Stigmergic Hyperlink: a New Social Web object

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ABSTRACT

Inspired by patterns of behavior generated in social networks we designed and developed the prototype of a new object for the World Wide Web – the stigmergic hyperlink or "stigh".

In a system of stighs, like a Web page, the objects that users do use grow "healthier", while the unused "weaken", eventually to the extreme of their "death", being autopoieticaly replaced by new destinations.

At the single Web page scale, these systems perform like recommendation systems and embody an "ecological" treatment to unappreciated links.

On the much wider scale of generalized usage, because each stigh has a method to retrieve information about its destination, Web agents in general and search engines in particular, would have the option to delegate the crawling and/or the parsing of the destination. This would be an interesting social change: after becoming not only consumers, but also content producers, Web users would, just by hosting (automatic) stighs, become information service providers too.

Keywords: internet; world wide web; social web; hypertext; hyperlink; social epistemology; stigmergy; engineering design; algorithms; stigh

INTRODUCTION

Regular Web hyperlinks have limitations like unidirectional linkage, unverified destination, and issues related to relevance, reputation and trust (Leuf, 2006), some addressed by technologies like XLink (W3C, 2001). The stigmergic hyperlinks (stighs) we designed embody an alternative for some specific applications and propose some interesting paradigmatic changes.

"Stigmergy" means the mark of the work (Grassé, 1959), and it is a form of indirect communication, effective for some distributed control problems (Marco Dorigo, 2004).

Stighs are "stigmergic" because they communicate indirectly and, as collective, display emergent behaviors (that are not the result of centralized control mechanisms).

Stighs are also "hyperlinks" because they can look and feel like regular hypertext hyperlinks (Wardrip-Fruin, 2004). The main difference is that stighs have a "life" attribute that increases when they are used and decays at a natural pace, eventually down to a "death" level. This dynamic drives interesting emergent systemic behaviors.

We elaborate on the stigh's architecture in the context of pervasive stigmergy, also in human-human relations and use other author's taxonomy (Parunak, 2005) to frame our proposed object and look at it from a social epistemology perspective (Marsh & Onof, 2007), that includes Word Wide Web cases.

We discuss applications for stighs at two scale levels: the single Web page and the "generalized usage" scenario. For the Web page scale applications, we provide a demo at http:/stigh.org that can exhibit the behaviors that support decentralizing the finding of useful Web resources across a community of users and the automatic replacement of undesired destinations. These applications have similarities with recommendation systems (Linden, Smith, & York, 2003).

Regarding the generalized usage scenario, we discuss decentralizing search and stighs and the Deep Web. Decentralizing search would increase the "calculative capacity" (Callon & Muniesa, 2003) of Web authors and that would be a noticeable social change – this could be achieved if search engines could, at least partially, outsource some of their tasks, like crawling and/or parsing (Brin & Page, 1997), delegating on stighs or equivalent objects. The same delegation could be an approach to the Deep Web – the Web that the search engines ignore (Bergman, 2001) – because it is hard to generalize how to crawl it. Instead of generalizing, specialized stighs could handle particular cases.

The structure of this paper is as follows: first we explain the stigmergic hyperlink from a high level perspective, including the architecture of the individual agent and its environment, one possible taxonomical classification, and a social epistemology perspective of stigmergy and stighs. We then discuss possible applications from the single Web page scale to the generalized usage scenario. In order to better understand the internals of stigmergic hyperlinks, there is a detailed engineering section. After one illustrated example of stighs in action, we state some technological considerations and, finally, future work.

STIGMERGIC HYPERLINK(s)

The Stigh

Social insects are one inspiration for this new type of hypertext object we call the ***stig**mergic **h**yperlink* – **stigh**, for short.

Social insects, such as ants and termites are capable of complex behaviors like traveling long paths to/from food, and building structures. As individuals they wouldn't be able to do it but as a collective body they indirectly communicate and forms of organization emerge. Stigmergy is this indirect communication via modifications on the environment and it can be a solution for distributed control problems (Marco Dorigo, 2004).

Stigmergy – from the Greek *stigma* (mark) and *ergon* (work) – means "the mark of work", in the sense that agents/workers acting/working on their local environment "mark" it in a way that probabilistically other agents/workers will acknowledge. This will reinforce the work process without the need for direct communication. The expression was introduced by the French biologist Pierre-Paul Grassé (Grassé, 1959).

Grassé observed that termites, when building a nest, modify their local environment by aggregating mud balls, marked with pheromones. These balls are more likely to be placed where other pheromone-marked mud balls already are, than elsewhere – the nest is built from this continuous depositing process, having arches as its fundamental building block (Grassé, 1959).

