Know-How Mapping: From i* to ME-maps

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Abstract. Much of the knowledge in technology domains is “how-to” knowledge that offers solutions to problems, or means to achieve desired ends. In previous work we illustrated how i*-based goal modeling can be used to map out the state of the art in a technical domain, detect gaps, and recognize advances. Our recent work, which includes user studies, suggests that the full expressiveness of i* may not be necessary for mapping know-how. In this paper, we propose ME-maps, a know-how mapping technique inspired by, but simpler than i*, with the aim of easier and wider adoption. We propose to use CmapTools, a widely-used platform for concept mapping, to support the collaborative construction and sharing of know-how maps. Lessons learned from this initiative could potentially inform the ongoing evolution and refinement of i*.

Keywords: know-how map, concept map, means-ends, CmapTools

1 Introduction

With the fast evolution of technological innovations, it has become a big challenge for researchers and practitioners to keep track of the latest development in domains of interest. Systematically organizing the knowledge of various studies reporting on technological advancements within domains has been increasingly important. Our previous work has illustrated how know-how mapping can be used to map out the state of the art and advances in a technical domain [1]. More specifically, using know-how mapping we can represent and capture means-ends knowledge in domains, and highlight their structure in terms of problems, qualifying properties and existing solutions.

In [1] we illustrated how i* based goal modeling can be used for know-how mapping, relying especially on means-ends relationships and softgoal contributions. However, our recent work, which includes user studies, suggests that the full expressiveness of i* [2] may not be necessary for this purpose. We thus examine a lightweight i* based approach that minimizes unfamiliar graphical notations and modeling constructs [3]. Our aim is to find a better balance between expressiveness and ease of use to facilitate wider adoption of the know-how mapping technique amongst researchers and practitioners, while retaining the core ideas behind i* modeling and reasoning.

2 An Illustrative Example

Fig. 1 shows a ME-map (short for Means-Ends map) of web page ranking techniques. The graphical notation of the ME-map builds on general-purpose concept maps [3], which are widely used in many settings, including in high school education. For ease of comparison and contrast, we use the same example domain as in [1], where the know-how map (reproduced in Fig. 2) was expressed in the i* notation. The domain knowledge was extracted from [4].

