SIXTH FRAMEWORK PROGRAMME
PRIORITY [#]
[PRIORITY TITLE]

Contract for:

SPECIFIC TARGETED RESEARCH OR INNOVATION PROJECT

Annex I - "Description of Work"

Project acronym: NEW TIES
Project full title: New and Emergent World Models Through Individual, Evolutionary, and Social Learning
Proposal/Contract no.: FP6-502386
Related to other Contract no.: *(to be completed by Commission)*

Date of preparation of Annex I: 5 April 2004

Operative commencement date of contract: *(to be completed by Commission)*

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1 Project summary

The project is concerned with emergence and complexity in socially-inspired artificial systems. We will study large systems consisting of an environment and an inhabitant population. The main goal of the project is to realize an evolving artificial society capable of exploring the environment and developing its own image of this environment and the society through cooperation and interaction. We will work with virtual grid worlds and will set up environments that are sufficiently complex and demanding that communication and cooperation are necessary to adapt to the given tasks. The population's weaponry to develop advanced skills bottom-up consists of individual learning, evolutionary learning, and social learning. One of the main innovations of this project is social learning interpreted as passing knowledge explicitly via a language to others in the same generation. This has a synergetic effect on the learning processes and enables the society to rapidly develop an "understanding" of the world collectively. If the learning process stabilises, the collective must have formed an appropriate world map. Then we will probe the collective mind to learn how the agents perceive the environment, including themselves, and what skills and procedures they have developed to adapt successfully. This could yield new knowledge and surprising perspectives about the environment and the survival task. The project represents a significant scale-up beyond the state-of-the-art in two dimensions: the inner complexity of inhabitants and the size of the population. To achieve and explore highly complex organisms and behaviours, very large populations will be studied. This will make the system at the macro level complex enough to allow significant behaviours (cultures etc) to emerge in separate parts of the system and to interact. To enable this we will set up a large distributed computing infrastructure, and a shared platform to allow very large scale experiments in a p2p fashion.

2 Project objectives

The goal of the project is to realize an evolving artificial society capable of exploring its virtual world and developing its own view of that world. The long-term target is to learn how to design agents that are able to adapt autonomously to, and then operate effectively in, environments whose features are not known in advance.

The main pillars of the envisioned research are *world models* and the *learning mechanisms* generating these. We shall not implement specific training facilities or feedback systems rewarding the learning of world models for its own sake. Instead, we are interested in **emerging world models** powered by a basic survival game. In order to obtain the expected emergent features, we shall work on a **very large scale** compared to that of today's common practice with respect to the size of the agent population and agent complexity.

Defining *culture* as knowledge structures shared among agents that reflect aspects of the environment, including the other agents, our first scientific objective is:

1. To develop an artificial society with an emergent culture.

This objective can be broken into the following sub-objectives:

1.1. To identify which system components carry the knowledge structures that make up world models.

1.2. To develop mechanisms to monitor the development of world models.

The population's abilities to develop advanced skills bottom-up consist of individual learning, evolutionary learning, and social learning. This motivates the second main objective.

2. To realise a powerful "emergence engine" consisting of a well-balanced combination of individual learning, evolutionary learning, and social learning.

This objective can be broken into the following sub-objectives:

2.1. To develop an understanding of the mutual effects of the three types of learning on each other and on the development of the individuals and the whole population.

2.2. To develop mechanisms for adjusting the balance between the three types of learning.

We consider individual learning and evolutionary learning as the two basic mechanisms and expect that social learning has a (re)combinative effect on the learning processes significantly boosting the population's adaptive capabilities and enabling the society to rapidly develop an "understanding" of the world collectively. One of the main innovations of this project lies in the way we approach social learning. It will be implemented in such a way that it allows passing knowledge explicitly (i.e., not only by imitation, but via direct messages) to others within the same generation. The corresponding scientific objective is:

3. To develop, evaluate, and use a range of social learning mechanisms that allow sharing knowledge with other members of the population.

Our approach to this objective is twofold. On the one hand we will study various protocols of information dissemination, implying the following sub-objective:

3.1. To set up **communication mechanisms** and investigate their effects on the efficiency of social learning mechanisms.

On the other hand we need to address issues about the form and content of messages. This leads to the second sub-objective, which relates to (the emergence of) language and its use:

3.2. To implement a framework enabling the **emergence** of the communication and cooperation essential to social learning.

Although these objectives are clearly ambitious, we treat them as measurable and we shall implement a targeted assessment of their achievement as part of the project.

By the end of the first year the software platform and experimentation tool will be built within workpackages (WP) 1 and 5. WP 1 focusses on the modelling aspects, e.g., to define the challenging artificial environments, and the simulation tool, whereas WP5 is primarily concerned with the underlying technology.

Objective 1.1 will be realised through WP 2 and 4. By month 10 the emergent knowledge bits will be specified (task 2.1, milestone M2.2, task 4.1, milestone M4.1), while the monitors for objective 1.2 come from task 4.2 and 4.3 (specs in M4.2 by month 16, delivered as D4.1 in month 24). The first scientific objective, objective 1, will be directly addressed by task 4.4 summarising our findings by D4.2 in month 36.

The stepping stones to the “emergence engine” from objective 2 are in the focus of WP2 (tasks 2.2, 2.3, and 2.4). The initial design is planned for month 6 (M2.1), the full working release a year later (D2.1 in month 18) followed by the summarising research report in month 30 (D2.2).

The social learning objective is supported by WP2 (task 2.3), WP3 (tasks 3.x), where WP3 is the principal workpackage concerning communication. By the end of the first year the main setup will be specified in M3.1, leveraging on M2.1 from month 6. Working implementation is scheduled for month 21 (D3.1), again relying on D2.1 in month 18.

As for the overall evaluation of the (success of) the project the following considerations are important.

The project aims to create a multi-agent system that can learn and survive in a demanding environment. In order to prove the system, we shall construct a number of environments drawing on the sociological and anthropological literature, each of which will pose a challenge to the agents. If the population of agents adapt and surive, we shall count this as a success. To avoid the temptation to build agents that are constructed to be fitted for a particular environment, we shall give the populations several distinct challenges and expect them to survive and flourish in them all.

We shall be interested to compare the strategies used by the agent populations with the strategies used by human populations in analogous circumstances. However, we expect there to be whole classes of possible strategies that will support population survival in the face of a challenge. Different strategies may be selected on different runs of the simulation. One would face an exponentially increasing search time if one would like to catalogue all such strategies and this is not our goal.. It is possible that none of the strategies that happen to be adopted by our agents will mirror those adopted by human populations.

Nevertheless, because of the nature of the challenges we set and the abilities of the agents to engage in individual and social learning, we do expect that agents will develop a language and a 'culture'. These will be identifiable by the experimenters because they involve a consensus among agents of the meaning of symbols (i.e. there is a shared lexicon, where the lexicon includes not only 'words' but also cultural symbols and artifacts). Moreover, we intend to measure the complexity of the information communicated as well as the behavioral relevance of the emerging language and 'culture'. This latter can be judged, for example, by the spreading of the population or by the wealth of individual agents.

These issueas will be taken into account throughout the project and for WP4 they will be essential.

3 Participant list

The following table gives an overview of the consortium

List of Participants

Partic .Role *	**Partic. no.**	**Participant name**	**Participant short name**	**Country**	**Date enter project ****	**Date exit project ****
CO	1	Vereniging voor Christelijk Wetenschappelijk Onderwijs, Department of Computer Science, Artificial Intelligence Section	VUA	NL	1	36
CR	2	Eötvös Loránd University, Faculty of Informatics, Department of Information Systems	ELU	HUN	1	36
CR	3	Napier University, School of Computing, Centre for Emergent Computing	Napier	UK	1	36
CR	4	The University of Surrey, School of Human Sciences, Centre for Research on Social Simulation	UniS	UK	1	36
CR	5	Stichting Katholieke Universiteit Brabant, Computational Linguistics, Induction of Linguistic Knowledge Group	UNIT	NL	1	36

*CO = Coordinator
CR = Contractor

** Normally insert “month 1 (start of project)” and “month n (end of project)”
These columns are needed for possible later contract revisions caused by joining/leaving participants

Special Advisor Professor Sander van der Leeuw

The consortium has obtained the agreement of Professor Sander van der Leeuw, an anthropologist of international repute, that he will act as an advisor to the project. Professor van der Leeuw will be consulted on the environmental challenges to be constructed in WP1 and their relevance to understanding human societies. He will also act as the point of contact between the project team and the Santa Fe Institute, especially their current programmes on Robustness and Social Scaling.

4 Relevance to the objectives of FET Open

This project brings together aspects of social sciences and information technology and as such is closely aligned to the societal aspects of the IST priority, making it clearly within the general scope of IST. The potential impact of the project will have effects reaching into some major IST areas. IST Strategic Objectives that may particularly benefit are:

[1] Distributed Resource Evolutionary Algorithm Machine, IST-1999-12679

- “Cognitive Systems” – Although this project will develop simulations of environments and agents, some of the knowledge gained will be directly relevant to the embodied agents of this strategic objective.
- “Mobile and wireless systems beyond 3G” – This project complements and enhances the work of this strategic objective by providing insight into the nature of the mobile agents and shared knowledge that might exist within future ad hoc radio networks.
- “GRID-based systems for solving complex problems” – The peer-to-peer computing issues of the project are directly relevant to this strategic objective. Aspects of the project which concern self-organisation, and the emergence of language and meaning have important implications for the “Semantic GRID”. The project can also be expected to give insight into the ways that complex problems can be solved in highly distributed systems.

