Extending Web Modeling Language to Exploit Stigmergy:

Intentionally Recording Unintentional Trails

Aiden Dipple, Kerry Raymond, Michael Docherty
Faculty of Science and Technology
Queensland University of Technology
Brisbane, Australia
aiden.dipple@student.qut.edu.au
k.raymond@qut.edu.au
m.docherty@qut.edu.au

***Abstract*—Software development and Web site development techniques have evolved significantly over the past 20 years. The relatively young Web Application development area has borrowed heavily from traditional software development methodologies primarily due to the similarities in areas of data persistence and User Interface (UI) design. Recent developments in this area propose a new Web Modeling Language (WebML) to facilitate the nuances specific to Web development. WebML is one of a number of implementations designed to enable modeling of web site interaction flows while being extendable to accommodate new features in Web site development into the future. Our research aims to extend WebML with a focus on stigmergy which is a biological term originally used to describe coordination between insects. We see design features in existing Web sites that mimic stigmergic mechanisms as part of the UI. We believe that we can synthesize and embed stigmergy in Web 2.0 sites. This paper focuses on the sub-topic of site UI design and stigmergic mechanism designs required to achieve this.**

Web Collaboration; virtual pheromones; stigmergy;

I. INTRODUCTION

Our research analyses a number of User Interface (UI) designs within popular Web 2.0 sites. The UI designs observed provide representations of user feedback along with representations of behavior trends from unintentional interactions which have been recorded. Examples of these UI designs can be seen in Facebook where users "Like" other user contributions causing an area of focused interest. Another example can be seen where Facebook has introduced a new "Seen By" representation of feedback where the number of users navigating to a specific article that has been broadcast is presented as a trail of evidence or virtual footsteps. This mechanism of users indicating content of interest and trail forming through unintentional footsteps closely matches a phenomenon called stigmergy. Stigmergy is a term originally used to describe the apparent decentralized coordination amongst certain insects when performing tasks such as food foraging and nest building [1]. While we observe that popular Web 2.0 sites contain these features there is no evidence to suggest that these designs were influenced by stigmergy. The UI designs observed in Facebook might have been introduced without initially understanding their similarity to stigmergy but we see an increasing number of web sites introducing similar mechanisms trying to emulate the same success that has been achieved in Facebook. The primary research question we are working on is whether these mechanisms can be synthesized into a generic design pattern that can be introduced as standard Web site UI elements to enhance coordination.

Web Modeling Language (WebML) is a method of modeling data content, user interaction and navigation flow for various Web 2.0 applications. WebML provides a way to design the mapping of a data model to different UI views and the navigation paths between those views. Given the unique requirements of web site development compared to traditional software development the Object Model Group (OMG) is establishing a standard in the area. The OMG has released a current Request for Proposal (RFP) [2] to formalize syntax, metamodel, UML profile and associated interchange format for languages used to model interaction flow. WebML is one modeling language implementation currently being considered for inclusion in the standard. The most pertinent aspect of the WebML framework to our research question is that WebML is designed to be extensible to facilitate new concepts, interface types and event types. Given the Web 2.0 UI designs which we have observed and a thorough analysis of how they correlate to stigmergy we believe that we can introduce the UI mechanisms as standard elements during web site implementations.

II. STIGMERGY

Stigmergy is a biological term that was first introduced in 1959 by a French zoologist named Pierre-Paul Grasse [3]. The term was used to describe how insects appear to coordinate successfully despite having no centralized management structure or direct observable intercommunication [1]. Stigmergy specifically refers to an indirect communication where the insects use signs mediated within the environment to aid their coordination. An example of stigmergy can be seen in the way that ants leave a pheromone trail during food foraging activities. The trail provides a signal to other ants as to which direction a food source can be found while the strength of the pheromones indicate the relevancy of any specific trail as being the current trail to follow. A positive feedback system is created where the trail strength will increase as more ants follow the trail and successfully return with food. Furthermore, the environment enacts upon the sign causing atrophy and entropy to diminish the signal strength. This decay provides the negative feedback to ensure only the most current trails can be sensed thereby ensuring that old trails don't interfere with the food foraging activities after the associated food supply has been depleted.

Previously [4] we have introduced a model of stigmergy including the concept of a stigmergy *grand purpose* and the core components of stigmergy: the *agent*, the *environment*, and the *sign*. The model is illustrated in Figure 1.