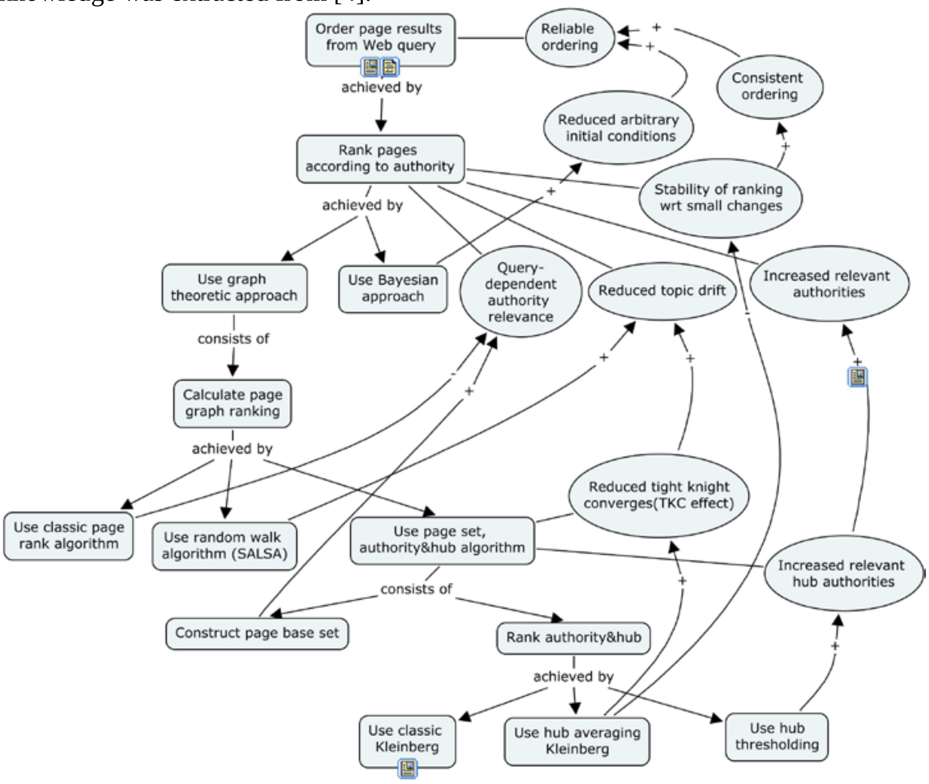

Fig.1. A ME-map of the page ranking analysis

Referring to Fig. 1, the main objective is to Order page results from Web query, with Reliable ordering as a desirable quality. One way to order pages is to Rank pages according to authority, with the following desired qualities: Query-dependent authority relevance, Reduced topic drift, Increased relevant authorities, and Stability of ranking wrt small changes. Rank pages according to authority can in turn be achieved by Use(-ing) graph theoretic approach or by Use(-ing) Bayesian approach. Use graph theoretic approach consists of task Calculate page graph ranking, as well as other tasks that are not shown on the map.

Fig. 2. An i* based know-how map of the page ranking analysis [1]

Each of the lower-level alternative solutions may affect some of the higher-level qualities. For example, Use hub averaging Kleinberg contributes positively ("+") to quality Reduced tight knight converges (TKC effect), but negatively ("-") to quality Stability of ranking wrt small changes. A quality at a lower-level may also contribute to qualities at the higher-levels. For example, quality Stability of ranking wrt small changes contributes positively ("+") to Consistent ordering, which further contributes positively ("+") to Reliable ordering.

Each node and link in the ME-map can have an associated context, and one or more references. Clicking on the note icon associated with Order page results from Web query reveals that it has a context Web pages are within a hypertext link structure, which is a condition for the task to be applicable. Clicking on the reference icon associated with Use classic Kleinberg leads to the original reference source via its URL, [5] in this case.

3 Overview of the ME-map

In the preceding section, we introduced ME-mapping with an example. We used a reduced set of i*-based constructs and avoided specialized graphical notations. In particular, we leverage the more broad based practice of concept mapping. We are therefore able to take advantage of existing platforms and tools. We are using CmapTools[1], which is extensively used in high school teaching [6]. It supports collaborative construction and sharing of concept maps. The Concept Maps approach was derived from the psychology of early childhood concept learning [3].

Table 1. Modeling constructs in i* and in ME-map

Element	**Know-how mapping based on i*[1]**	**Know-how mapping based on the ME-map**
Node	*Goal* (usually, plays the role of a problem)	*Task* (unifies both problem and solution perspectives)
	Task (usually, plays the role of a solution)	
	Softgoal	*Quality*
Link	*means-ends* link	*achieved-by* link
	decomposition link (refers to softgoals or tasks)	*consists-of* link (refers to tasks)
		association link (refers to qualities)
	contribution links (make, some+, help, unknown, break, some-, hurt)	*contribution* links (+, -)
Attribute	[not exist]	*Context* (can be assigned to nodes and links) is applicable condition
	[not exist]	*Reference* (can be assigned to nodes and links)

While the user may have a general concept mapping tool at their disposal, the ME-mapping approach guides the user towards focusing on means-ends relationships. Table 1 summarizes the differences of modeling constructs in i* and in ME-map. Compared to i*, we have reduced the constructs to 2 types of nodes and 4 types of links.

The *task* is the main node type in the means-ends hierarchy. We avoid the extra mental effort to distinguish between goal and task and to interleave them in the means-ends hierarchy, as recommended in i*. The distinction is implicit and implied by the relationships. The notion of task (in ME-map) thus plays a dual role. Depending on its relationship with other tasks, a task can be interpreted either as a problem (in relation to lower level nodes) or a solution (in relation to higher level nodes). In some cases, this also results in a more condensed means-ends hierarchy.