This project is particularly suited to the objectives of the FET Open Initiative being visionary, sometimes even futuristic. The high level of innovation required to achieve each research objective will take the project beyond the state-of-the art in each area. In addition to the individual advances in research areas, the interdisciplinary nature of the work will bring together the complementary expertise necessary to achieve simulated societies with a scale and complexity not attempted before.

Relation to the state-of-the-art

Since its birth in the early 1990s (e.g. Gilbert and Doran 1994), the field of social simulation has grown extremely quickly. There is now a journal, the *Journal of Artificial Societies and Social Simulation*, a European and a North American learned society (the European Social Simulation Association and the North American Association for Computational Social and Organizational Science), regular workshops and conferences, and many volumes of edited proceedings (a small selection is: Carley and Prietula 1994; Troitzsch, Mueller et al. 1996; Conte, Hegselmann et al. 1997; Ahrweiler and Gilbert 1998; Gilbert 1999; Sichman, Conte et al. 1999). The volume of work produced now is such that it is not feasible to review it all in this proposal (but for recent surveys, see Gilbert 2000; Cederman 2002; Macy and Willer 2002).

The idea of experimenting with ‘artificial societies’ in order to learn about social systems was proposed at an early stage (e.g. Gilbert and Conte 1995; Epstein and Axtell 1996; Doran 1997). However, how this is best done remains an open question. The main issues are:

1. Should the agents be simple (e.g. consisting of a few condition-action rules) or complex (e.g. including a full behavioural model)?
2. Should there be many agents (e.g. agents numbering thousands) in order to detect large-scale emergent patterns, or few?
3. Is it necessary to represent language generation and understanding, or will ‘brain-to-brain’ message passing suffice?
4. How one can detect emergent features – the state of the art rarely rises above the qualitative observation that clustering has been detected.

The debate on these issues continues in part because of perceived computational constraints. For example, in the present state of the art, it is not considered feasible to build models that include a very large number of relatively complex agents because of the demands on computer resources that running the model would require. Hence researchers are forced to choose between designing simulations with many simple agents *or* few complex agents.

All these issues will be addressed by this project, which will be the first to have the resources and expertise to build an artificial society that includes many thousands of relatively complex agents. As such, it will be seen to be leading the way in terms of its ambition and impact in the social simulation community. The society we shall construct will develop its own ‘e-language’ (i.e. a language used by agents for communication with other agents) and, because of the size of its population and the sophistication of its agents will create relatively complex emergent social structures. One workpackage (WP4) will be devoted to moving forward the state of the art in detecting such emergent features using techniques such as data mining which will be applied to this problem for the first time in social simulation.

Computational research on language evolution finds its roots in Hurford’s work from 1989 (Hurford 1989). After a relatively slow start, the research area began to grow around 1996 with pioneering work on the evolution of vocabulary systems in simulations (e.g., Oliphant 1996; Steels 1996), on real robots (Steels and Vogt 1997), on the evolution of communication as such (Di Paolo 1997), the origins of sound systems (De Boer 1997), and on the emergence of syntax (Kirby and Hurford 1997). That the field is rapidly growing can be observed in this year's proceedings of the European Conference on Artificial Life (Banzhaf et. al. 2003), where 22% of the papers deal with language evolution and computation, while the proceedings of 1997 had only 12.5% (Husbands and Harvey 1997). The community of language evolution and computation has its own web resource page (http://www.isrl.uiuc.edu/~amag/langev/) with a large collection of the available literature, and co-organises a bi-annual conference called "Evolution of Language" of which the fifth version will be held in 2004 in Leipzig. This year, a first workshop on Language Evolution and Computation was held during the European Summer School on Language, Logic and Information in Vienna. This workshop is intended to become a bi-annual workshop that alternates with the Evolution of Language conference.

Language evolution and computation (LEC) models have meanwhile provided various explanations of aspects of language evolution, see, e.g., (Briscoe 2002; Cangelosi and Parisi 2001, Christiansen and Kirby 2003; Kirby 2002) for overviews. It is widely believed in the LEC community that language emerges as a complex dynamical system resulting from cultural evolution and individual adaptations (Steels 1997; Hurford et al. 1998; Knight et al. 2000; Wray 2002). We follow this idea and assume that some biases, for instance toward the ability to learn language, could be innate, but that languages (i.e. the linguistic structures and universal tendencies) themselves emerge as a cultural phenomena (Kirby and Hurford 2001; Smith 2003).

It is meanwhile fairly well understood how to model the origins of vocabulary-like languages that are grounded in a real world setting (Cangelosi 2001; Steels et al. 2002; Vogt 2003a). In addition, there are studies that show how communication can emerge to serve a drive to optimise cooperative behaviour in a population (De Jong 2000; Noble et al. 2001; Quinn 2002). However, it is still unclear how these models scale to more realistically sized populations. The Talking Heads experiment (Steels et al. 2002) is, up-to-date the only large-scale experiment on language evolution. In this experiment a population of 6000 robots, which were distributed across the world and connected through the Internet (in a peer-to-peer kind of fashion we will be using here), developed a grounded lexicon. The population dynamics of this experiment was completely uncontrolled, and of these 6000 robots few robots remained active throughout the entire experiment, which lasted a few months, while others were only present for a few hours. In addition, the robots had no other challenge than to evolve a lexicon. We intend to set up experiments that have very large population sizes throughout the entire period.

A lot of progress has been made with respect to the emergence of syntactic structure, such as compositionality. Most successful models rely on iterated learning (Batali 1998; Brighton 2002; Kirby 2001), but little research has been done on how to ground the semantics of such languages (Steels 2003; Vogt 2003b). Moreover, these studies typically use extremely small populations.

So, according to the state-of-the-art, a lot is known on how to evolve linguistic aspects in small populations, but no research attempts are known that scale these models to really large populations. Research into these issues is extremely important from a scientific point of view (language is used by all humans) and from an engineering point of view if we wish to use these techniques in future multi-agent systems.

We are also going to go beyond current frontiers with the "emergence engine": the combination of lifetime learning, evolution, and social learning will be a novelty. Combinations of the first two, individual learning and evolution, have already long been known as Lamarckian evolution and the Baldwin effect, (Baldwin 1896, Hinton and Nowlan 1987, Belew 1989). However, most studies address simple neural net evolution or simple scenarios and only a few take a viewpoint that we consider relevant to our multi agent societies (Ackley and Littman 1992, Parisi, Nolfi and Cecconi 1992, Nolfi and Floreano 1999). This project will build on existing results, but also differ in several respects. Our settings will be much more complex than the commonly investigated systems in terms of agent structure, population size, and the richness of the environment. Our environments are not only complex because many other agents have an impact on an agent's fitness, but also because of the "physical" topology induced by the p2p infrastructure. Under these circumstances previously proposed theories and hypotheses are unlikely to be valid. For instance, some studies suggest that learning is first selected for and then selected against as evolution progresses (Mayley 1996), but in our environments it can be expected that the advantage of instinctual traits will be limited and that learning remains a key feature over long periods of evolution.

Incorporating social learning into the emergence engine adds a new dimension with three expected effects: it can speed up individual learning processes, by providing relevant knowledge from others; it can increase the scope (range of applicability) of knowledge of the individuals by preparing them for situations they have not encountered themselves; and it can make possible collective problem solving, i.e., the ability to solve problems that no single individual would be able to solve by itself alone. Some results concerning learning and (co)evolution indicate that the same types of behavioural strategies are rediscovered over and over again during the course of a long evolutionary process (Nolfi 1999). It is to be expected that additional social learning might be able to preserve such knowledge, preventing (or at least reducing) deterioration and improving performance.

5 Potential Impact

The project has the potential to have a huge impact if successful. The impact can be summarised by saying that at present information and communication technologies are in general slaves to the demands of their users; the project will show how autonomous, virtual agents can self-organise to survive in a challenging virtual world, operating in ways that the software designers have not imagined.

Perhaps the most dramatic impact of the project will be the **change in world-view among the public** that such a development could trigger. The idea of autonomous agents capable of virtual 'life' in parallel with human activity is one that is recognised as a realistic possibility among the IST community, but so far exists only as science fiction among the public. For example, the press would no doubt relate the outcomes of the project to the disotopias foretold in many science fiction stories. As usual with technological developments, such scare-mongering would fail to acknowledge the benefits that one could also anticipate. We suggest some practical examples of the use of ideas stemming from the project below.

5.1 Technological and scientific impact

The **technological impact** will arise from:

1. A deeper appreciation of and a practical implementation of the combination of individual, evolutionary and social learning. Improved learning mechanisms and algorithms ('machine learning') will have a high impact on a wide variety of information technology areas, from knowledge management to hardware design, fields where learning algorithms in the present stage of development have already been exploited.
2. A new understanding of the way to design communities of self-organising autonomous agents. This is likely to be exploited in developing agents that operate on the internet, providing services, but also in the longer term for agents that are embedded in mobile devices or even in 'smart dust'.

The **scientific impact** will arise from:

1. Linking the field of machine learning to linguistics and in particular the evolution of languages, where the outcome is expected to be enhancements to both fields.
2. A major impact on social science, where there has been an increasing interest in 'computational social science' to study human societies by experimenting on computational analogues. However, to date, most of these experiments have been hindered by a lack of sophistication of the models and inadequate scale (e.g. 'societies' of a few tens of individuals) .

Because the project is long-term and foundational it is not easy to estimate reliably its economic and social consequences. Instead, we offer two examples of potential impact on very different areas. In both cases, the impact one would expect would be very substantial.