Stighs have a "life" attribute that reflects (marks) what the users of the Web page where they "live in" have been doing (working) with them. Web page visitors perform like ants or termites, leaving a digital pheromone that reinforces a stigmergic hyperlink's life, whenever they click it. On the other hand, a neglected (not used) stigh will slowly wither, until its life level eventually zeroes, which would represent its death.

Although "under the hood" stighs are not regular hypertext hyperlinks, they can be displayed by Internet browsers exactly like if they were – see (Wardrip-Fruin, 2004) on Hypertext – and they will behave accordingly: when someone clicks a stigh the browser loads the corresponding destination resource.

Regular hyperlinks have limitations like unidirectional linkage, unverified destination, and issues related to relevance, reputation and trust (Leuf, 2006). More recent technologies, like W3C's XLink (W3C, 2001), try to address some of the limitations. Stighs are not a replacement for the regular hyperlinks – they build on them to represent an alternative adequate for specific and pertinent purposes.

While an individual stigh is a very simple object – a hyperlink with a floating energy level, reflecting its relative usage, and some actions/methods – what emerges from a system of stighs, and/or from its collaboration with other Web entities, is more complex and can have very interesting applications.

Agent and environment architecture

(Parunak, 2005) explores human-human Stigmergy and its ubiquitousness. He also presents an architecture and a taxonomy for Stigmergy. Stighs fit in both frames, as described below.

Regarding the architecture of Stigmergy there are two fundamental components: a population of agents and an environment. A collection of stigmergic hyperlinks living in the same Web page is a population of agents. A Web page containing stighs is their environment.

Each **agent** has:

– An **internal state**, "usually not directly visible to other agents".

In the case of stighs, all attributes are protected and only indirectly exposed via "properties". These "attributes" and "properties" are meant in the context of the computer programming language C#, which was our choice for the current prototype. The main attribute is the hyperlink's life, which represents its energy level. Other attributes include a clicks counter and the destination URL.

– **Sensors**, "give access to some environment's state variables".

Stighs' sensors read values that are shared via the Web page/environment, like a "trigger" value, that sets the "natural" decay pace for any stigh's life. These read-only shared values act as the system's configuration, imposing the decay rhythm, the maximal and the minimal values for the life attribute.

– **Actuators**, that "change some of the environment's state variables".

When a stigmergic hyperlink is clicked, its OnClick actuator/method directly increases the object's own clicks counter and can, indirectly, update a global clicks counter.

– A **program** that "governs the evolution of its state over time".

For stighs, this program is their methods collection, namely getStronger and getWeaker, which, respectively, increase and decrease, the object's life, in response to click events or to the natural decay.

The **environment** has:

– A **state**, with "certain aspects generally visible to the agents".

Since stighs are part of a Web page's structure, they explicitly compose the environment where they work on – hence the environment's state is also composed by the states of all embedded stighs.

– A **program** "that governs the evolution of its state over time".

This program could be seen as the pairs of {events, event handlers}, which the page supports. For example, for the click event, stighs will respond with their OnClick method as the event handler – usually, stighs will only respond to clicks. But, on a higher level, the page's program/behavior is just an emerging function from the embodied objects/agents, namely the stighs.

Agent behavior taxonomy

One possible classification of the type of stigmergy distinguishes between "marker" and "structure" (sematectonic) based action (Wilson, 1975).

Stigmergic hyperlinks have a mark that reflects their relative usage - their life attribute. This mark is reinforced when Web users use them. Eventually, because a "healthy" stigh will probabilistically remain longer in the system, it might be more used. In this positive feedback sense, a stigmergic hyperlinks system could be considered "marker" based.

But stighs are themselves part of the environment's structure and their destination resource should be a reason to follow them, or not. In this sematectonic perspective, one structural element is the reason for the users' actions, so structure also provides signals for the work that will, or not, happen.

Moreover, Web content authors can decide the stigh's appearance, for example allowing the life attribute to be rendered / shown, as it is by default, in the current demo version, available at http://stigh.org/.

This life value can signal the same information that the number of people bookmarking a resource does in social bookmarking systems like http://del.icio.us/ – that is, people will use/work the resource based on the work of previous users.

The same way people might browse to some del.icio.us destination, because it has already been visited by "many", as made explicit by the number of its visitors, a stigmergic hyperlink destination might be visited, just because it is more "lively" than others, as made explicit by its shown life attribute.