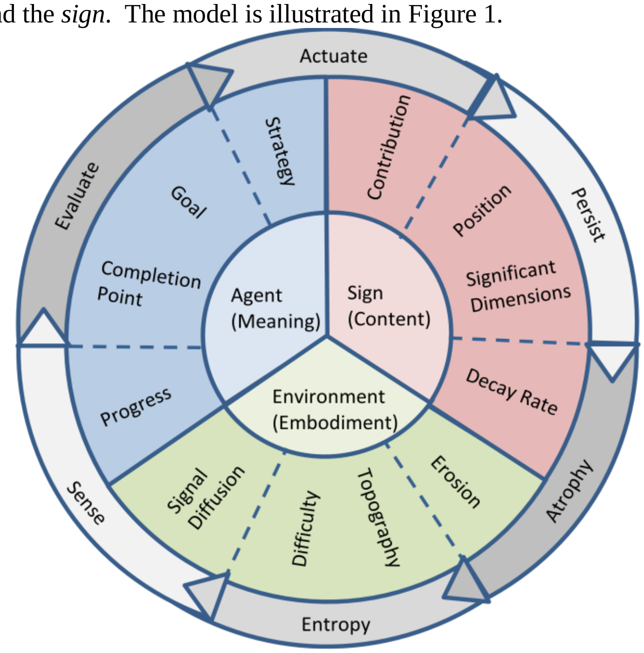

Figure 1. The Stigmergy Cycle.

The model as illustrated in Figure 1. ties together the core components of stigmergy, an inner band representing the *attributes* of the components, and an outer band representing the *dynamics* acting on those attributes. Furthermore, the outer band dynamics are either internal to each component, or defining the interface between components. Our model describes the dynamics of equilibrium between positive feedback (contributions) and negative feedback (decay) illustrating how the positive feedback is contributed by the agent, where the negative feedback is applied by the environment. The paper where we presented the model was focused on a holistic model of stigmergy which applies for the world of entomology, the human world and the virtual world. This paper is focused specifically on how the varieties of stigmergy manifest as Web environment UI elements. In context to this paper, these three components correlate to the users of Web environments, and the contributions that the users make.

There has been a significant amount of research focused on stigmergy in robotics and Web environments [5, 6]. Web environments provide a close facsimile to stigmergy in physical environments where a large number of users coordinate in a highly organized manner, specifically based on indirect communication through the contributions they make within the Web sites. In Facebook (see Figure 2.) there are similarities to the pheromone marker already observable in the Web.

Figure 2. Example of a Facebook LIKE mechanism.

Another variety of stigmergy describes the development of unintentional trails within the environment. An example of this is best shown by people wearing a path into a lawn when a short-cut is taken across the lawn. This unintentional trail is similar to another type of UI mechanism found within Facebook (see Figure 3.).

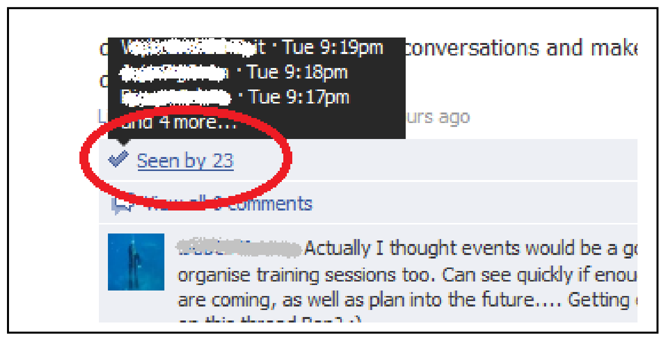

Figure 3. Example of a Facebook SEEN-BY mechanism..

Stigmergy provides a model of both *active contributions* and *passive interaction* with both varieties having numerous examples within the Web. The examples above for the two varieties of stigmergy have been categorized as *marker-based* [1] and *sematectonic* [7]. Marker-based stigmergy describes an explicit modification of the environment by leaving a sign with the intention of signaling other agents. Furthermore, Marker-Based stigmergy is broken into two sub-types: *qualitative* and *quantitative* [1]. This sub-type categorization is to clarify the difference between single contributions being sufficient to elicit a response as opposed to an accumulation of responses being required.