Autonomous mobile devices

In ten to fifteen years, we can expect there to be a vastly greater number of 'intelligent' devices (as suggested by, for example, the 'disappearing-computer' FET initiative (http://www.disappearing-computer.net/).) All of these will be connected using either IPv6, or UMTS or other techniques not yet designed. For example, about 80% of UK citizens have a mobile phone; when these become 3G phones, each will all have the functionality and computing power at least equal to that of a present day PC. It has been suggested[2] that within 10 years, the price of UMTS modems (i.e. 3G phones) will be sufficiently low that all dog collars will include them to enable owners to locate their pets!

These devices will not only be ubiquitous, they will also differ greatly in their capabilities, their design and their communication protocols (there is for instance, little point in making a dog collar capable of doing the same things as a PDA; and while it might be useful if all the devices used the same standard high-level protocols, in practice there will be variations between them). For political, social and commercial reasons it will be impossible and undesirable to impose a universal high level (i.e. semantic) protocol on all the devices.

The way out of this problem is to allow the devices to self-organise. This has already been achieved to some degree with the world wide web, with spectacular results. However, the WWW is, relatively speaking, ‘dumb’: it communicates only un-interpreted text and graphics; is modest in size (the number of devices will be order of magnitudes greater than the current number of web servers) and is geographically static (web servers do not change location; many of the devices of 10 years time will be mobile).

In this project, we shall begin to understand how one might foster the conditions under which such heterogeneous computational agents can self-organise and communicate without outside control or a strictly defined externally imposed communication protocol.

Ad-hoc networks of minute autonomous specks

In ten years time, it is expected that it will be possible to purchase VLSI ‘specks’ that encapsulate sensing, processing and wireless networking capabilities in objects with diameters of a fraction of a millimetre. Such ‘specks’ or ‘smart dust’ will be a disruptive technology with many, as yet barely imagined applications. For example, it will be possible to control temperature and humidity in homes and offices much more finely and exactly than currently envisaged. There will be applications in mechanical control and transport. There will also be many major medical applications. For example, deep brain stimulation systems have been shown to ameliorate the condition of Parkinson’s Disease patients. Currently, such systems are being evaluated in the treatment of multiple sclerosis induced tremor, dyskinesias, dystonias, chronic cluster headache and obsessive-compulsive disorder. Accelerometers and stress sensors implanted in different parts of a patient’s body can provide feedback on the patients’ movement and muscular status, allowing the neural implants to self-adjust. Complex systems can be also conceived, where a neurostimulator is collaborating with other neurostimulators that are interacting with the cortex or peripheral nerves. Moreover, neurostimulators can also be networked with muscle stimulators in order to restore muscular function or with other medical devices such as augmented reality systems (visual feedback through goggles) and delayed audio feedback systems.

Techniques and protocols that support the communication infrastructure of such complex medical systems are currently under intensive development. The heterogeneous and highly critical data requires a flexible and extensible communication framework that incorporates information security. In particular, the system may need to be able to self-(re)organize the network if parts are lost or become faulty, and self-optimise using patient reinforcement. The knowledge gained in this project could be fundamental to understanding how best to achieve secure, robust and self-repairing networks of such systems.

The impact of the project can thus be stated in summary as ‘generating the foundational knowledge required to maximise the effectiveness of the vast populations of ubiquitous computational agents that we can expect in a decade’s time’. Later on in Section 6.2 we sketch other examples of potential areas of exploitation.

6 Project management and exploitation/dissemination plans

6.1 Project Management

As project co-ordinator, the VUA will be responsible for the day-to-day co-ordination of the project, and will be the main interface between the project and the European Commission. It will consolidate the progress reports, cost statements, budget reports, etc., using input from the other partners. The project co-ordinator will also be responsible for communication between partners and for the dissemination of information provided by the partners. Interaction with other research projects and networks working in the area will be co-ordinated by the VUA.

[2] David Birch, Hyperion Consulting, speech July 2003

Two committees will oversee intra-project communication and co-ordination:

The first, the Management Committee will consist of one senior research supervisor from each of the participants. Its role is to monitor the project progress and the budget taking corrective action if necessary. The Management Committee will also be responsible for any changes to workpackages or responsibilities that may arise as a result of new information learnt in the course of the research.

The Management Committee is expected to meet 2-3 times a year in the course of the project at approximately equal intervals, but the frequency may change according to circumstances. It is expected that meetings will be held at the participating institutions, although other venues may prove more efficient, for example, if several members are already attending the same conference. Meetings held at partner institutions will be chaired by the hosting senior researcher, unless agreed otherwise; meetings held elsewhere will have a chair selected for that occasion. Each member will provide a progress and budget report to the chairman for distribution prior to each meeting. The report will detail the milestones reached and draw early attention to any anticipated delay in reaching any milestone, so that appropriate action can be taken.

The second committee will be the Scientific Committee, consisting of the researchers employed to carry out the research. The role of the Scientific Committee is to co-ordinate the exchange of technical solutions, scientific results, hypotheses, and research ideas. It will also be responsible for requesting the Management Committee to change workpackages or responsibilities as may be required as a result of new information learnt in the course of the research.

It is anticipated that the Scientific Committee will meet 2-3 times a year during the course of the project at approximately equal intervals, but the frequency may change according to circumstances. It is expected that meetings will be held at the participating institutions, although as with the Management Committee, other venues may prove more efficient. It is expected that many of the Scientific Committee Meetings will be arranged to coincide with Management Committee meetings to allow Management Committee members to attend. The rules of rotating chairmanship outlined for the Management Committee will also hold for the Scientific Committee. Each member will provide a scientific progress report to the chairman for distribution prior to each meeting. The report may be of any appropriate length but must include a one-page summary. During each meeting, each member will give a short (around 15 minutes) scientific presentation of scientific results, hypotheses, and ideas.

In the event that the Scientific Committee cannot reach a consensus on some matter, that matter should be referred to the Management Committee for a decision. If the event that the management committee cannot reach a consensus on some matter, then the final decision will be made by the Management Committee member representing the partner who is the lead contractor for that workpackage. Where a matter under consideration affects more than one workpackage, then the co-ordinator's decision will be final.

Committees may make decisions without physically holding a meeting. Decisions may also be taken using media such as e-mail, telephone, web-based meetings, and video conferencing. All such decisions will be reported to and ratified by the next meeting.

In addition to the formal committees, where a workpackage is being undertaken by more than one participant, workgroups will be formed to co-ordinate activity within the workpackage. It is expected that most workgroup communication will be carried out electronically, although informal workgroup meetings will take place when the members are attending Management or Scientific Committee meetings.

Besides these management activities, deliberate effort will be put into team building to help project integration and prevent segregation. To this end a number of instruments will be used:

- A quarterly project Newsletter with a rotating copy editor, made publicly available through the project Web-site, also helping to promote the project worldwide.
- Monthly electronic chat session for the Management Committee, where the chat-log will be only distributed internally.
- Monthly electronic chat session for the Scientific Committee, where the chat-log will be only distributed internally.

Risk assesment and contingency measures

This project represents ambitious research with the corresponding possibility that it may fail to reach some of its objectives. It is therefore necessary to have contingency plans that will allow the project to maximise its achievements even in the face of problems. The following are what are seen to be the major risks (ranked from greatest to least), and the avoiding action that will be taken to ameliorate their impact on the rest of the project:

1. Objective 3: If the emergence of communication and cooperation (objective 3.2) is only partially achieved, we shall fall back on a human engineered language with largely hard-wired syntax and semantics. In this case, it will still be possible to realise a working social learning mechanism (objective 3.1).
2. Objective 2: Failures in achieving objectives 2.1 and 2.2 can be circumvented by tuning the “learning mix” through extensive experimentation to explore the parameter space. In this case the emergence engine will be based on a pragmatic rather than a theoretical foundation.
3. Objective 1: we believe that the chance of failing sub-objectives 1.1 and 1.2 are low. However, there is a danger that the emerging patterns we detect will either be incomprehensible or too volatile, especially in the very large system we shall be working with. In this eventuality the main benefit from the project will be the theoretical and conceptual framework of world views and culture that we will have developed, and the pattern extraction techniques that we will have refined.
4. Technical failure of experimentation infrastructure. P2P networks are still research vehicles, but the project will be relying on one for its computing infrastructure. This is also low risk, because the DRM infrastructure will be brought in as background from an existing project that two of the proposers have been involved with. If insurmountable problems are encountered, it will be possible to use alternative open source public domain software (chosen following a planned survey of the alternatives), or reconfigure local networks as Beowulf clusters. During this contingency change project systems will continue to run on a single machine. As for the simulation platform itself we do not expect dangers.

Failure to recruit appropriate staff. Because of the nature of the project, the ideal recruits will be post-docs who have experience in both computer science and social science (including linguistics). Such multi-skilled people are rare, although there is no doubt that the project will seem extremely attractive and exciting to those with the right skill set. If such people cannot be found, the project tasks will be divided into those requiring computational and those requiring social science skills, with the integration between the two disciplines falling on the proposers.

6.2 Plans for using and disseminating knowledge

It is important that the results from the project should be **disseminated** widely, not only to the academic community, but also to business, industry and the wider public; and that the project outcomes should be exploited to the fullest extent. To this end, we shall:

1. Publish scientific articles in a number of leading journals, conferences and more popular scientific oriented media.
2. Build and maintain a project Web-site providing all available information, free code, challenges and relevant publications. We will put special effort into “marketing” to popular-scientific forums Ideally we can build a virtual community for users, including students, fellow researchers and interested laypeople.
3. Challenge other scientists to design better populations and provide a test bed for such a challenge. The objective of the challenge(s) will be to allow scientists to compare different models on one platform, which is similar to the objective of the Robocup challenge.
4. Release the extended DRM platform and open the source code, such that we provide a platform for other researchers to test agent populations of their own design.
5. Organise a workshop for a scientific and industrial audience to investigate how we can further exploit our results. This workshop should disseminate the main results of our project and relate it to advances made by other researchers. The primary goal, however, is to set out directions to be

taken to further advance the science and technology of this project. To this end industry involvement is essential.

