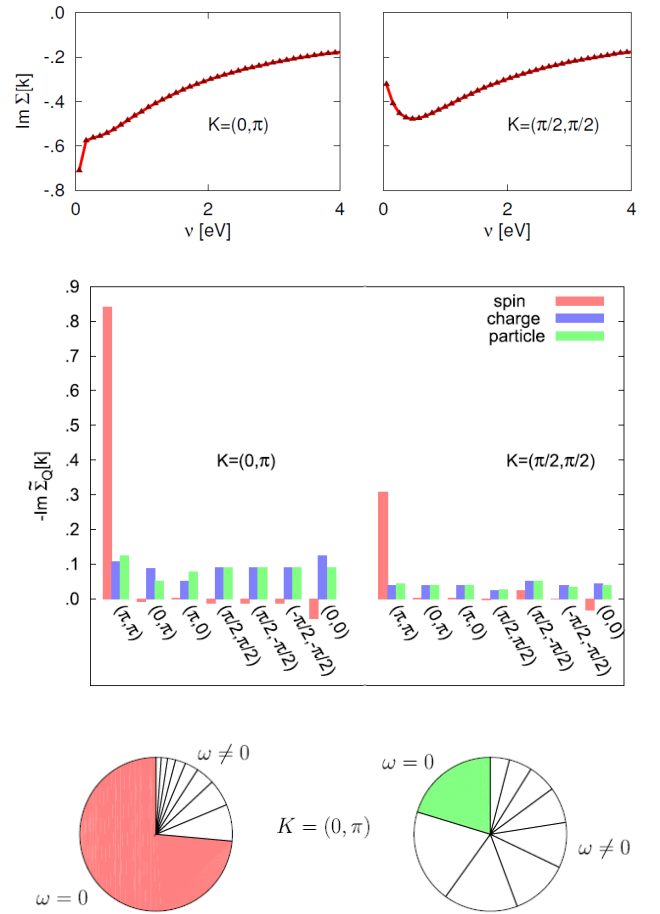


Figure 2: Self-energy and its Fluctuation Diagnostics (reproduced from [1]).

RING QUANTUM CASCADE LASERS FOR CHEMICAL SENSING AND SPECTROSCOPIC APPLICATIONS

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INTRODUCTION

Quantum Cascade Lasers (QCLs)^[1] are compact photonic devices that can be designed to emit light at specific wavelengths. Modern fabrication technologies within a cleanroom environment make it possible to build these laser sources for custom applications, e.g. chemical sensing, analysis of gases and liquids or spectroscopy. Because many molecules have characteristic absorption lines in the mid-infrared spectral region (3 - 25 μm), each of them can be identified by its unique chemical fingerprint when illuminated at these specific wavelengths.

Ring-shaped laser cavities^[2] have the advantage of collimated emission beams. Driving the ring QCL with a DC-current is highly demanded as it reduces measurement artefacts like pulse to pulse fluctuations, which occur when operated under pulsed conditions. Unfortunately, a huge amount of heat ($\sim 10^{14} \text{ W/m}^3$) needs to be dissipated from the active region as self-heating limits the laser performance. Therefore, thermal bottlenecks are analyzed by simulation and ways to improve the thermal management are presented.

THERMAL MODELLING

The heat dissipation from the active laser material in ring QCLs is studied within a finite element based model by solving the steady-state 2D Fourier heat transport equations^[3]. In semiconductor materials used for QCLs, most of the heat is transferred via acoustic phonons. As the active region consists of about 770 interfaces the phonon mean free path is strongly reduced by scattering. Therefore, the in-plane thermal conductivity k_{\parallel} is ~ 3 times higher than in the perpendicular direction, suppressing an efficient upward/downward heat flow.

The investigated laser has a waveguide width of 10 μm , a diameter of 400 μm and the active region is made of $\text{In}_{0.53}\text{Ga}_{0.47}\text{As}/\text{In}_{0.52}\text{Al}_{0.48}\text{As}$ with the emission wavelength designed for $\lambda \sim 9 \mu\text{m}$. Fig. 1 shows the simulated temperature distribution in the cross-section of the laser. Most of the heat is transferred directly downwards to the heatsink, which is kept at constant temperature. The laser core temperature rises 213 K above the heatsink temperature.

