Can Intelligent Agents Invent Creative Concepts?

Rabee M. Reffat
Key Centre of Design Computing and Cognition,
University of Sydney, NSW 2006, Australia
E-mail: rabee@arch.usyd.edu.au

Abstract

This paper is concerned with the potential of developing design agents that are capable of inventing creative concepts while involved in designing. An approach of exploiting the notion of displacement of concepts with regard to concept invention in designing is introduced. A conceptual framework of concept invention agents and its potential role in concept invention and design creativity are presented.

1 Motivations

The process of designing is intertwined with discovery within and between design episodes whereby unintended consequences of design actions occur. A recent protocol design study has provided evidences that unexpected discoveries (inventions), play an important role in designing [1]. This study introduced "situated-inventions" as the generation of issues or requirements in the current design task. The situated inventions form the basis for the formulation of new and creative design goals. Creativity includes the processes of: (a) combining ideas from different domains; (b) using visual imagination and analogy; and (c) expanding and varying the search space of alternatives [2, 3]. There is novelty in the formation of concepts, that is the displacement of concepts [4]. New concepts emerge out of the interaction of old concepts and new situations.

Designing agents perform actions that form specific concepts in the resulting artefact and achieve design goals in relation to specific situations. The course of actions is not based on the execution of a fixed plan that is given in advance or at the beginning of the design process. Actions are determined and executed in relation to: (a) some goals; (b) observations of the circumstances in which they were performed; and (c) internal state of the agent that performs the actions. Each design agent contributes a particular body of knowledge in deriving the overall solution. Intelligent agents enjoy the following properties: autonomy, reactivity and pro-activeness whereby they do not simply act in response to their environment but they are able to exhibit goal-directed behaviour by taking the initiative [5]. An agent is situated within its environment. An agent senses the environment and acts on it, over time, in pursuit of its own agenda and so as to affect what it senses in the future [6].

A general view of invention is as a search through a virtually infinite "problem space" of possible solutions whereas the challenge of an invention-agent is to reduce the size of, or find a route through, the problem space [7]. Inventive-agents are mode shifters and adroit in any situation they encounter it and ready to bridge boundaries by flexible casting or by following the thread of logic wherever it may lead in. Also, they will convert old concepts to new ones by adroit abstraction, reasoning and the use of heuristics [8]. This paper presents a theoretical conceptual framework of concept-invention agents that have the potential to support design creativity.

2 Displacement of concepts and concept invention

Concept-invention refers to the act of discovering new concepts for the first time. Concept-invention requires breaking the settled ways of looking at things, to come apart with respect of them, prior to the discovery of new a concept. Concepts are to be distinguished from their instances and from situations. This is a distinction rather than a separation. It is through a process of abstraction that agents use to distinguish between concept-tools and the situations within which they were used. While a given situation can be conceived in a variety of ways, it is always a *concept-structured-situation.*

Learning is interaction with new concepts. Because a new concept is one that comes up for the first time, it is unexpected. It is subject to a special sort of attention and comes to be perceived like a *figure* against the *background* of familiar and therefore relatively unnoticed situations. Discovering unexpected concepts that may be new in some respects and old in others requires distinctions in kinds of novelty. New concepts may have grown out of what has gone before and can be seen as changes in the old. In some cases the new concept is recognisable as a minor variation of an old one, as in the case of derivation of "superjet" from "jet". In other cases the new concept connection with the old might be obscure. There is a difficulty in perceiving the discovery of new concepts in a vocabulary that is appropriate only to their justification after-the-fact focusing on the concept-instance relation. It is as though trying to understand the emergence of new species in terms of concepts of existing species. This may force the thinking of the newness of new concepts as either illusory or mysterious [4].

New concepts come through the shift of old concepts to new situations. In this process, the old concept is not applied to new situation, as a concept to an instance, but is taken as a symbol for the new situation. The new concept grows out of the making, elaboration and correction of the symbol. A number of phases are included in this process: transposition, interpretation and correction. These phases always occur in a specific context and situation. These are not discrete events following one another in a fixed order but aspects of the process often out of sequence and often inseparable. The phase of transposition goes on indefinitely as more and more concepts from the old concepts cluster are shifted to the new situation. This is part of elaboration of the symbol. Transposition is inseparable from interpretation. An old concept is not transposed to a new situation without transposing it to some specific aspect of the new situation, yet the two phases are still distinguishable. However, the new situation has conceptual structure of sorts before any old concept is displaced into it. This process in not a one-way affair in which the old concepts is corrected to suit the new situation. It is a mutual adaptation in which the old concept and new concept-structured situation are modified to suit one another. The mutual adaptation may take a variety of forms: (a) old concepts may be compounded in order to become more appropriate to the new situation; and (b) the interpretation given aspects of the old concepts may be changed.