So, a stigmergic hyperlinks system is simultaneously a marker and a sematectonic case of stigmergy. While the structural destination attribute is determinant for the browsing endpoint, the life mark captures and signals what a community of agents has been doing, and that information can be relevant for users.

A social epistemology perspective of stigmergy and stighs

In (Marsh & Onof, 2007) the authors consider that the subject of social epistemology is "the formation, acquisition, mediation, transmission and dissemination of knowledge in complex communities", and "recommend a stigmergic framework for social epistemology". Because stigh systems capture the relative browsing preferences of a community of Web users and convey that acquired information following a stigmergic approach, they are another manifestation of how pervasive stigmergic systems are in human societies (Parunak, 2005), including the World Wide Web.

Amazon.com's recommendation system and Google's search algorithm are discussed in (Marsh & Onof, 2007) from a stigmergic perspective and as WWW examples, along atemporal references, like a market place of commodities. In all cases, the loop *agents(s)* **à** *environment* **à** *agent(s)* **à** *environment* is key for the reasoning: Amazon users' behavior might be influenced by others' recommendations and will itself contribute to future recommendations, explicitly (by rating some product, for example), or implicitly (not by rating, but by buying, for example).

In the following section we explain how a stigmergic hyperlinks system can perform as recommendation system and how stighs could contribute to an alternative decentralized approach to the Web search problem.

STIGMERGIC HYPERLINKS APPLICATIONS

In this section we discuss applications on two scale levels: the single Web page and, on the limit, the whole Web.

The current prototype is a single page stigmergic hyperlinks system that can only perform the "Decentralizing the finding of useful Internet Resources" and the "Automatic replacement of undesired destinations" applications.

The other applications that we discuss depend on wider scale usages. Considering the World Wide Web an information market that permanently calculates – in the (Callon & Muniesa, 2003) meaning – its goods and services, structure and content, from the interactions of many heterogeneous agents, that produce and consume information, we look at some "calculations" and try to approach some of their stages using stighs.

Decentralizing the finding of useful Web Resources across a community of users

A system of stighs can locally (at the single Web page scale), automatically (without human intervention) and transparently (requiring no extra user input) capture the navigation preferences of the community of its users.

When clicked/used, a stigmergic hyperlink will see its energy level increase; when not clicked/not used, the stigh's vitality will decrease. In time, appreciated stighs/links will "live" and the neglected will "die" being replaced by new destinations, potentially more useful to the community, chosen from a pool of possibilities that consists of all the hyperlinks contained inside the resources pointed by the surviving links, on the assumption that they probably connect to more attractive destinations than the terminated stigh did.

This all happens automatically without the need for a "Webmaster" to update the local pages, and transparently, without requiring visitors to login or input extra data – users just need to browse and won't distinguish between stighs and regular hyperlinks.

This way, a system of stighs is an approach for the maintenance of a dynamic Web of preferred destinations for a community of users.

Automatic replacement of undesired destinations

The problem of automating the replacement of undesired destinations, like connections to resources that disappeared (dead-links), is related to the prior: odds are that dead-links and their corresponding http-404-error responses won't captivate anyone so, in time, as users perceive the destination as useless, the stigh with that URL will see its energy level sink to death/replacement. Again, the replacement will happen automatically.

Hence, a system of stighs also works as a solution for Webmasters to publish-and-forget external links (links to destinations outside their control) believing that, in time, if for example an external resource changes location, the corresponding stigh won't remain indefinitely pointing to what is gone, as a regular static hyperlink would.

Because once published any stigh system escapes its creator's control, stigh systems are examples of feral hypertext systems (Walker, 2005).

Like a recommendation system

Amazon.com's recommendation system, via item-to-item collaborative filtering (Linden, et al., 2003), was designed to identify and suggest related items, from a catalog of million(s). Since users shop or browse via the Website's pages, those pages are the environment that mediates the (indirect) communication between the human agents. The agents' interaction is stigmergic because it is indirect and every user's buying and/or ranking behavior might affect everyone else's.

The life attribute of a stigmergic hyperlink can be interpreted as a reading of its relative quality, to the community of users of a mediating Web page: users might decide to (not) browse to a destination, based on its life value alone; when doing so, they will be influencing the signal/recommendation. Thus, the emergent behavior of a stigmergic hyperlink system is comparable to that of a ranking/recommendation system.

Decentralizing search

Search engines like the ones made available by Google, Yahoo, and others, are precious intermediates between searchers and content. They are also hugely outnumbered: the Internet grows in new data by the minute while new search services are a rare event. This disproportion reflects the dominant centralized approach to the Internet search problem.