6. Edit a special journal issue and special tracks during conferences that cover (aspects of) the challenges we set. This allows us to further disseminate our results and attract other scientists to join in on our efforts.
7. Organise tutorials during summer schools or conferences. This, too, allows us to disseminate the results and attract other scientists to join in on our efforts.
8. Towards the end of the project, we shall organise a demonstration and publicity event (in the form of a Summer School, targeted workshop, or alike) on the subject of ‘artificial societies’ for researchers, PhD students and post-doctoral researchers as well as industrials from Europe.
9. Actively seek contact with larger European initiatives, such as networks of excellence and integrated projects in relevant areas, e.g. Exystence and AgentLink III, EC-AGENTS, ISCOM, EVERGROW, and also smaller research projects, for instance SWARM-BOTS.
10. Special attention will be devoted to participation in (co-organising) European conferences in related areas, in particular Exystsnce workshops, symposia and conferences.

Most actions are intended to spread the knowledge and technology gained during this project. Other actions are intended for the industry and other researchers to pick up on the project to further advance and exploit the proposed technology.

The project will generate fundamental knowledge that will be ripe for **exploitation** in a range of novel technological areas, but bringing these to market will require the active cooperation of technology companies. The demonstration and publicity event mentioned above will serve as a showcase towards the end of the project to which selected potential developers will be invited. At earlier stages in the project, the management committee will ensure that relevant companies are kept informed of the opportunities that may become available.

In addition to the exploitation areas mentioned in section 5.1 (autonomous mobile devices and smart dust), we have identified some further potential areas for exploitation:

- **Understanding real societies**. There is potential for the project to give insights to sociologists studying real societies. For example, the study of real world "communities of practice" (Wenger 1998) might be informed by studying the ways in which communication, cooperation and social structure aid virtual agents working collectively in achieving goals. In particular, knowing the ways in which shared world views emerge in our virtual world can help with understanding how concepts such as gender emerge and are perpetuated in the real world (Paechter 2003).
- **Social robotics**. Distributed autonomous robots are not autonomous as a group if the system depends on external intervention to maintain its fundamental functions. Self-referential coupling of self-organizing systems as a design framework is a potential application resulting from our project.
- **Bioinformatics.** Bioinformatics is a rapidly growing field, one of whose objectives is to model the natural world. Recent developments suggest a convergence of nanotechnology with the cognitive sciences. This convergence is based on material unity at the nanoscale and the ability to manage information on biological systems at various scales from DNA to society through bioinformatics. Insights from our project relating to the ability to manage information in a large society of artificial systems could contribute to advances in bioinformatics.
- **Pro-active threshold cryptography.** The idea of threshold cryptography is to protect sensitive information by distributing it among a cluster of cooperating computers in a fault-tolerant manner. This information can only be retrieved when a certain threshold is reached by a cluster of machines. The main goals are: improve the security and/or efficiency of cryptographic applications, design new secure cryptographic primitives, formalise and rigorously analyse common cryptographic practices, protect against key exposure, and make distributed/multiparty computations secure. Our dynamic methods of distributing information on a cluster of machines, and our insights into knowledge shared between and amongst agents could contribute to these goals.

- **Automatic ontology mapping**. The vast collections of databases around the globe often have different ways of storing ontologies containing similar data. Communication between these databases is desirable for many reasons and in many places. Our project can provide the insight for developing intermediate languages to communicate between the ontologies of these databases.

Companies working in these areas will be targeted for invitation to the project exploitation workshop, and for possible individual technology transfer activities. Further areas for potential exploitation are expected to arise as the project progresses and matures, and as the surrounding state-of-the-art changes. Our exploitation plans will be continuously updated to account for this.

On the long term one of the main promises of this project is the ability to tackle problem solving in and generate knowledge about complex environments in a new way. An important category of applications is formed by resource seeking and utilisation, i.e., detecting and collecting some targeted resources, and possibly even processing (manufacturing) them in a prescribed way. Imagine a complex virtual or real environment, such as the Internet or Mars. A complex Internet task in our category is compiling a structured catalogue from items found on the Web for a special interest group, such as a European Network of Excellence. On Mars, or any other hostile and unknown terrain, one can think of constructing a desired object from local raw materials. Having achieved the goals of NEW TIES a collective of agents (virtual or physical) can be prepared by programming/hard-wiring some appropriate features and skills, thereafter they can be released in the environment. The collective will be able to rapidly learn about the circumstances they operate in through sharing individually acquired knowledge with each other. They can collectively develop the necessary "understanding" of and the appropriate response to those aspects of the environment that influence their survival and task performing abilities and the performance of the whole society will quickly increase. In a large society we might witness speciation, for instance the emergence of explorer, collector, and constructor individuals, each focussing on a particular subtask, learning different aspects of the environment and developing special skills accordingly. This could yield new knowledge and surprising perspectives about the environment and the given task.

6.3 Raising public participation and awareness

The project has a natural interface appealing to laypersons: society modelling as whole and the envisioned challenges are easy to understand without a scientific background. This fact forms a good basis for approaching a wide audience. The project will invest targeted effort in contacting journalists and have them publicising the general philosophy behind the project, as well as the specific project objectives, and achievements. Additionally to the intra-project newsletter, a project presentation extended with an annual publicity document for laypersons will be presented on the project website and distributed to a mailing list of public media persons.

7 Work plan for the whole duration of the project

7.1 Work Plan Introduction

For non-trivial behaviour to emerge, a population of agents should have a demanding environment confronting them with a challenge they can meet only by becoming advanced. Designing such environments and challenges is, therefore, a fundamental requirement for our project. We meet this requirement by seeking inspiration in the social sciences and setting up artificial worlds that originate from challenging problems there.

On the other side of the coin are the agents. These must be suited for the environment(s) in question, but not be pre-engineered for the specific environmental challenge. We have to maintain a balance between agent properties that are hard-wired, i.e., properties that agents *do* have, and emergent properties that agents *might* have, i.e., that need to be acquired by adaptation and learning. We attempt to achieve such a balance by a minimalist approach, trying to keep the hard-coded intelligence at a minimum, enriching the lean agent structure only if necessary.

We make a distinction between individual and evolutionary learning on the one hand, and social learning on the other. As for the first two, we intend to use existing mechanisms adjusted to our purposes. That is, we enable the agents to learn from the situations they encounter and make them evolvable, but major innovations concerning these mechanisms are not among our initial targets. The opposite is true for the social learning mechanism. In particular, we shall develop social learning mechanisms that do not work through social facilitation or imitation. Instead, we will implement mechanisms that allow passing knowledge by means of an evolved language to others within the same generation (with no permanent knowledge store such as a library). Our approach is based on perceiving a population as a collection of entities that process data and execute some machine learning algorithms to generate models matching these data. In this way, individuals might eventually have models which match the experience of large numbers of population members. In developing social learning systems we will build on the "newscast model" of computing, developed by an FP5 project[3]. In particular, we will investigate social learning mechanisms which allow information dissemination through epidemic protocols which have proved to be highly robust and effective in simple data mining tasks (Kowalczyk, Jelasity, and Eiben 2003). Within the NEW TIES project we shall develop a far-reaching generalisation of this procedure to be applied for knowledge sharing in an artificial society.

In order to have the chance to observe language and culture emerging, the individual agents must have the ability to exhibit complex behaviour. These individual agents must then have considerable interaction with each other, and their environment, in order for the emergence to happen. Coupled with this, we hope to observe sub-cultures and dialects in spatially separated parts on the environment, and to see those local characteristics compete and recombine with each other, meaning that the environments and populations we will use must be very large. All of this will happen while the population is evolving over maybe hundreds, but perhaps millions, of generations. Given the processing power required to achieve all of this, it is unlikely that interesting results will be achieved on a single machine within the lifetime of the project. The consortium therefore proposes to utilise a peer-to-peer (P2P) infrastructure to allow the processing to take place across a number of machines (at least 10 per partner, 50 across the project). This infrastructure will be decentralised, serverless and scaleable, so that the hardware can easily be extended by adding either more dedicated machines, or the spare processing power of machines normally in use for other tasks.

7.2 Work planning and timetable

The project is arranged into a number of work packages (WP). Each WP covers a logically distinguishable part of activities, possibly contributing to more than one objective. Integrating work performed through various WPs is a key issue in managing the project and is elevated to a separate WP, accompanied by Evaluation. In this section we present a WP overview and a timetable embedding the WPs together with their milestones and deliverables in the 36 months project duration period. The logic behind arranging the work is based on the following rough division of necessary activities:

1. Setting up simulated environments and defining challenges to the populations inhabiting these.
2. Developing agents that could exist in these environments and enrich them with learning and evolution facilities.
3. Developing advanced solutions for social learning, including general communication protocols and evolvable language.
4. Running simulations and recognising and monitoring the emergence of world views and culture.