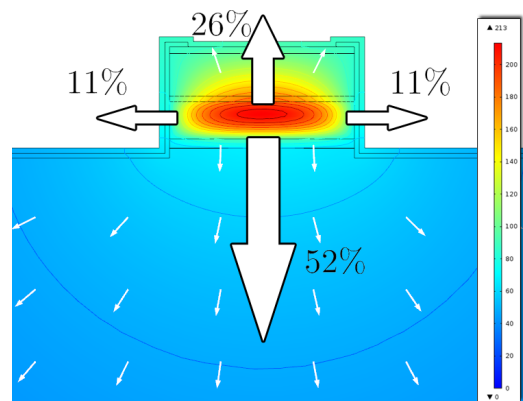


Figure 1: Simulated temperature distribution of a InGaAs/InAlAs ring QCL. The arrows visualize the portion of the heat flux through the boundaries of the lasing region.

EXPERIMENT

The heat dissipation through the sidewalls is improved by a lateral regrowth^[4] with electrical semi-insulating InP:Fe, as shown in Fig. 2. On top of the waveguide a 2nd order distributed-feedback grating is etched to maintain mode-selection and vertical light out-coupling. The whole laser is covered with a thick gold layer, which also influences the behavior of the grating. The measured spectrum in Fig. 3 shows that the modified grating is working and the ring QCL emits single-mode light at 8.6 μm .

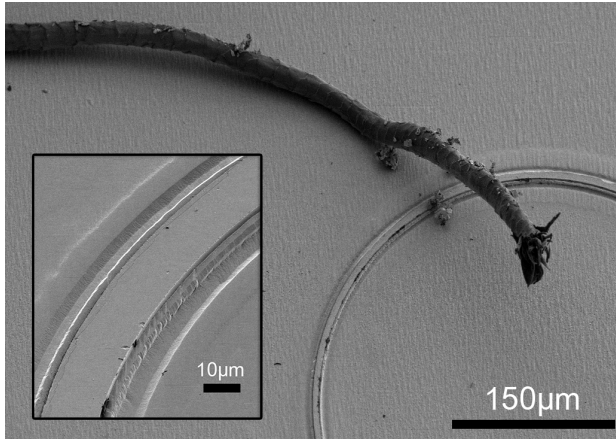


Figure 2: Scanning electron microscope image of a ring QCL after lateral regrowth with InP:Fe.

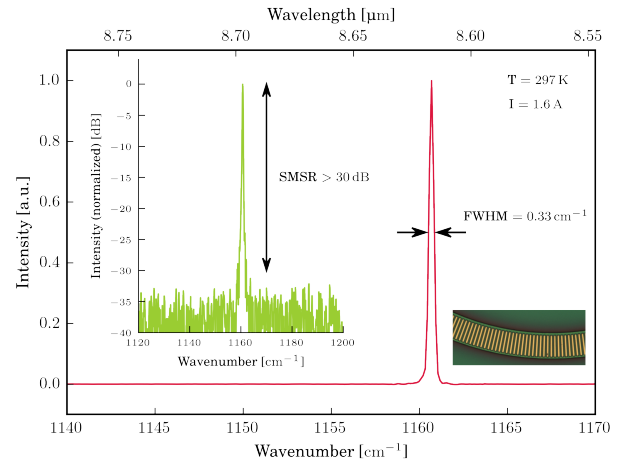


Figure 3: The laser shows single-mode emission around $\lambda = 8.6\mu\text{m}$ together with a side-mode suppression ratio of better than 30 dB.

CONCLUSION

Thermal simulations confirm a limited heat dissipation capability due to ternary materials. An enhancement of the heat flow through the sidewalls can be achieved by a lateral regrowth of InP:Fe. A metal-covered grating enables single-mode emission through the substrate and also helps to efficiently remove the heat from the laser core. Further improvements can be achieved by e.g. using a laser material with lower threshold or mounting the chip epitaxial-side down on the heat sink.

ACKNOWLEDGMENT

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