Crawling and indexing are major tasks for search engines (Brin & Page, 1997). Stigmergic hyperlinks have a method for the retrieval of information about their destination that might contribute to decentralize crawling and/or indexing. This method processes (crawls to and retrieves data about) the linked resource, returning information about it. If the returned information is of value to some search engine's procedure, for example as complementary data that can guide to higher quality results, or even as a principal data source, there would be an alternative to the current non delegating approach – search engines would be able to outsource some processing and Web agents, in general, would have many more data sources available.

The external information retrieval method is not exposed in the current prototype – it is yet to be decided the default information to return, and how it can be invoked by Web agents. We intend to allow stigh users to be able to replace the default method by their own (or do nothing and accept the default behavior).

In a scenario of generalized usage, the stigh could, transparently, transform Web users, hosting stighs, into information providers about hyperlinks' destinations, eventually paving the road for a change in search engine design, via the externalization and decentralization of tasks. This would increase the "calculative capacity" (Callon & Muniesa, 2003) of Web authors.

Stighs and the Deep Web

The publicly indexable Web is the fraction of the Web that search engines cover, but it is a subset that ignores large amounts of high-quality information (Raghavan & Garcia-Molina, 2000). Many Web contents are only available on very precise requests, some requiring user authentication, and some denying access to bots. These hard to index contents, often stored in databases of undisclosed structure, unreachable to the classical search engines, are popularly known as the Deep Web (Bergman, 2001).

Content producers (authors) and content consumers (readers) can facilitate the finding of relevant Web content, by providing metadata, like tags, from prebuilt closed classification systems (taxonomies) and/or creating their own labels (folksonomies) (Marlow, Naaman, Boyd, & Davis, 2006). The hyperlink alone can represent much information about its destination (Marchiori, 1997), not only via the URL, but also via its anchor text and other data (Brin & Page, 1997). This applies to both the "surface" (publicly indexable Web) and to the Deep Web.

The Deep Web particularity is that it is much harder to generalize and automate how to crawl it.

The stigh's architecture can contribute to an approach to the Deep Web challenge: search engines could abstract the specialized crawling required for deep sites and delegate that on stighs with very specific information retrieval methods, or other objects capable of performing the equivalent task. Those hosting the stighs would be the ones directly addressing the Deep Web issue, for the specific cases they would link to.

ENGINEERING / SYSTEM INTERNALS

Every Web page with at least one stigh object is considered a stigh system.

A stigh object has some attributes and actions/methods: the more relevant attributes are "life" (its remaining energy), "URL" (the resource to where it points), and "text" (the anchor text, usually shown underlined); the more usual methods are "getStronger" (increases life) and "getWeaker" (decreases life).

Whenever a stigh is clicked its "life" increases by a configurable reward. The other stighs in the page are not directly affected, but the system has one "trigger" property that affects all: this integer value imposes an ageing/withering pace for everyone, measured in page clicks. In the current demo, trigger equals 2, meaning that every two clicks in the page/stigh system, all stigh objects will lose vitality.

In the current demo configuration, the loss of life is half the reward, and the reward is double the trigger, but all this is adjustable. Notice that different values determine different systems.

The system also imposes a maximum value for "life" in order to minimize the long term effects of fake usages, aimed at artificially inflating the hyperlink's energy.

Stighs are high level entities, processed on the Web server side. Because plain regular hyperlinks are processed on the client side and the Web server needs to track the "life" of stighs, we needed a solution to take the hyperlink processing to the server side: in the current prototype stighs are buttons disguised as regular HTML links.

When someone clicks a stigh object, that stigmergic hyperlink's attributes change globally, for all the active browser sessions and not just for who did the click. This way a stigh can be marked/worked by a global community. One consequence is that what a user sees in his/her browser window, might not correspond to the latest version of the page. In some occasions this can surprise someone who clicked to browse to a destination, but then the browser loaded a different resource… That might have happened because, during the time that lapsed between the page load and the click, other user(s) interacted with the system in a way that caused the replacement of the object that was still being displayed at the out-of-date browser.

The "death" or replacement of a stigmergic hyperlink is performed by a method currently named "extinction". This method is more complex than the trivial sums/subtractions involved in "getStronger" and "getWeaker". Currently when a stigh "dies" what really disappears is the neglected destination, replaced by a new one, drawn from the pages linked by the "survivors". The assumption here is that pages on similar subjects probably interconnect so a living/pleasing stigh eventually connects to other potentially agreeable locations.