Further to these the basic peer-to-peer infrastructure must be set up to support massive experimentation. The resulting list of necessary work packages is as follows:

1. Environments and Challenges
2. Agents and Learning
3. Language, Communication and Co-operation
4. Emerging world models and culture
5. Peer-to-Peer Infrastructure
6. Integration and Evaluation
7. Dissemination and Exploitation
8. Management and Coordination

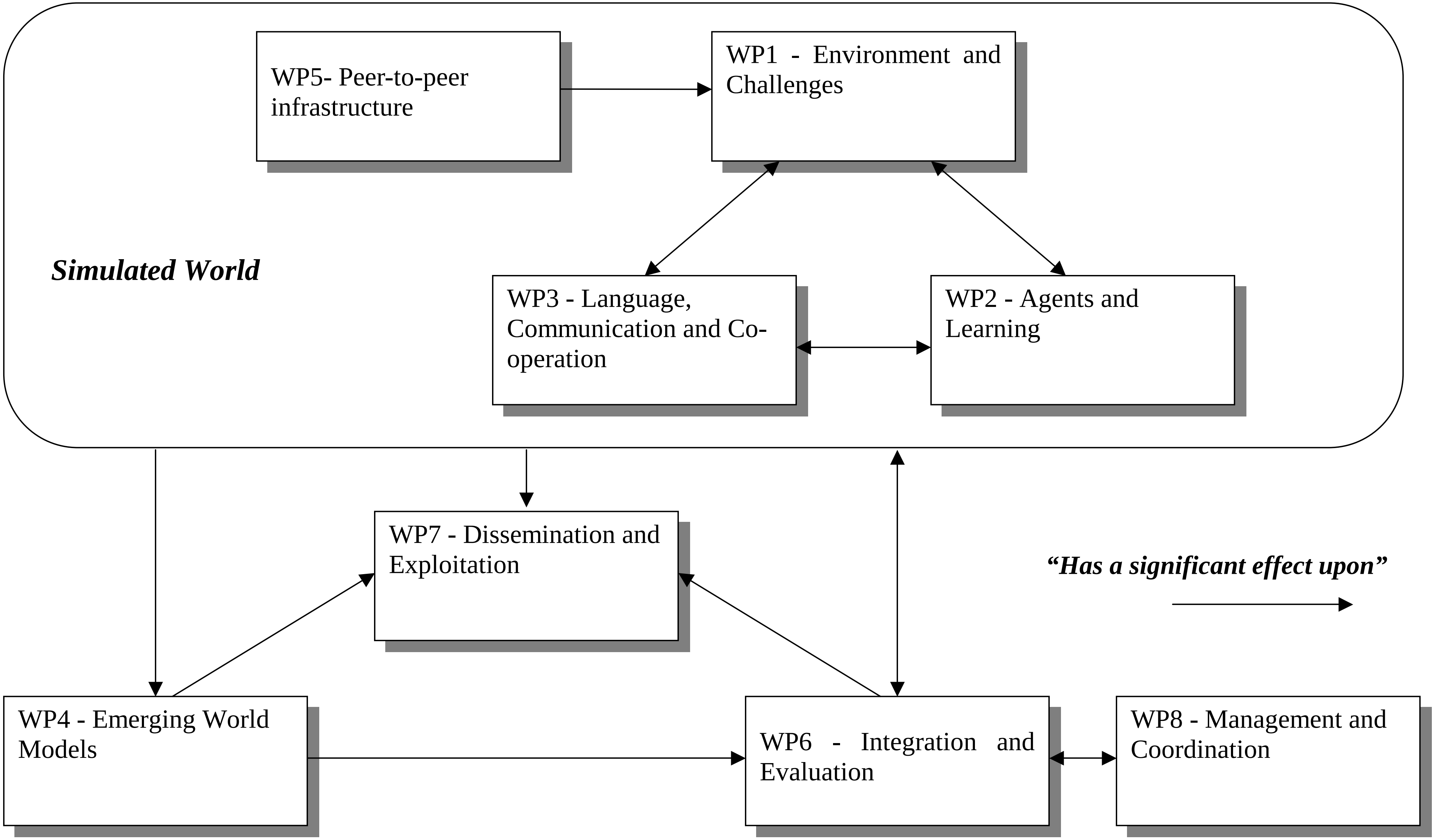
[3] Distributed Resource Evolutionary Algorithm Machine, IST-1999-12679

Gantt Chart showing project timetable

	Month																	
Wp	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1						M1.1						M1.2						D1.1
2						M2.1				M2.2								D2.1
3											M3.1							
4										M4.1						M4.2		
5					M5.1	M5.2					D5.1	M5.3						
6				M6.1								D6.1						
7														M7.1				
8				M8.1														

	Month																	
Wp	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1															M1.3			D2.1
2												D2.2						
3			D3.1					M3.2										D3.2
4						D4.1												D4.2
5																		
6																		D6.2
7				D7.1								M7.2			M7.3			D7.2
8																		D8.1

7.3 Graphical Presentation of work packages



7.4 Workpackage List

Work-package No[5]	Workpackage title	Lead contractor No[6]	Person-months[7]	Start month[8]	End month[9]	Deliv-erable No[10]
1	Environments and Challenges	4	21	1	36	D1.1 D1.2
2	Agents and Learning	1	45	1	36	D2.1 D2.2
3	Language, Communication and Co-operation	5	27	4	36	D3.1 D3.2
4	Emerging world models and culture	2	27	9	36	D4.1 D4.2
5	Peer-to-Peer Infrastructure	3	21	1	36	D5.1
6	Integration and Evaluation	1	33	1	36	D6.1 D6.2
7	Dissemination and Exploitation	1	42	4	36	D7.1 D7.2
8	Management and Coordination	1	8	1	36	D8.1
	TOTAL		224			

[5] Workpackage number: WP 1 – WP n.
[6] Number of the contractor leading the work in this workpackage.
[7] The total number of person-months allocated to each workpackage.
[8] Relative start date for the work in the specific workpackages, month 0 marking the start of the project, and all other start dates being relative to this start date.
[9] Relative end date, month 0 marking the start of the project, and all ends dates being relative to this start date.
[10] Deliverable number: Number for the deliverable(s)/result(s) mentioned in the workpackage: D1 - Dn.

7.5 Deliverables List

Deliverable No	Deliverable title	WP No.	Lead Partic.	Estimated pers. months	Delivery date	Nature	Dissemination level
D5.1	Peer-to-peer foundation software	5	3	12	11	P	PU
D6.1	Software Interface Specifications and Test Software	6	1	6	12	P	PP
D1.1	Implementation of the environment and two challenges	1	4	18	18	P	PU
D2.1	Implementation of agents and learning mechanisms	2	1	18	18	P	PP
D3.1	Implementation of language evolution and communication functions	3	5	15	21	P	PP
D.7.1	Downloadable package of the research platform	7	1	24	22	P	PU
D4.1	Implementation of inspection methods	4	2	15	24	P	PP
D2.2	Research report on the interactions among our three types of learning	2	1	21	30	R	PU
D1.2	Review of work and comparison with human societies	1	4	9	36	R	PU
D3.2	Research report on the evolution of language, communication and cooperation	3	5	15	36	R	PU
D4.2	Report on emergent world views and cultures in artificial societies	4	2	15	36	R	PU
D6.2	Final Evaluation Report	6	1	9	36	R	PP
D7.2	Final plan for using and disseminating knowledge	7	1	9	36	R	PU
D8.1	Full project documentation	8	1	9	36	R	PU
			TOTAL	216			

7.6 Work package descriptions

7.6.1 Environments and Challenges Workpackage Description

Background

This project is based on a large number of agents operating and learning in a simulated world. This workpackage is about creating that world and the challenges that the agents will face. A set of learning agents will only do something 'interesting' if they are given something demanding to do. Agents that have no challenges will simply do nothing (and survive nevertheless). Hence it is important that their environment should pose appropriate challenges. This is not a trivial task, because what the agents will learn will depend on the challenge. If the challenge is too specific, the agents will learn only to solve that specific challenge and probably do so in an uninteresting way; if the challenge is too broad, or too hard, the agents will learn little or nothing and may not survive the challenge.

Objectives

A major objective of the WP is to *build* the software environment in which the agents operate and learn to survive in the face of the challenges.

Another important objective will be to *define* suitable challenges. Given that the aim is to create a society of agents, it is essential that the challenges are 'social' ones, and it would be helpful if the challenges were analogous to problems that human societies have faced and overcome.

The third objective is to *formalize* the notion of challenge and understand better what makes a challenge easy or hard, and the relationship of the challenge to the culture and structure of the agent society that develops.

The fourth objective is to *compare* the solutions found by the society of agents to the solutions found by human societies facing analogous challenges.

Details

The agents' environment

The planned environment is based loosely on the Sugarscape model of Epstein and Axtell (1996), but extends it in a number of key ways in order that the full complexity of behaviour we wish to observe can develop through individual, social and evolutionary learning. Genetically specified *Agents* exist in this environment, and their broad challenge (or rather that of their genes) is to survive.

The environment allows agents to move in a two dimensional virtual world in which (many hundreds of) *places* exist. Some of these places are linked by *roads*, which have varying quality. The ease of travel between places depends on the distance between them, the quality of the road linking them and what they are carrying.

Agents have *energy* which they use up by their activities (moving, communicating etc.) or just by being alive. Agents that run out of energy die.

Agents need to eat food in order to produce energy for survival. There are a number of food types. These food types grow at various places in the environment but their availability is seasonal, and this seasonality differs according to the place. Food starts to decay as soon as it is moved from its origin. As food decays its energy value decreases, and can eventually have a negative effect on energy if eaten. Different agents require different amounts of each food type. Agents can carry limited amounts of food around with them, but this does not stop it perishing. It is cheaper to move food to a number of agents than for all the agents to move to the food.