3 Concept-invention agents (CIAs)

A concept-invention agent is supposed to come up with creative suggestions towards its owner, that is the user who activated the agent. Creativity might seem like a quality that will not fit in a computer. However, if we define creativity in terms of displacement of concepts as

explained in the previous section, it can be defended. There are different approaches that have been tried to construct the best agent architecture: programmable interface agents, knowledge base agents and self-learning agents [9]. This paper is considering the approach of self-learning agents. The users are offered an agent that can be trained without the user having to learn the agent language. Instead of the traditional programming, the agent is instructed through importing functionality from other agents within or outside its execution environment, observes other agents and figures out what it should do from that.

A concept-invention agent should capable of:

- Observing the environment using its sensors and forming a situation;
- Forming concepts from its observations using both its preceptors and conceptors;
- Performing actions and changing the situation as well as its environment using its effectors;
- Conceiving the effects of its actions in the environment and forming a new situation;
- Discovering new concepts from its multiple views of the environments;
- Operating without direct control from people or other agents, i.e. autonomous;
- Acting automatically towards other agents in its environment or other environments, i.e. communicating;
- Reacting to various forms of stimulation from its surroundings, i.e. reactive; and
- Taking initiatives to get closer to its defined or emerged goals.

3.1 Development of a single concept-invention agent (CIA) in its execution Environment

A proposed framework of a single concept-invention agent (CIA) is shown in Figure 1. A CIA builds its view about the environment through its sensors. It has containers of information, called pools, and functions that process information and transfer it among pools. The pools contain representations of the CIA's internal model. Each sensor detects the environment and, perceives its representation and places its outputs in the Precepts pool (PERC). Depending on the agent's goal and focus of attention, the external representation can be perceived in various ways. Based on the current goal and focus of attention the Perception function (P) constructs its Precepts and places them in the PERC pool. The Cognition function (C) provides a means of extracting additional cognitive inferences based on different Precepts in the PERC pool, constructs the current situation from its Precepts and places its output in the Concepts pool (CON). The Handling function (H) given the current concept organises its actions and places them in the Effects pool (EFC). The Action function (A) executes these actions using the agent's Effectors prepared by the Handling function (H) causing some transformations in the environment. In response to the new changes in the environment (e.g. external representation), the CIA's sensors are reactivated and consequently the CIA's updated view of the environment is constructed. Constructing different views of the environment provides a platform for each CIA via its Cognition function (C) to discover new concepts.

The following example is a tentative illustration of a single concept-invention agent (CIA) in the domain of designing shape compositions. This CIA is preprogrammed to have a set of sensors with which it detects its encountered environment. This set of sensors incorporates the recognition of square, rectangle and triangular shapes as shown in Figure 2(a). When the CIA encounters an environment that includes an external representation of a shape composition as shown in Figure 3(a) it generates an infinite maximal line representation of this external

representation as shown in Figure 3(b). The infinite maximal line representation is generated by extending the line segments in the external representation to the boundary of a selected frame.

The CIA develops a set of representations from the infinite maximal line representation using its initial sensors as shown in Figures 3(c) and (d). The infinite maximal line representation provides a platform for new invented concepts to be discovered by the CIA such as the set of shapes shown in Figure 2(b). The CIA uses its discovered concepts as new sensors to perceive the environment, e.g. external representation. Figures 3(e) to (h) show different set of representations of the environment using the new sensors.