The picking of a replacement destination is done by first spinning a roulette wheel with as many slices as the number of survivors. The more "life" a stigh has, the bigger will be its slice in the roulette wheel, therefore increasing, but not guaranteeing, its chances of being chosen as the seed. The seed's destination is then scanned for HTML links and one of them will be randomly picked to set the replacement stigh's URL.

One interesting situation happens when the stigh selected for seeding is "sterile", in the sense of pointing to a page that is a dead-end, linking to no other places. When the selected page can't provide destinations, the "dying" stigh performs a radical maneuver, randomly picking one entry from Google's Zeitgeist service, which lists the top searched expressions, for the running week. The idea is to introduce some mutation, in order to avoid stagnation, allowing some serendipity.

AN EXAMPLE

The following illustrated example is taken from a stigh system, composed by four individual stigmergic hyperlinks, ageing/withering every two clicks (“trigger” = 2 clicks).

As previously stated, in the current demo configuration, the loss of life, due to ageing/withering, is half the reward, and the reward is double the “trigger”, so

selection reward = 2*trigger = 2*2 = 4
and
ageing penalty = reward/2 = 4/2 = 2.

In this example, all stighs were born with “life” = 10, but each could have been declared with a different value. Low initial “life” values facilitate the observation of “death” events.

Every stigh has a unique identifier. In this case, the identifiers are CS1, CS2, CS3 and CS4, standing for “class stigh object” #1, #2, #3 and #4. Currently, stighs can run on any Web server that can serve .NET ASPX pages: the declaration syntax for objects hosted in such pages is behind the scope of this article, but, for stighs, it looks like this:

<cc1:cStigh ID="**CS1**" aLife="**10**" aUrl="**http://www.digg.com**" runat="server" aConfirmMessage="**Follow the link?**" aShowConfirm="**true**"></cc1:cStigh>

Figure 1 illustrates the initial system.

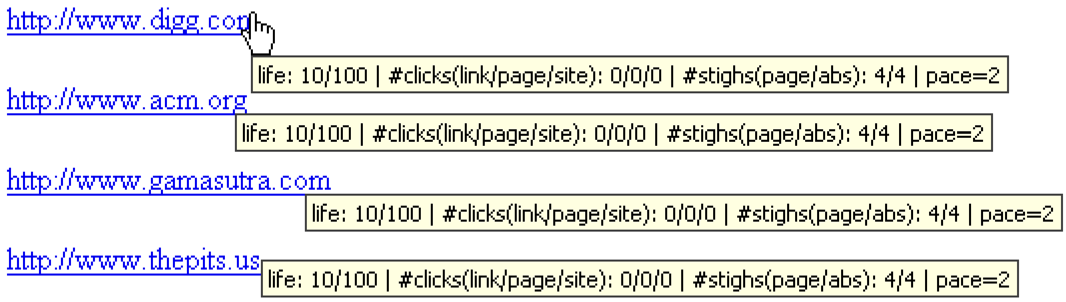

Figure 1 - Web page with 4 new stighs

The tooltips (text on yellow background) appear only when the mouse goes over the stigmergic hyperlinks, but the image was composed in order to show all the tooltips at the same time. The displayed “pace” value is the system “trigger”.

The tooltips’ numbers read that all the stighs have a current “life” of 10 and a maximum of 100 (life: 10/100). No stigh has been clicked individually, or on the page, or on the whole hosting Website (#clicks link/page/site: 0/0/0). The page holds 4 stighs and the Web server created a total of 4 stigh objects (#stighs page/abs: 4/4).

If the Web page was reloaded, the absolute number of stighs (abs) would then read 8, because a total of 8 stighs would have been served by the Web server, but no other number would change. If there were other pages with stighs – other stigh systems – then the absolute number of objects created would also account for their presence.

If a visitor clicks the acm.org (CS2) link, then that object’s “life” will become 10+4=14 and the click counters will reflect the event. It is important to understand that a regular visitor typically does not see the updated numbers, because, in response to the click, he/she will be visiting the destination URL… One way to see the updated data is to use the browser’s “go back” function and reload the page, or run a “debug” version of the system that behaves exactly like the “end-user” version, except that it doesn’t load the linked destinations and thus allows watching the objects’ state evolution without “back and refresh”. See Figure 2.