Other objects known as *tokens* can be found at certain places. These have no natural value. There are several token types, with varying rarity. The purpose of these tokens is not defined, although their use by agents as currency or other grounded symbolism might develop.

Agents can sense their environment. All agents can sense objects at the same place as them; some agents can sense objects in further away places. All objects (places, food, tokens, roads and agents) have sensible features; in the case of agents these features are genetically controlled. There are a large number of sensible features, and similar objects have similar but distinct features. Some features change over time.

Agents can affect their environment in three ways, assuming they have enough energy. They can move food from place to place, they can become road builders/improvers, and they can become farmers. Agents can also perform the following actions, assuming they have enough energy:

- Eat food
- Move from one place to another (with their food and tokens)
- Take/put food or tokens from/at a place
- Give/receive food or tokens to/from another agent at the same place.
- Send a message to an agent located within a certain distance
- Broadcast/receive a message to/from all agents located within a certain distance
- Breed with another agent at the same place as them.

The features of the environment described above are such as to allow and encourage:

- Cooperation (to make tasks more efficient)
- Planning (building, farming, fostering goodwill and trust)
- Trade (when an agent has the wrong food type)
- Language development (in order to achieve all the above). In particular the sensible features are designed in order to allow linguistic categories, e.g. Nouns – "Road", Adjectives – "Round and Hairy" and Verbs – "Growing"

The environment can be parameterised in a number of key ways in order to adjust the challenges facing the agents. For example:

- Food might be abundant or in short supply
- Food might be uniformly distributed or concentrated in certain areas
- Food growth might be uniform or depend on the amount of food left untouched at the place
- Food growth might include a random element
- Places might be uniformly distributed or clustered
- Roads might be uniformly distributed or clustered
- Sensible features of places might be few (most places look the same), or widespread (most places look different)
- Sensible features of agents might be few (most agents look the same), or widespread (most agents look different)
- Communication might be possible over smaller or larger distances

The parameters of a given simulation might be constant or might change suddenly.

Challenges

By changing the parameters of the agent's environment, the challenges facing the agents can adjusted. The following example challenges have been selected as *a priori* interesting and useful. They are all drawn from sociological and anthropological studies of human societies. The first two will be the main focus of the project. Challenges three and four will constitute an evaluation set to which the agents will be exposed towards the end of the project, to see whether they can master novel situations.

As understanding of the idea of challenges improves, the list may be altered and extended. At the end of the project, the challenges will be publicised in the form of a competition for other research groups to design agents that can survive in the face of the challenges. This has the potential for inspiring significant international advances (compare for example the effect of the Robocup competition http://www.robocup.org on the design of embodied agents capable of teamwork).

In the descriptions below, the human system is first summarized, the challenge stated in terms of the environment parameters, and the observable outcome that might be expected is specified.

Development challenges

1. The Kula Ring

A complex system of visits and exchanges among the Trobriand Islanders of the western Pacific first described by Bronislaw Malinowski in 1922. Necklaces were exchanged in one direction among the residents of a chain of islands and armbands exchanged in the opposite direction (hence the notion of a ring). These exchanges did not primarily serve an economic function but created social obligations among peoples which could be depended upon at various times in an individual's life. The person who gave the most gifts would create the most obligations and in this sense create the most wealth by forming a relational net which could be depended upon.

The challenge parameters:

Food is distributed in spatial patches and the amount of food in a patch varies over time. The overall quantity is more than enough to feed the population, but there may be short-term local shortages. Food is perishable and so agents need to find and consume a constant supply of food in order to survive. Food needs long term cultivation for it to grow.

Expected outcome:

The establishment of a 'gift-exchange' system in which not only food but also tokens are exchanged.

2. Herders in a semi-arid area

Nomadic herding is another human solution for dealing with variable and uncertain shortages. Herders and their cattle move to where food is available, leaving exhausted areas until the grass has re-grown. This requires herders to find ways of managing common pool resources (the grass) so that no individual herder overgrazes the grass. The human solution involves well developed status hierarchies and no private property.

The challenge parameters:

Food is randomly distributed with the mean level of food just sufficient to support the population. The rate of food growth randomly varies over time. Food is perishable. Some food must be left uneaten on each patch since subsequent growth is proportional to amount of food left uneaten.

Expected outcome:

Agents leave uneaten food when they move away, even if they leave hungry.

Evaluation challenges

3. Central place theory

Walter Christaller developed the Central Place theory in 1933 to explain the size and spacing of cities that specialize in selling goods and services.

The theory consists of two basic concepts:

- threshold -- the minimum market needed to bring a firm or city selling goods and services into existence and to keep it in business
- range -- the average maximum distance people will travel to purchase goods and services

The theory predicts that settlement size will follow the rank size rule. It works well for human settlements.

The challenge parameters:

The distribution of types of food is such that agents need to trade food with other agents. The food types vary in their transportability. Agents can move to find the best location to maximise their income from trade.

Expected outcome:

Agents settle into spatial clusters separated by relatively empty areas. The size of the clusters is power law distributed.

4. Branding

When producers produce and consumers consume complex goods (i.e. ones with a large number of distinct attributes), and there are a large number of producers and consumers, search problems occur. Producers find it hard to locate consumers that desire goods having the precise set of attributes that a producer is selling, and consumers find it hard to identify producers with the desired goods. One 'solution' to the problems each side face is for producers to brand their range of goods (targeting them at a subset of consumers) and for consumers to use the brand as the major preference criterion. Similar processes may help to account for prejudice and discrimination among human populations.

The challenge parameters:

Agents have characteristic sensible attributes ('tags'). Agents seek to locate other agents with a similar or identical set of tags (through movement and communication), but this search is expensive. Agents are able to create additional tags (the brand) by collecting tokens and carrying them around.

Expected outcome:

Agents either generate one additional tag or specially distinguish an existing tag and this becomes a linguistic category that labels agents and leads to differences in behaviour towards those agents that are labelled and those that are not.

Workpackage name	Environments and Challenges							
Workpackage number	1		**Start date or starting event:**		1			
Participant id		4	3					
Person-months per participant:		12	9					

Objectives

To *build* the software environment in which the agents operate and learning to survive in the face of the challenges.

To *define* suitable challenges. Given that the aim is to create a society of agents, it is essential that the challenges are 'social' ones, and it would be helpful if the challenges were analogous to problems that human societies have faced and overcome.

To *formalize* the notion of challenge and understand better what makes a challenge easy or hard, and the relationship of the challenge to the culture and structure of the agent society that develops.

To *compare* the solutions found by the society of agents to the solutions found by human societies facing analogous challenges.

Description of work

The work will consist of three sequential tasks:

Task 1.1 Implement an environment suitable for setting up the challenges

Software for the environment that is capable of being distributed over the P2P infrastructure provided by WP5 and that provides the following environmental features will be designed, constructed and tested:

- c. 1000 virtual locations (places) linked by
- roads of varying quality
- several types of food object, located at places with varying availability (growth and decay)
- tokens with different attributes and in different locations

The characteristics and quantities of these objects will be adjustable. A set of graphical interfaces will be created in order to visualise this environment for the benefit of the experimenters.

Task 1.2 Formalise the challenges and set up the environment (by adjusting parameters) to represent them

Challenges 1 and 2 will be formalised in terms of the environmental objects devised in task 1.1 and the environmental parameters (e.g. the number of food types and their rates of growth and decay) will be set to establish the challenges in the environment.

Later, the same will be done for challenges 3 and 4.

Task 1.3 Compare the solutions found by the agents with the solutions found by human societies.

WP 3 will generate data about the way in which the agents have adjusted to the challenges. This will be compared with data from human societies (in the case of challenges 1 and 2, from studies of relatively simple societies by anthropologists; in the case of challenges 3 and 4, from studies of urbanised societies by geographers and sociologists).

Deliverables
D1.1 (Month 18) Implementation of the environment and two challenges (software code + documentation)
D1.2 (Month 36) Review of work and comparison with human societies (research report)

Milestones and expected result
M1.1 (Month 6) Agreement on challenges, summarised in interim specification document
M1.2 (Month 12) First implementation of environment
M1.3 (Month 33) Implementation of challenges 3 and 4

7.6.2 Agents and Learning Workpackage Description

Background

Workpackage 1 is concerned with the environment the agents operate in. Workpackage 2 is about the agents themselves. We consider a set of agents suitable for our project if they have the necessary basic features to operate in the environment and the learning abilities to empower the emergence of world views.

Our agents possess "physical" (e.g., memory size, maximum lifetime, fertility rate) and "mental" features that determine their behaviour. Mental features can be carried by (parameterised) decision procedures, represented in a symbolic, neural, or any other appropriate form. Mental parameters can be part of the agents' genetic makeup that does not change during lifetime, e.g., an agent's tendency to seek mates, that can be used as a parameter within the decision procedure selecting the next action. Alternatively a parameter can be part of the agents' mental state that is changing in time, e.g., the weights of a neural net classifying other agents as friends or enemies. **Individual or lifetime learning** is performed by the agents independently, although possibly involving other agents. When an agent encounters a situation it does not only (re)act, but also processes the data corresponding to the situation including its own (re)action in order to improve its performance in similar situations in the future. The acquired knowledge –improved skill– will become part of the agent's "personality": it will have an impact on its behaviour. From the knowledge transfer point of view, the learning agent is a sink. Individually learned knowledge remains with the agent that acquired it, it is not passed to its offspring and in the absence of social learning it is not transferred to other fellow agents either. Physical and mental attributes that belong to the individuals' genome are inheritable. These attributes also influence the agents' behaviour but do not change during its lifetime in a non-Lamarckian system. They undergo variation (mutation and recombination) and selection, hence they are subject to **evolutionary learning**. The learned knowledge here is in the form of superior values and value combinations for the given genes. Learning takes place at population level, good genomes are contained in well-performing individuals that obtain more offspring thus changing the allele distribution. Knowledge is transferred *vertically* here, down along the line of successive generations. **Social learning** is approached from a new angle in our proposal. We interpret social learning as sharing the knowledge that inhabitants learn individually by explicitly "telling" it to each other, thereby collectively developing knowledge that covers different situations they are encountering. This amounts to *horizontal* knowledge transfer. From a machine learning perspective we see individuals as collecting data from a given situation and learning from these data. Thereafter they share the knowledge (model) they generate, but not the detailed description (data) belonging to the learning situation.