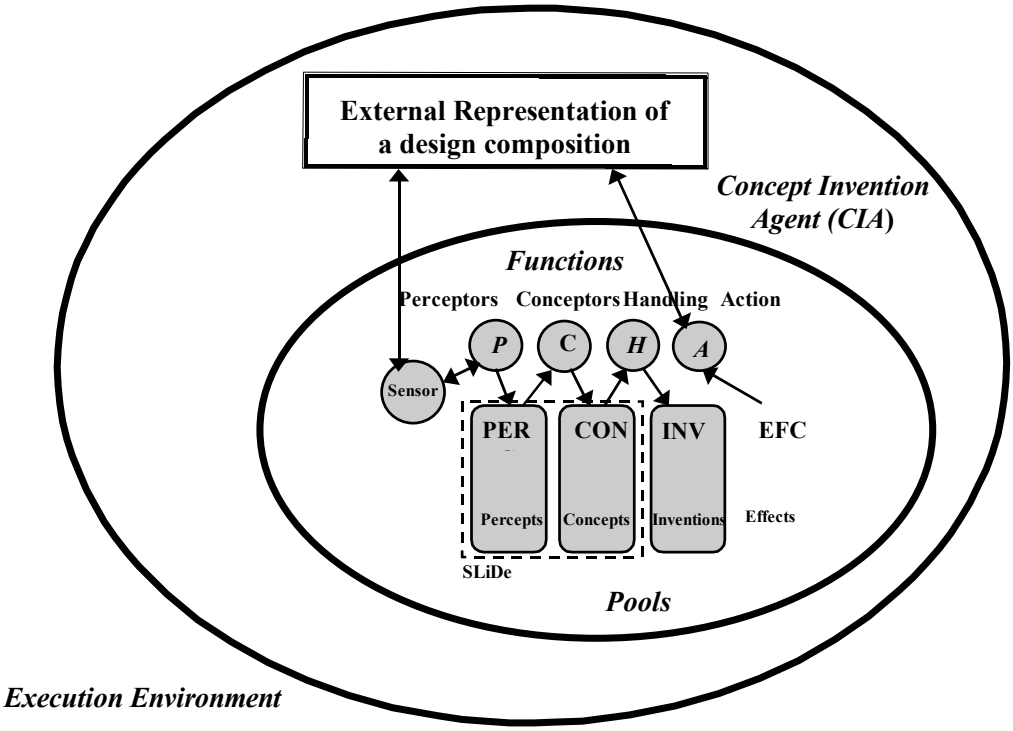
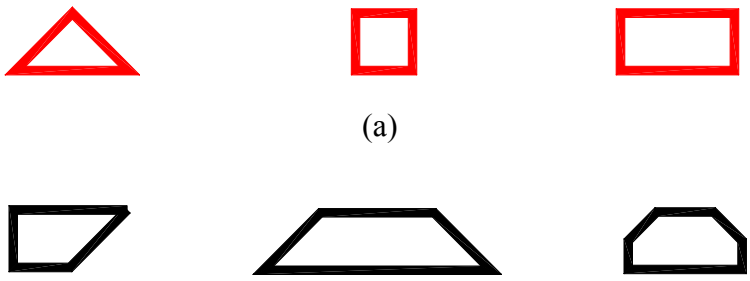


Figure 1. A framework of a single concept-invention agent in its execution environment.



(a)

(b)

Figure 2. (a) Initial sensors available to a CIA and (b) invented concepts discovered by the CIA and used as new sensors to detect the environment.