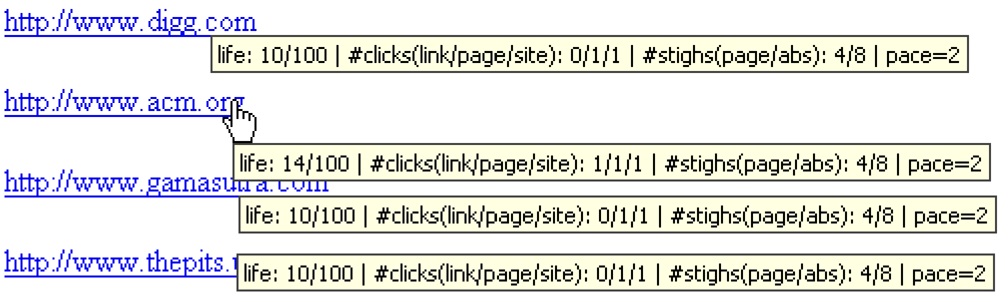

Figure 2 – System, after click #1 on CS2 (acm.org). The page was also reloaded

Assuming that the next click is again on CS2 then CS2's "life" will become 14+4=18, minus 2 (=16) because the system aged and all objects withered. The other stighs life is now 10-2=8.

Assume that the next click is on CS3 (gamasutra.com): its "life" will be 8+4=12; no other "life" attributes will change. Insisting on CS3, its "life" will become 12+4-2=14. CS1 and CS4, still neglected, will weaken to 8-2=6. CS2 will weaken to 16-2=14. See Figure 3.

Figure 3 - System, after click #2 on CS2 (acm.org) and clicks #3 and #4, both on CS3 (gamasutra.com)

If the next two clicks are on CS1 (digg.com) then CS1 will strengthen to 6+4=10, and then to 10+4-2=12. CS2 and CS3 will weaken to 14-2=12. CS4 will weaken to 6-2=4, nearing death… See Figure 4.

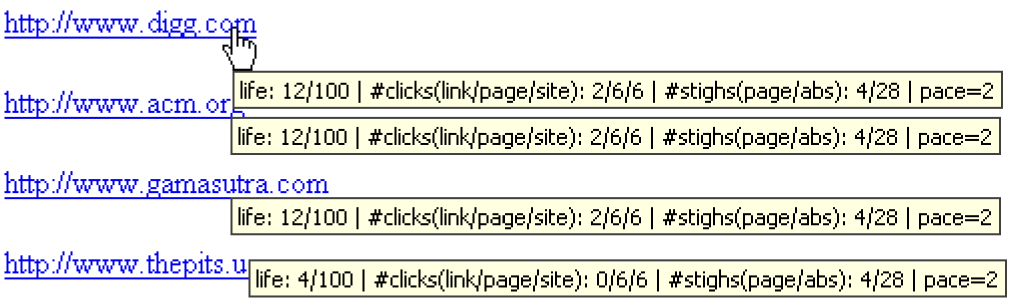

Figure 4 - System, after clicks #5 and #6, both on CS1 (digg.com)

If the next click is on CS2 and the following on CS3, those stighs' "life" will strengthen to 12+4-2=14. CS1 will weaken to 12-2=10. CS4 will weaken to 4-2=2. See Figure 5.

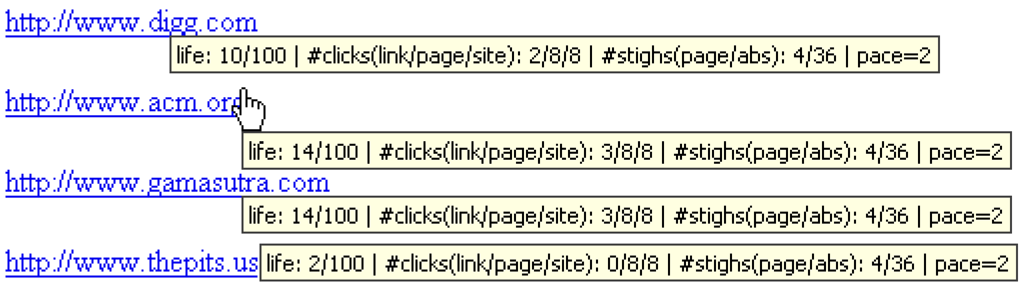

Figure 5 - System, after clicks #7 (on CS2) and #8 (on CS3)

Assume now that CS1, then CS3, will be clicked.

CS1 will strengthen to 10+4-2=12. CS3 will strengthen to 14+4-2=16. CS2 will weaken to 14-2=12. CS4 will weaken to 2-2=0. This will spark its "death".