In contrast to the explicit method of leaving contributions, sematectonic stigmergy is defined as a modification to the environment as a by-product of actions being performed. These by-products are occurring inadvertently and unintentionally to the primary task being performed. For example, when considering a path being left in a lawn when people take a short-cut across it they have no intention of signaling to others that they have taken a short-cut. The short-cut is the purpose of the action, but the environment will retain the footstep impact as an alteration of the environment. There is no explicit foot-step left in the environment (obviously excluding cases such as wet feet leaving wet foot prints) however the action has altered the

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environment and the cumulative foot-step action manifests in the format of a path rather than something recognizable as an aggregation of individual feet traces.

If we consider the two different varieties of stigmergy we can divide the notion of intentionality of communication as being either explicit or implicit [8, 9]. Marker-based stigmergy can be considered as an explicit form of communication where the contribution made by the agent is intentional; it is explicitly left with the intention of the *sign* being interpreted as a *signal*. Sematectonic stigmergy can be considered as implicit communication where the primary activity being performed by a user leaves implicit modifications to the environment unintentionally just as with a trail. We would consider that an explicit sign left unintentionally would not constitute a signal, but could be interpreted as one. Similarly we would consider that an intentional generation of an implicit *trail* would be a *counterfeit* and also not be considered stigmergic, although it must be noted that it can trigger the same behavior in agents receiving the signal.

III. WEB MODELING LANGUAGE

Web Modeling Language (WebML) is a platform independent way to express the interaction design, data model and business rules of Web application development separately from the implementation platform [10]. WebML permits the formal specification of the data model, interface composition and navigation options and ultimately be supported by tools for the auto-generation of code. WebML describes a visual notation for designing Web applications which is intended to be exploited by the visual design tool WebRatio [11].

WebML specifications are based on four perspectives:

1) *Structural Model:* Data Model for dynamic content.

2) *Hypertext Model:* Site Views of the data model, which in turn are comprised of two sub-models:

a) *Composition Model:* Page composition and how the data model maps to a view.

b) *Navigation Model:* How pages are inter-linked (contextually and non-contextually via passed parameters).

3) *Presentation Model:* Layout and graphic appearance of pages independent to output device.

4) *Personalization Model:* Individualisation of pages based on User / Group categories, prefereneces, etc.

The four modeling perspectives describe the principal facets of data-driven Web sites and therefore provide an excellent experimentation lab for our research when attempting to test stigmergic mechanisms. WebML represents specifications using XML. Examples of XML for the data entities of the structural model, data within a page view and the navigation links (including parameters in the case of contextual links) are provided.

IV. INCORPORATING STIGMERGY WITHIN WEBML

At this stage we are determining whether our implementation would be an extension to the existing WebML classes or a design pattern within the modeling language using the existing classes. The simplest outcome of our research would be to prescribe a design pattern to follow when creating web sites which incorporate stigmergic mechanisms but we anticipate that a more prescriptive approach would be to create explicit stigmergic extensions to WebML. Initial examination of the WebML XML elements suggests that they would be easily extended to include additional attributes which support runtime instantiations of the stigmergic mechanisms. Furthermore the WebML submission to the OMG RFP describes *ViewComponent* as objects that display data or accept input [12]. This verifies that WebML can be extended to provide customized visualization components to display the stigmergic signals and trails to Web users.

We endeavor to design User Interface (UI) mechanisms to record both intentional and unintentional web site interaction based on our model of stigmergy. To provide environment mediated communication our UI mechanisms will need to trigger events which record user activity within a persistence layer specifically for stigmergy data. To enable the environment to provide negative feedback the environment must be able to trigger its own events to modify the stigmergy data. As discussed in Section III, WebML provides a collection of standard UI components with associated user and system triggered events to facilitate this within the *Hypertext Model*. WebML also provides the *Structure Model* that can facilitate stigmergy data persistence and access in conjunction to site specific data.

This section describes specific UI mechanisms available within the WebML *Hypertext Model* (including the ability to create custom controls) and how they apply to *input* and *output* components, events and persistence observed in examples of web-based stigmergy. We generalize these specific components into conceptual mechanisms which facilitate that contribution (input) and representation (output). For example, UI components such as drop-down lists, sliders and radio buttons are all representations of a single option selection, but each are different in their visual presentation. Understanding the fundamental mechanisms can extend the collection to encompass new UI components.