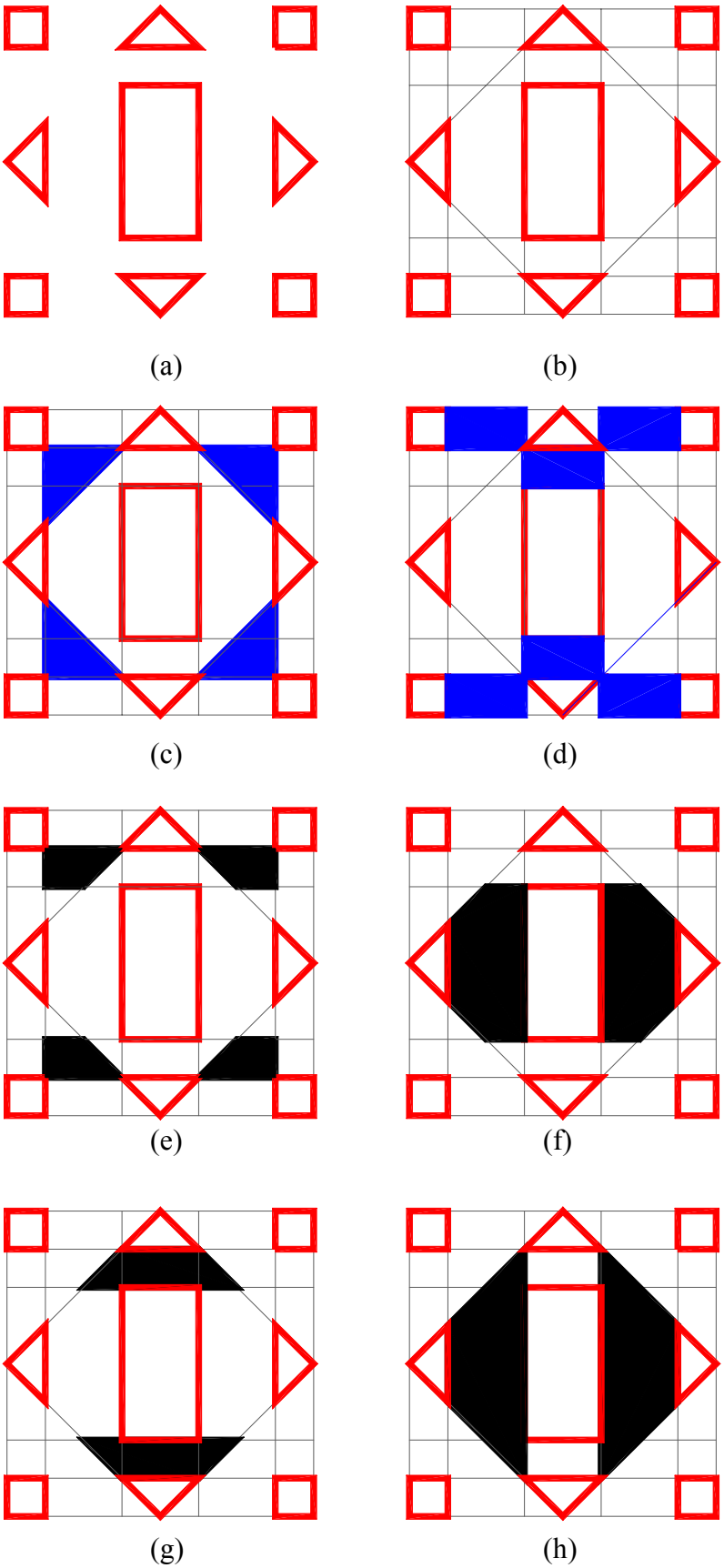


Figure 3. (A) An external representation available in the design environment, (b) an infinite maximal line representation of the external representation, (c) and (d) two representations developed by a CIA using its initial sensors, and (e) to (h) four representations developed by the CIA using its discovered concepts as new sensors.

3.2 Development of multiple concept-invention agents (CIAs) and multiple execution environments

If agents were to be isolated in their own little world, they would rarely be capable of doing many interesting things. In order to maximise their usefulness they must be able to communicate with the surrounding world to access different kinds of views and concepts. We can separate between communication between agents with similar functions or cooperation between agents with different functions. An example of various types of communications and interactions among CIAs are shown in Figure 4. It may be interesting to export parts of the knowledge of an agent to one or more other agents. The concepts that an agent has struggled to acquire and found interesting might be useful to other agents that share similar interests. Furthermore, if an agent is unsure about what to do with a piece of information, it could ask another, more experience, agent about what to do with it. This research adopts Maes's approach [10, 11] to shorten the training period before a CIA is competent enough to make the right decision.