On “death”, CS4 will draw a replacement URL from the survivors set = {CS1, CS2, CS3}. Chances are that CS3 will seed the new resource but there is no guarantee. The proportional roulette wheel to be used is computed and shown in Figure 6.

stigh ID	life	probability	P
CS1	12	2/∑ = 12/40 = 3/10	0.3
CS2	12	12/∑ = 12/40 = 3/10	0.3
CS3	16	16/∑ = 16/40 = 2/5	0.4
CS4	0	0	
sum of lives = ∑	40	sum of p =	1

Figure 6 - Probabilities in the roulette wheel, for seeding a replacement for CS4, after clicks #9 (on CS1) and #10 (on CS3)

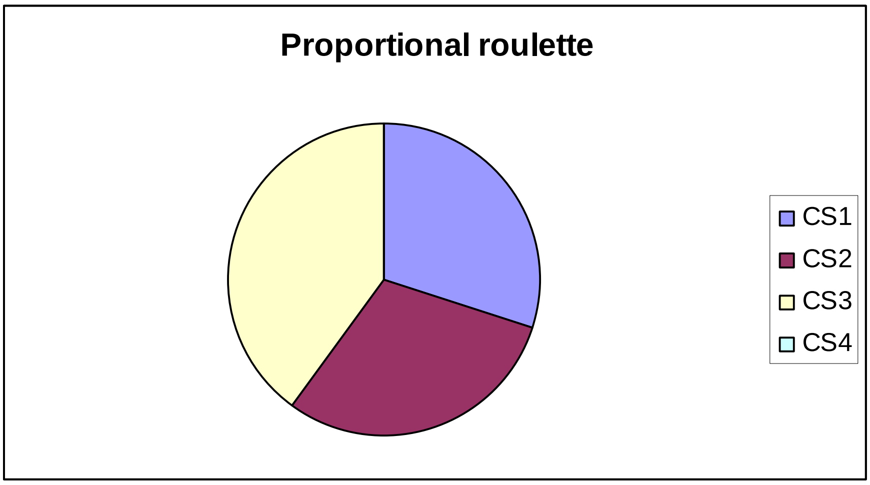

Figure 7 - Proportional roulette wheel to be used

In this example an article from Wikipedia replaced the previous CS4’s URL. We could learn that it was extracted from CS1 / digg.com, by looking at the logs that are kept for each stigmergic hyperlink.

The new stigh is healthy, with half the maximum life (100/2=50). Higher values facilitate the survival of newborns; lower values contribute to a certain effervescence of the system.

This 10 clicks example shows all the main events in the life of a system of stighs. As illustrated, the stigmergic hyperlinks can look like regular HTML links and apparently behave like them… but they are running on the server side and keeping track of a “life” attribute, which strengthens on clicks and weakens at a regular pace – whenever the shared environment signals “withering time”.

Stighs can read/“smell” the pheromone/”life” of their siblings in the same immediate page/“territory” and use that information on “death” time in order to select their successors, via a proportional roulette wheel draw.

The demo page is available at http://stigh.org – if trying it, please remember to “go back and refresh”, after any click(s), in order to see the objects’ state evolution reflected in your browser, or you’ll be just browsing to the chosen destinations. There is also an artificial user, which simulates a specified number of random clicks on stighs, to speed up the observation of extinctions – again, “go back and refresh” after using it.

TECHNOLOGICAL CONSIDERATIONS

Current stigmergic hyperlinks are instances of a class named **cStigh**, programmed in C#. The class was compiled in “Visual Studio 2005”, as a “class library project” – the output is a DLL file (**Webstigh.dll**).

Equipping a .NET enabled Website with stigmergic hyperlinks just requires the hosting of the **Webstigh.dll** file at its \bin folder. This class library includes **cStigh**, allowing the site to serve its instances (stighs). See Figure 8, for a class diagram of **cStigh**.

Other technologies are being considered.