To incorporate stigmergy into WebML we need to understand the general ways the system would receive input, and how it should display output. If we consider our model of stigmergy (see Figure 1.) we understand that this will correlate with the environment having the facility to record contributions, process them and represent them back to users.

A. Qualitative, Marker-Based Stigmergy

Qualitative stigmergy is defined as discrete stimuli that can trigger a response in agents that encounter it. An example of this can be seen in Facebook with the “Share” functionality or within text messaging using emoticons [13]. Emoticons are icons included within the body of text messages to indicate to recipients the feeling or mood associated with the text (e.g.: “smiley faces”). The senders and recipients of text messages understand the associated meaning of the icons and as a result the emoticons add significant meaning to a text message without the use of language. The marker-based variety of stigmergy requires an intentional contribution by the user, and must incorporate a UI control enabling the user to create the contribution.

In the example of the Facebook "Share" we observe that a single user can broadcast content discovered by the user performing the "Share" so that it is visible to that user's group of friends (or level of privacy as selected). This represents the simplest input mechanism where there is only the requirement to intentionally trigger an interface element and that the user is aware of what signal it will contribute to.

The example of text messaging emoticons requires users to inherently know what emotions specific icons correlate to. There needs to be some UI mechanism for informing new users of the possible icons and their definition (e.g.: a context-sensitive, online help web function). Depending on how esoteric the required knowledge of available icons and their meaning are there might need to be instructions on appropriate reactions. The UI requires an administration function to define the possible icons in a given context. This administration function is considered outside the scope of this paper and is listed as an outstanding issue in Section V.

Our examples all generalize to one case: existing Web UI components which trigger an event (e.g.: radio buttons, etc). Each mechanism in the examples above equate to the user being presented with single or multiple options, however only a single option can be selected. We consider the generalized input mechanisms observed in the examples in this sub-section are:

- Single option intentionally triggering event.
- Single selection from predefined options using controls restricting selection and intentionally triggering event.
- User generated/input of content with predefined meaning (e.g.: using ascii text such as ":)" to be transformed to an icon representing a smiling face).

If we consider the output representations in the Facebook "Share" example and the text messaging emoticon example, the pattern can manifest in virtually any form. There are some simple and reusable patterns observed where verbatim representation or image substitution per associated option is provided. E.g.: smiling face emoticon entered as text and displayed either verbatim as ":)" or transformed as "☺". Conversely there might be customized, proprietary implementations required such as colour coding of warning types using the green for safe, red for danger representations. Again these UI components map to existing (or extendable) components within the WebML *Hypertext Model* which use event listeners to process data from the *Structure Model*.

Within Facebook we see the representation mechanism as an embedded link to the shared content providing a preview as a teaser to get other people to "View", "Like" or "Share" further. NOTE: The sharing of content by a user doesn't necessarily mean that the following user whose behavior is triggered by the signal will choose the same, single-option response. The emoticon example represents the user entered text within a text editor and requires the user to only enter tags with predefined meanings (and understand the connotation of those representations).

Our output examples clearly show that there are business rule requirements to access at stigmergy data layer and to present that data to the user with specific representation. The output mechanisms seen in our examples for this variety of stigmergy are:

- The (hyper-linking or verbatim) display of a UI component, whether contextually driven (e.g.: Display of the "Shared" content whether textual, image, html, multimedia, etc) or non-contextually (e.g.: "Terms and Conditions of Service" links).
- The input which was entered textually, but that requires recognition and interpretation by users who understand the signal representation (or the transformation where images are substituted).

We must remember that these abstractions are solely for our examples and is not intended to be an extensive list of all UI manifestations possible. An extendible WebML standard will enable future additions as required.

B. Quantitative, Marker-Based Stigmergy

Quantitative stigmergy is based on an accumulation of stimuli that do not differ qualitatively but that will reach a threshold and increase the probability of triggering a response. An example of this is demonstrated within the Facebook "Like" functionality which is a type of endorsement/acknowledgement system. A user who has made a contribution is hoping to provoke the response from their friends to "Like" it. The more people who "Like" the contribution increase the attention that the contribution receives. As the SUM total of people increases the probability of more people responding to the page increases, creating a positive feedback loop.