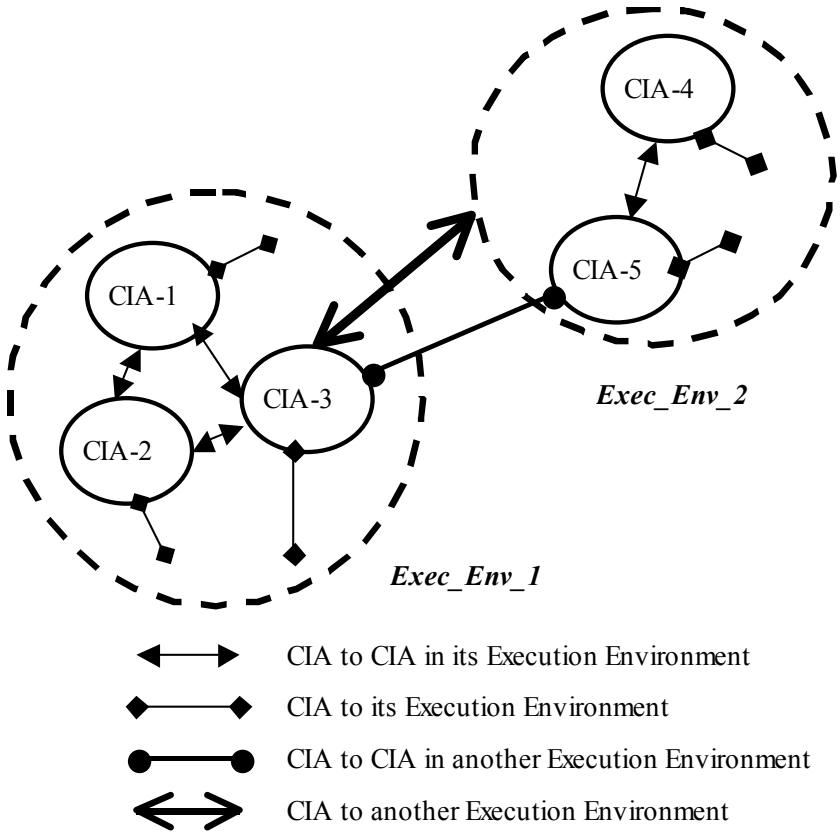


Figure 4. Various types of communications among CIAs within and outside its execution environment.

Development of Mobile agents for concept invention

A mobile agent is an agent that can move or migrate from its initial environment to a new environment. This reason for doing this is to provide a platform for the displacement of concepts to occur. The actual immigration can be done in primarily two ways [12]: either the entire thread context and the state of the agent is sent over, or only the state is sent over. The former approach is used by the most popular agent systems available, such as Voyager [13] and Aglets [14]. Aglets supports remote communication among agents. Voyager is essentially

not an agent framework but rather an application server with agent support. However, agents are not only made up of states. The code that is used to run the agent must also be transferred to the new execution environment. A graphical representation of a migrant agent between two execution environments is shown in Figure 5. The framework of concept-invention agents supports static and mobile agents. Static agents execute on a single environment while mobile agents can migrate to other environments. There is an adaptation process involved for a mobile agent to reside in its new environment. The SAFT, Software Agent Framework Technology, Blixt and Öberg's model [15], is utilised as an initial start yet with primary conceptual difference in structuring the framework of concept-invention agents in designing.

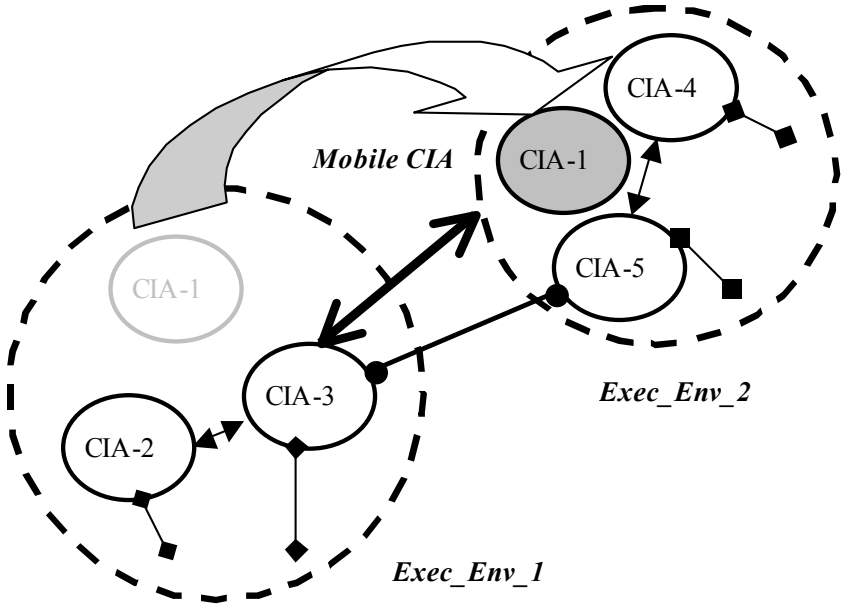


Figure 5. An example of a mobile CIA migrating from its initial execution environment to another environment.