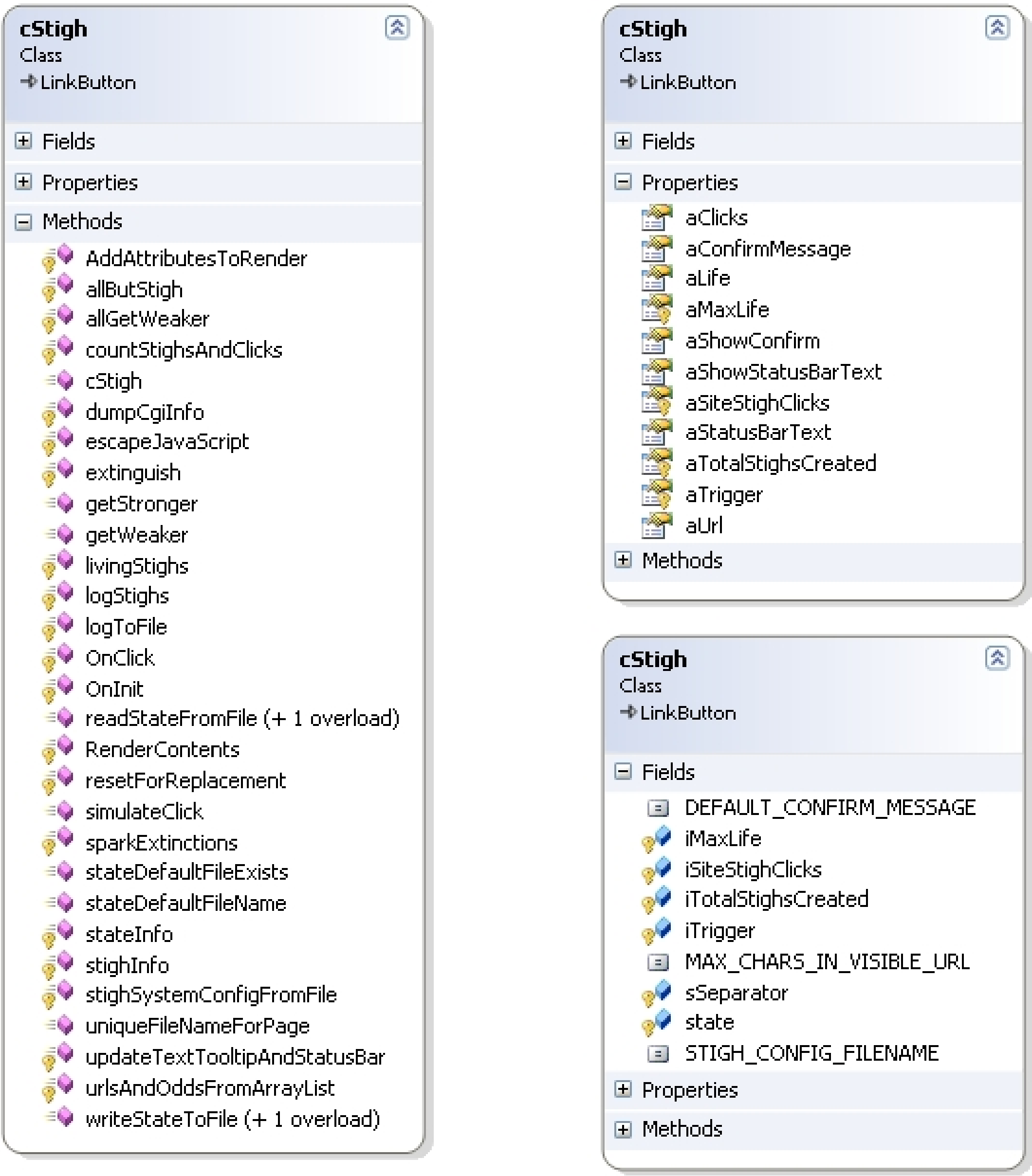

Figure 8 - cStigh class diagram

FUTURE WORK

Currently, each stigh has its own dedicated state URL: for example, for the CS1 object on stigh.org, the URL is http://stigh.org/~_Default.aspx_CS1_STATE.TXT . This logging solution is granular and doesn't provide a systemic view. We will address this with an administrator's console, oriented to the big picture, but also allowing to read/set individual variables. The console's main purpose will be to provide a more informative reading about all that has been happening in the stigmergic hyperlinks system.

Also in the "to do" list is exposing the method for the retrieval of external information about the destination resource and decide how Web entities can use it.

Finally, we'll research how the stigmergic hyperlink technology can relate to business models, for example supporting dynamic pricing systems based on relative usage, or supporting new Web relations with the potential for monetization.

CONCLUSION

We introduced the prototype of a new Web object, named "stigmergic hyperlink", or "stigh": a server side hyperlink with a floating energy level and some actions.

Stigmergy was first observed on social insects, but has always been pervasive on human-human interactions. We addressed the concept from its roots to recent Web cases.

We argued that a system of stighs can perform as a recommender system of preferred Web destinations and as an automatic solution for the replacement of undesired links. These applications emerge at the single Web page level and can be observed on the public demo available at http://stigh.org/ . We also provided a 10 clicks illustrated example and detailed the internals of the object.

At the World Wide Web scale, we discussed applications that have disruptive potential: to decentralize the current approach to (Deep) Web search would create a new social Web of information service providers.

We now need better tools for the observation of stighs and to expose the method for the information retrieval about the destination, in order to make the potential clearer.

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