A more complex example of quantitative marker-based stigmergy is where there is more than just the single-option, signal contribution possible. In the online auction site eBay we have an example illustrated with the reputation feedback (see Figure 4.). There are a number of different criteria to answer, and each criteria has a 0 – 5 choice options where 0 represents a very negative feedback and a 5 represents a very positive feedback. As with the example in Section A if we generalize the mechanisms then we observe a single-choice selection from a group of possible options, however in this example there are multiple categories aggregated into a single contribution. The eBay example uses a non-standard UI component of a 5 star rating system. However any single selection UI controls (e.g.: drop-down list, radio button group, slider, etc) could be effectively used.

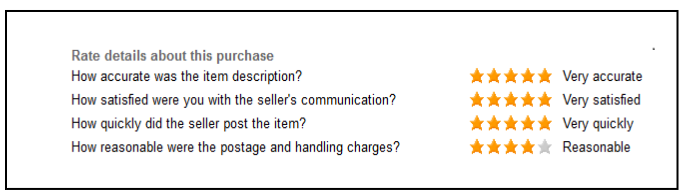

Figure 4. Example of an eBay feedback mechanism.

Just as with qualitative contributions, the WebML *Structural Model* will store the contribution triggered by events from the *Hypertext Model*. The UI has no other purpose than to facilitate the contribution of the stigmergic signal. The generalized input mechanisms observed in the examples in this sub-section are:

- Single option intentionally triggered.
- Single selection from predefined options using controls restricting selection and intentionally triggering event.

When considering output the Facebook example the response of “Like” is signaled to all parties with access to the original contribution and displayed as a simple SUM total of the number of people who have intentionally chosen to respond with a “Like” to the same contribution, and re-ordering the original contribution higher within the news feed. All contributions are based on the same qualitative stimuli, with the environment providing an accumulation function as part of the output mechanism presented to the user. As with qualitative contributions, the UI components link the WebML *Hypertext Model* through event listeners to process and present data from the *Structural Model*.

The eBay reputation feedback signal appears to be a composite, aggregation function of all purchase history for the user via multiple criteria. We see that the input parameters of multiple-choice to multiple criteria are transformed through the aggregation function and result in an output value that is applied to the users’ current reputation status value (either positive or negative). We can see how the environment (which consists of other users) and the user provide the positive and negative feedbacks to the signal and how the WebML *Structural* and *Hypertext Models* can facilitate that. An interesting observation is that Wikipedia has adopted this quantitative, marker-based mechanism for soliciting user feedback on the quality of specific articles and pages [14].

We consider the generalized output mechanisms seen in our examples for this variety of stigmergy are:

- UI component display or modification representing the aggregate function of the contribution.

C. *Sematectonic Stigmergy*

Sematectonic stigmergy is defined as a modification of the environment as a by-product of actions being performed. These by-products are occurring inadvertently and unintentionally to the primary task being performed.

If we consider the “Seen By” example in Facebook we understand that the user is not making any intentional contribution by viewing a specific piece of broadcasted contribution, however their action of viewing the contributions has been recorded in the environment. The user has left a trail for others to see. In the Facebook example the user has only clicked on a hyper link in response to another users suggested interest point (see Figure 3.).

A more complex example of sematectonic stigmergy can be seen in the Amazon recommendation system (e.g.: “People who bought this also bought …”), where product purchases made by a user are used as suggested items of interest to other users. In this example the input is virtually any potential sale item as the contextual input to the aggregation function. Irrespective of what manifestation the contextual input takes, we can observe that while the content type can take virtually any form the abstract mechanism equates to hyperlinks and interaction flow points. These interaction flow points occur whether based on following hyperlinks or other action events (e.g.: selecting the “purchase now” button on Amazon).

In both examples we see unintentional user-triggered events which store that activity in the persistence layer. We consider the generalized input mechanisms observed in the sematectonic examples in this sub-section are:

- Unintentional trace logging via event-triggered interaction incidental to using primary functionality.

In the Facebook example the current state of “Seen By” is visible to all parties with access to the original contribution and displayed in two different ways: The first representation is a simple SUM total of the number of people who have intentionally chosen to view the contribution but who did *not* have the intention to let people know that. The second representation is the discrete list of the users who view the contribution and the date-time of viewing. This second representation can be seen in the top section of Figure 3. The instigating behavior in this example is the viewing or navigating to a user contribution with the unintentional by-product of leaving a trail.