A *quality*, the second node type, is used to express a quality attribute that is desired for the associated task. It takes the place of the i* concept of softgoal, but opting for an everyday-language term.

The *achieved-by* link represents the means-ends relationship that is at the heart of ME-mapping. It indicates that the children tasks provide potential solutions for the parent task. The siblings are alternative means to the end represented by the parent task.

[1] http://cmap.ihmc.us/

The *consists-of* link indicates that a task has several sub-parts, all of which are required to be performed for the parent task to be accomplished.

Instead of using stylized graphical symbols (in contrast to the means-ends and task-decomposition links in i*), we have opted to spell out the English word labels to denote these two link types in the ME-map. This is intended to draw attention to these crucial relationships which constitute the main means-ends hierarchy in a ME-map, and to minimize cognitive effort so as to appeal to the casual reader. A first-time user of a ME-map is expected to be able to verbalize and paraphrase its content by “reading out” these relationships.

The *association* link is an unadorned straight line connecting a task and an associated quality. It indicates the quality is desired for that task.

The *contribution* link indicates a contribution towards a quality, from a task or another quality. In i*, different degrees of contributions are indicated. According to our preliminary evaluations in several domains conducted by several participants, it was found contribution strengths are difficult to assess. For simplicity, we only indicate contributions as being positive (+) or negative (-).

Any element in the ME-map can have associated references and contexts. A *reference* is the actual knowledge source from which an element was derived. A *context* is the setting or assumptions in which a specific element exists.

For better readability, we recommend a layout convention in which achieved-by and consists-of links point downwards, contributions flow upwards, and that association links are roughly horizontal or slightly downwards on one side of the associated task.

4 User Study and Supporting Tool

To evaluate the usefulness and usability of the ME-map approach, we conducted a preliminary user study. Four computer science graduate students (3 PhD and 1 MSc) participated in the exercise which consisted of the following stages: preparation, training, know-how map construction, completing questionnaires individually, and group discussion. The students constructed maps for their respective areas of research, which included software ecosystems, organizational flexibility, data mining business applications, and real-time business intelligence. Participants indicated that the proposed approach is easy to use, and can facilitate the task of positioning a research agenda.

The user study was conducted using CmapTools, which was previously unfamiliar to the participants. The reasons we adopted this tool are summarized as follows. Firstly, CmapTools provides a client-server architecture, which allows easy publishing and sharing of knowledge models, and enables such models to be linked to each other. Secondly, CmapTools offers collaboration capabilities, which can enable users in a distributed environment to asynchronously or synchronously collaborate in constructing concept maps. Thirdly, CmapTools provides modeling facilities to create general purpose knowledge models. The shapes of nodes and links can be customized according to users’ needs. Fourthly, it offers a view mechanism, so that different views of the same ME-map can be shown to serve different purposes. For example, users can view the partial model about problem analysis, view the partial model about the details of technical solutions, or view the evaluation of a specific solution. Finally, it has a functionality to link any elements in a concept map to other types of resources such as documents, images and Web pages. This allows any elements in a ME-map to be linked directly to original knowledge sources.

5 Conclusion and Future Work

The longer term vision is to develop a global platform for the collaborative construction and sharing of know-how maps. Such a platform will help research communities consolidate their efforts, facilitate dissemination of research advances, and promote recognition of contributions and impact. The experimentation with ME-mapping reported in this paper is a step in this direction. While know-how mapping has different objectives than i* modeling, the work could nevertheless generate insights on how i* might evolve, for example, simplification for wider adoption.

In ongoing work, we are developing guidelines to help users extract know-how from knowledge sources and to construct know-how maps. We will investigate how such knowledge can be extracted automatically or semi-automatically from textual sources, and be added to existing know-how maps. We plan to use sentiment analysis techniques to assign positive and negative contributions to qualities [7]. We also plan to equip the map with citation information in a way that would provide evidence for the impact of the work.

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