Objectives

The main objectives of this WP are:

To give a full specification of the agents and to implement the agents according to this specification.

To specify which individual, evolutionary, and learning mechanisms will be used and to implement all these mechanisms in order to achieve a fully working system ready for experimentation.

To perform an experimental exploration and theoretical analysis of the relationship between the three types of learning.

To provide the primary list of knowledge bits that form the components of world models and ultimately that of culture.

Details

The main challenges of this WP are to define the "right" agents and to develop learning mechanisms that are "powerful" enough to generate non-trivial development, i.e., lead to the emergence of interesting world views.

A balance between hard-wired and emergent agent properties will have to be found. Concerning individual and evolutionary learning, we intend to use existing mechanisms adjusted to our purposes and the structure of the agents. However, this does not mean that the application of these two features will be trivial. The ways to combine them and their mutual effects will have to be investigated, since the existing literature is far from being unanimous about this issue. For instance, some studies suggest that learning is first selected for, and then selected against as evolution progresses (Mayley 1996), or that even if the changes caused by Baldwinian learning are large then a learning-evolutionary hybrid might be inferior to evolution alone (Ku, Mak, and Siu 2003). On the other hand, some authors report that evolutionary progress concerning a given task might benefit from learning on a different task that does not even have to be correlated (Parisi, Nolfi and Cecconi 1992, Harvey 1997). In general, the advantage of combining learning mechanisms is well supported and it has been proposed that for adaptive agents in an artificial ecosystem the Baldwin effect is beneficial because it allows agents to stay longer in the ecosystem (Ackley and Littman 1992). This can be nicely connected to our idea of social learning that can exploit "old-and-wise" agents in the population.

The social learning mechanism will be one of the main research subjects and innovations. Our approach to this feature is different from that of, for example, Conte and Paolucci (2001) in that we will use techniques to pass knowledge explicitly via direct messages to others within the same generation. Viewing a population as a collection of entities that process data and execute some machine learning algorithms to generate models matching these data, our social learning mechanism amounts to distributed data mining, where the mining algorithm belongs to our individual learning procedure. The way the learned models are disseminated is a crucial parameter of the total mechanism. We will study this aspect intensively, developing and evaluating different solutions for a general communication protocol for information dissemination. We will consider various schemes, for instance one-to-one communication, broadcasting systems, and the so-called 'newscast' model of computing. The latter, developed by the DREAM project, amounts to maintaining a dynamic network of "friends", sending all news to these friends only, and updating the list of friends regularly. The resulting p2p epidemic protocol is extremely scaleable and robust for adding or removing agents – two features that are of pre-eminent importance for our application. It is also very adaptive, adjusting to new information rapidly. Distributed data mining methods using this protocol have proved to be highly effective (Kowalczyk, Jelasity, and Eiben 2003). Within this workpackage we shall develop and compare generalisations of distributed data mining procedures to be applied for knowledge sharing in an artificial society.

The fact that three different learning mechanisms are applied in concert implies an additional challenge. Tuning their combination requires an understanding of the mutual effects of the *three* types of learning on each other and on the development of the individuals and the whole population. The experiences with two of them (individual and evolutionary learning) will serve as a stepping-stone in developing this understanding and in implementing mechanisms for adjusting the balance between them.

All the knowledge, world models, and culture we are seeking resides in the agents – in single agents or in a group of agents collectively. This workpackage therefore lays the foundation for investigating their emergence, and provides the starting point for WP4.

Workpackage name	Agents and learning						
Workpackage number	2	**Start date or starting event:**	1				
Participant id	1	2	3	4	5		
Person-months per participant:	12	12	6	9	6		

Objectives

The main objectives of this WP are:

1. To give a full specification of the agents and to implement the agents according to this specification.
2. To specify which individual, evolutionary, and learning mechanisms will be used and to implement all these mechanisms in order to achieve a fully working system ready for experimentation.
3. To perform an experimental exploration of the relationship between the three types of learning.
4. To provide the primary list of knowledge bits that form the components of world models and ultimately that of culture.

Description of work

The work will be divided into the following tasks.

Task 2.1 Define and implement the agents appropriate to meet the challenges as given by WP1 and identify the components of world models in them.

Task 2.2 Define and implement appropriate individual learning procedures, evolutionary mechanisms and possibly interconnect them into a Lamarckian evolution mechanism.

Task 2.3 Define and implement a number of social learning mechanisms allowing the exchange of information (knowledge) among agents and identify research issues.

Task 2.4 Execute an experimental study on the combined effects of various learning mechanisms and provide recommendations for an "optimal" set-up, or (more realistically) multiple set-ups "optimised' for different preferences.

Deliverables

D2.1 (Month 18) Implementation of agents and learning mechanisms (software code + documentation)

D2.2 (Month 30) Research report on the interactions among our three types of learning.

Milestones and expected result

M2.1 (Month 6) Agreement on agent architecture and learning mechanisms, summarised in interim specification document

M2.2 (Month 10) Agreement on the "knowledge" bits of agents and groups of agents that form the components of world models, summarised in interim specification document. Cf. also M4.1

7.6.3 Language, Communication and Co-operation Workpackage Description

Background

A social community such as intended in this project is heavily dependent on communication and cooperation. The challenges that will be set in WP 1 are such that they rely on cooperation and they cannot be achieved without using communication. As the agents develop knowledge based on their own interactions with the environment, their experiences differ from each other. Hence, communicating knowledge requires a communication language. This language will develop during the evolution of the experiment, such that it aids optimising cooperation. To achieve this in the environment of WP 1, the agents have to solve the symbol grounding problem.

Objective

The main objective of this workpackage is to design a population such that it is capable of evolving one (or possibly more) languages that enables them to optimise cooperation. A secondary objective is to design the experiment such that the agents will discover communication as a useful strategy and find ways to use this strategy effectively.

Details

To achieve these objectives, we have to design agents that are capable of doing, at least, three things: (1) evolve a language, (2) learn to use communication, and (3) learn to react properly such that cooperation emerges.

***1. Evolve a language*.**

It has been repeatedly shown in computer simulations and robotic experiments that aspects of language can evolve through self-organisation by a group of agents who interact with each other, and who invent and adopt aspects of the language such as words, meanings and grammatical rules, see, e.g., (Briscoe 2002; Cangelosi & Parisi 2001, Kirby 2002, Steels 1997) for overviews.

Following the models outlined by Steels (2003) and Vogt (2003a), meanings will be grounded from the interaction of the agents with their environment by (1) detecting features about the events they are experiencing, (2) categorising these, and (3) associating the categories with existing or newly invented words. The features agents can detect relate to the features of objects and actions. These features are categorised into categories stored in the agents' memories, or into newly constructed categories in case of failure, thus expanding their memories. This way, agents develop their own private repertoire of categories used to form the meanings of the language.

The categories are to be associated with words and become meaningful in the way they are used by the population. If the categories are novel to agents who wish to communicate, the agents can invent new words. Sharing is done by communication and learning from each other. It has been shown in Vogt and Coumans (2003) that learning is most efficient if learners learn a language from experienced language users, as modelled by the iterated learning model (Kirby & Hurford 2001). Therefore our population will consist of adult agents and learners.

Largely unexplored in language grounding is the emergence of grammatical structures. The core innovation of the language evolution model we intend to implement relates to the emergence of compositional structures in a grammar that is grounded. This part will be largely based on studies investigating the origins of syntactic structures with predefined semantics (e.g., Brighton 2003, Kirby 2001) and a recent prototype on grounding compositional structures (Vogt 2003b).

One of the main issues will be scaling the existing models. It is expected that this will be partly solved by the distributed nature of the environment and the spatial organisation of the agents themselves. This will cause the agents to communicate locally, thus evolving local languages or dialects. The more agents will spread out, the more the languages will distribute over the population, and possibly put pressure on the need to converge into one shared language. This will be tricky though, because if the agents spread too fast, convergence will be hard as the flux of agents becomes too large (Steels et al. 2002).

The evolution of language will basically be regarded as a cultural evolution (cf. Christiansen and Kirby 2003). Some mechanisms, such as learning or feature selection could be subject to genetic evolution. Learning at all levels (meaning, words and grammar) will be based on the examples generated and/or observed by the population itself and will be guided by the task-environment at hand and the effectiveness of achieving the tasks through cooperation (if relevant).

2. Learn to use communication

Although the agents are given the means to engage in communicative interactions, they are not given the language (see above), nor are they given the knowledge to decide when or what to communicate. As a part of the way agents learn/evolve to select proper actions, the agents learn/evolve when to select communication as the proper action. Although simulating the evolution of communication has been studied elsewhere (e.g., Di Paolo 1998, Noble et al. 2001), these studies usually relate to communication as such, but tend not to investigate language as the subject of evolution. Our project combines them both. In addition, the agents will have to learn what aspects of events are useful to communicate. We will investigate how the agents can learn what is relevant to communicate. A possible candidate is learning by trial and error in a similar way the language itself is learnt. Alternatively, agents could have a bias to communicate about what is in their current focus of attention. If agents who share joint activities such as foraging meet, this would help to settle joint attention, which is very useful in language acquisition (Vogt and Coumans 2003). This issue is an extremely hard problem relevant to solve the symbol grounding problem.