Exploitation of novelty detection approach to concept classifications

Novelty Detection techniques are concept-learning methods that proceed by *recognising* positive instances of a concept rather than *differentiating* between its positive and negative instances. Novelty Detection approaches consequently require very few, if any, negative training instances. A particular Novelty Detection approach to classification that uses a Redundancy Compression and Non-Redundancy Differentiation technique [16] based on the Gluck & Myers model of the hippocampus, a part of the brain critically involved in learning and memory is exploited. In particular, this approach consists of training an *autoencoder* to reconstruct positive input instances at the output layer and then using this *autoencoder* to recognise novel instances. Classification is possible, after training, because positive instances are expected to be reconstructed accurately while negative instances are not.

4 Conclusion

This paper introduced a theoretical development of concept-invention agents. The deployment of the notion of *displacement of concepts* into design agents has been considered to provide the capability of inventing new concepts. A conceptual framework of a concept-invention

agents and a mobile agent was introduced as well as an example in the domain of shape compositions. However, this paper presented a new theoretical architecture of agents that has the potential to provide a platform to support design creativity, the ideas in this paper are currently under further research and development as well as developing a computational model of concept-invention agents.

References

[1] M. Suwa, J.S. Gero & T. Purcell, Unexpected discoveries and s-inventions of design requirements: A key to creative designs, *Computational Models of Creative Design IV*, J. S. Gero & M. L. Maher (Eds), Key Centre of Design Computing and Cognition, University of Sydney, Sydney, Australia, 297-320, 1999.

[2] A. Koestler, *The act of creation*, Hutchinson, London, 1964.

[3] M.A. Boden, *The creative mind: myths and mechanisms*, Cardinal, London, 1992.

[4] D.A. Schön, *Invention and the evolution of ideas*, Tavistock Publications, London, 1967.

[5] M.J. Wooldridge & N. Jennings, *Intelligent agents: ECAI-94 Workshop on Agent Theories, Architectures, and Languages*, Springer, Berlin, 1995.

[6] S. Franklin & A. Graesser, Is it an Agent, or just a Program?: A Taxonomy for Autonomous Agents, *Intelligent agents III : agent theories, architectures, and languages*, N. Jennings et al (Eds), Springer, Berlin, 21-35, 1997.

[7] W.B. Carlson & M.E. Gorman, A cognitive framework to understand technological creativity: Bell, Edison, and the Telephone, *Inventive minds: creativity in technology*, D. N. Perkins and R. J. Weber (Eds), Oxford University Press, New York, 48-79, 1992.

[8] D.N. Perkins, The topography of invention, *Inventive minds: creativity in technology*, D. N. Perkins and R. J. Weber (Eds), Oxford University Press, New York, 238-250, 1992.

[9] B.C. Tørrissen, *Intelligent agents and conceptual modelling*, Master Thesis, Department of Computer and Information Science, Norwegian University of Science and Technology, Trondheim, 1996.

[10] P. Maes, Agents that reduce work and information overload, *Communications of the ACM,* Vol. 37, No. 7, 31-40, 1994.

[11] P. Maes, Reflections of agents that reduce work and information overload, *Readings in Intelligent User Interfaces*, M. T. Maybury and W. Wahlster (Eds), Morgan Kaufmann Press, San Francisco, CA, 1998.

[12] M. Hohlfeld & B. Yee, How to migrate agents?, *Technical Report*, Department of computer Science and Engineering, University of California, San Diego, 1998.

[13] ObjectSpace, I. Voyager, Homepage, *http://www.objectspace.com/default.asp*.

[14] IBM-Corporation Aglets, Homepage, *http://www.trl.ibm.com/aglets/*.

[15] K.-F Blixt & R. Öberg, *Software Agent Framework Technology*, Master Thesis, Department of Computer and Information Science, Linköping University, Linköping, Sweden, 2000.

[16] N. Japkowicz, C. Myers & M. Gluck, A Novelty Detection Approach to Classification, *in proceedings of the Fourteenth International Joint Conference on Artificial Intelligence (IJCAI-95)*, Montreal, Canada, 518-523, 1995.