The Amazon recommendation example shows how the contextual input can result in an aggregate function used to influence other site user purchasing behavior just as described in the qualitative, marker-based variety of stigmergy. Again we see that the output is represented through UI components linking the WebML *Hypertext Model* through event listeners triggering business rules to process and present data from the *Structural Model*.

A final and important example of output representation was demonstrated in a trial of Wikipedia article edit contributions [15]. In an attempt to display the verifiability of articles which had been edited (relatively) recently the article would have its page display a colour-tinted background. The background colour of the article page (or part thereof) would appear a pinkish-red colour to signal that article had previous un-validated modifications. This colour would slowly change through orange and yellow pastels until an undisclosed number of visitors to the article would presumably indicate that no ensuing modifications (indicating potential corrections) would imply that the original modification could be considered appropriate and correct. The importance of this example is that it relies on the user’s cultural understanding of colour association where warm colours such as red/orange imply caution and where green / white (default representing standard conformity) imply safe and reliable state. This illustrates the potential for new and insightful ways to provide implicit representation rather than using explicitly defined categories and numerical values.

We consider the generalized output mechanisms seen in our examples for this variety of stigmergy are:

- UI component display or modification representing the aggregate function of the contribution.

V. Discussion

This paper has presented the varieties of stigmergy and briefly provided Web site examples of how the input and output for each variety might be implemented. Our examples have explored simple implementations along with more sophisticated implementations. An initial analysis of User Interface (UI) components indicate that they might be independent to the variety of stigmergy they apply to. For example, we see that both qualitative and quantitative marker-based stigmergy can use a single selection type input element irrespective of the different types of output implementation. Similarly the output implementation of both quantitative marker-based stigmergy and sematectonic stigmergy appear compatible. If we are able to decouple the input/output implementations from the stigmergy varieties then we might enable a level of reuse of these mechanisms.

Our analysis has been focused on our UI observations which clearly correlate to the WebML *Hypertext Model* (both *Content* and *Navigation Models*). By definition stigmergy stipulates that communication occurs indirectly through environment mediated signs and indicates some form of data layer must exist.

Our model of stigmergy describes both positive feedback from users and negative feedback from the environment. The stigmergy data within the WebML *Structural Model* will therefore require data persistence accessible by the UI components as well as environment triggered events. This will be analyzed and included in the next phase of research when designing how stigmergy integrates with WebML. This metadata persistence is expected to also afford the administration of available qualitative marker-based options (e.g.: available text messaging emoticons and associated images/icons) and integrate into some form of tag disclosure through integrated online help. Our current work involves providing a model of how stigmergy as a design pattern integrates with WebML framework extending UI components and events within the *Hypertext Model* and how that maps to the *Structural Model* within WebML.

In the Facebook "Seen by" example we illustrate a single stigmergic mechanism resulting from a single input component (e.g.: The following of a link to a suggested content article) and how it can have two different output representations. The Facebook example showed that there can be a SUM aggregate function of the users who visited the suggested content, but also a chronological listing identifying the distinct database entry level data including the date/time of the event. This clearly highlights that when incorporating stigmergy into WebML we must accommodate multiple output visualizations (and different view locations where they are accessed) representing the single output state.

VI. CONCLUSION

What we hope we have clarified in this paper is how different stigmergic mechanisms might be implemented such that there is both an intentional and unintentional set of input elements. These input elements map to relevant output elements which include both visualization and representation (embodiment) of the contributions. This representation is determined by aggregation functions which are calculated using the business rules against persistent data for the specific stigmergic mechanism. These generate signals and trails ranging from simple SUM aggregate functions to multi-criteria and multi-selection aggregate formulation into a final representation.

Stigmergy is not merely input and output mechanisms as presented within this paper; they are only part of the stigmergy phenomenon. For the mechanisms to work as intended a web site must be built analyzing the grand purpose of the site, and how stigmergic mechanisms can be employed to improve site coordination. The intra-site location of where the mechanisms are deployed (e.g.: specific users or role groups) ultimately depends on the development project sponsor. Similarly the WebML *Personalization Model* of a Web site might employ a fee paying structure where access to the mechanisms might be restricted. These issues are accommodated for within WebML and are ultimately expected to make the efficacy of introducing stigmergic mechanisms into Web application design significantly value-added.

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