3. Learning to react properly on communication

The communication will be used to transmit knowledge and to elicit behaviour of other agents. For instance, when one agent has found a food source, it may want to describe the nature of the food source (i.e. the knowledge what food it is), but in addition, it may want to elicit the other agent to ‘go and get it’ or it may want the other agent to ‘buy it’. Depending on what the first agent says, the second agent should react properly. The effect can be measured directly if both agents end up happy, i.e., their current needs are fulfilled. This effect serves as feedback for learning the proper reaction, but in addition may serve as a feedback to the language use of one or both agents. Such feedback, however, may arrive with a certain delay, for instance after the food has been retrieved. Such feedback may serve as a form of (delayed) joint attention, aiding the population to evolve a shared language (Vogt and Coumans 2003).

Workpackage name	Language, Communication, and Co-operation						
Workpackage number	3	**Start date or starting event:**	4				
Participant id	5	1					
Person-months per participant:	21	6					

Objectives

The main objective of this WP is to design a population such that it is capable of evolving one (or possibly more) languages that enables them to optimise cooperation.

Description of work

The work will be divided into the following tasks.

Task 3.1 Define, in close cooperation with task 2.1, the required set-up for evolving language, learning how to use communication and how to react properly on linguistic communication (as discussed above).

Task 3.2 Implement the code for under 3.1 defined specifications and integrating the results achieved in tasks 2.2 and 2.3.

Task 3.3 Perform experiments with the system as implemented in task 3.2.

Task 3.4 Report on the experiments performed.

Deliverables

D3.1 (Month 21) Implementation of language evolution and communication functions (code + documentation)

D3.2 (Month 36) Research report on the evolution of language, communication and cooperation.

Milestones and expected result

M3.1 (Month 11) Agreement on the set-up required for evolving language, learning how to use communication and how to react properly on linguistic communication, summarised in interim report.

M3.2 (Month 26) Point at which the language evolution part is integrated in the entire project, so that the real experiments can start.

7.6.4 Emerging World Models and Culture Workpackage Description

Background

The first scientific objective of this project is "To develop an artificial society with an emergent culture". Being able to recognize this culture when it emerges is therefore essential to the success of the project. This is not a trivial task, since "cultured" behaviour may not show itself explicitly on the surface.

For example, our population may develop a "tradition" that a certain exchange of phrases, followed by the giving of a otherwise worthless gift, can be taken as a promise of food during the next season. Recognising something like this when it occurs within the vast sea of data that can be collected requires the use of existing specialised machine learning techniques and the development of some new ones.

This workpackage is concerned with the recognition of language, culture and social structures when they emerge within our simulated world. In order to do this, the first task will be to more clearly define what we mean by these terms within the context of this project. But it will suffice here to say that what all of these have in common is that they are represented by a view of the world which is, at least in part, *shared* by large numbers of agents. In this respect, this workpackage is concerned with recognising *shared world views*.

Our goals are to *discover* and *recognize* shared world views by controlling the environmental parameters. That is, we shall do *data mining, noise filtering, and goal-oriented control.* To avoid any confusion, we shall talk about *machine learning* if learning, adaptive filtering of data, adaptive control, etc., is accomplished by a computer algorithm.

Objectives

The first objective of this workpackage is to more clearly define the categories of "shared world views" (language, culture, social structure etc) which we hope to observe.

The second objective of this workpackage is to develop methods that allow us to discover and recognise shared world views if they emerge.

Details

To achieve the objectives of this workpackage the following tasks have to be performed:

Identification of relevant emergent entities

We shall identify the system components that carry the knowledge structures that make up the agents' world models and that are the building blocks of the social-structure. We shall review existing theoretical ideas about emergence in agent-based systems, and relate these to concepts from the social sciences. Emergence has two flavours, a temporal flavour and a structural flavour. Emergence is local both in time and in the space of possible structures. At the same time, a structure that has emerged has two-faceted features like stability and plasticity over time. Related ideas have been developed in information theory (Kolmogorov complexity), artificial neural networks (learning to maximize information transfer (Bell and Sejnowski, 1995, Amari, 1998, Hyvarinen, 1999, Lee and Seung, 1999, Lee and Seung, 2001), extraction of hidden variables (Jordan, 1999)), and physics (self-organizing systems (Olemskoi, 2002), scale-free worlds (Kleinberg and Lawrence, 2001, Albert and Barabási, 2002)). These terms will be embedded into social sciences.

It is important to note that the identification of relevant emergent entities is an ongoing activity. An initial list of such entities can be made before setting up the inspection toolkit (see below), but the experiments will certainly deliver new insights and motivate adjustments of this list.

Specification of inspection methods

We shall review and select from available tools a software suite for data-mining the descriptive data generated from the simulated world. Machine learning techniques, especially those that deal with data mining, prediction, control and goal oriented control will be reviewed and the description of their capabilities will be aligned with the list of features to be monitored from the previous task. Requirements will be collected and iterated and an appropriate collection of methods (algorithms) will be established.

Implementation of inspection methods

We shall design and implement software that will automatically (or semi-automatically) locate and quantify emergent phenomena from the simulation data. Software components that robustly recognize structures, filter noise, can complete patterns, and predict will be included into the software to allow time-saving data analysis. Automated system interrogation tools will be included to search for efficient environmental parameters that promote or inhibit the development of particular social structures.

Discovery of emerging world views

Using the achievements and insights of all other WPs and the inspection toolkit we shall monitor the development of our artificial societies to establish what culture emerges and how it emerges. After termination we will probe the society, inspect the knowledge that emerged in individual agents and detect shared knowledge structures (culture) in groups of agents.

Workpackage name	Emerging world models and culture							
Workpackage number	4	**Start date or starting event:**		9				
Participant id		2	1	4				
Person-months per participant:		12	9	6				

Objectives

1. To more clearly define the categories of "shared world views" (language, culture, social structure etc) which we hope to observe.
2. To develop methods that allow us to discover and recognise shared world views if they emerge.
3. To perform research on such emerging phenomena.

Description of work

The work will be divided into the following tasks

Task 4.1 Identification of relevant emergent entities

Task 4.2 Specification of inspection methods

Task 4.3 Implementation of inspection methods

Task 4.4 Experimental and theoretical study of emergent world models and cultures

Deliverables

D4.1 (Month 24) Implementation of inspection methods (code + documentation)

D4.2 (Month 36) Report on emergent world views and cultures in artificial societies

Milestones and expected result

M4.1 (Month 10) Agreement on relevant emergent entities, summarised in interim report. Cf. also M2.2.

M4.2 (Month 16) Agreement on relevant inspection methods, summarised in interim report

7.6.5 Peer-to-Peer Infrastructure Workpackage Description

Background
This project seeks to work with a simulated agent environment that is beyond the state-of-the-art in terms of the complexity of its agents coupled with the size of their virtual world. The consortium wishes to conduct some very large experiments in which there is the possibility for niches, subcultures and dialects to emerge in separate parts of the environment, and compete and interact with each other. It is clear that such experiments will benefit greatly from increased computing power.

While it would be possible to use specialised parallel hardware to run some of the required experiments, the consortium has decided instead to utilise the power of several ordinary machines connected together over the Internet in a peer-to-peer fashion. Machines assigned specifically for the experiments can then provide the core processing power, but in addition, the spare computing power of many other additional machines can also be utilised.

This approach has a number of advantages:

- The use of expensive specialised parallel hardware is not required
- Extra machines can simply be added to the system to increase the processing power (with some communication limits based on the environment topology)
- Some extremely large experiments can be carried out using the spare computing power of a very large number of machines.

This project is in a special position to be able to make use of these advantages, as the experiments that will be run are asynchronous, and will usually be tolerant to unexpected changes in the hardware (e.g. a machine gets switched off, or its spare capacity drops sharply). In addition, most large experiments will involve worlds that are "clumpy" topologically and so are ideally suited to distribution over a number of computers.

This workpackage involves the development of a foundation layer of software that will allow the simulated worlds to be run on anything from a single machine to many hundreds of machines as necessary.

Objectives
The primary objective is to provide the peer-to-peer infrastructure necessary to support the extraordinarily large systems of complex agents required of this project. A second objective is to provide on-site training and electronic support for the software infrastructure to partners in the project, and to maintain the software throughout the life of the project.

Details
It is the expectation of the consortium to use the Distributed Resource Machine (DRM) developed as part of the Distributed Resource Evolutionary Algorithm Machine (DREAM) Framework 5 project (IST-1999-12679), as the basis for the peer-to-peer system (see Paechter, Bäck, Schoenauer, Eiben, A, Merelo, and Sebag 2000 and Arenas, Collet, Eiben, Jelasity, Merelo, Paechter, Preuß, and Schoenauer 2002). The DRM system is a fully distributed (serverless), peer-to-peer system which was designed for exactly this type of application (see Jelasity and Preuß 2002, Jelasity Preuß and Eiben 2002, Jelasity and van Steen 2002, Jelasity, Preuß and Paechter 2002a and 2002b). Two of the consortium partners have experience developing this system. However, the workpackage will commence with a survey of the peer-to-peer technologies available, in order to ensure that the most fitting technology is used.

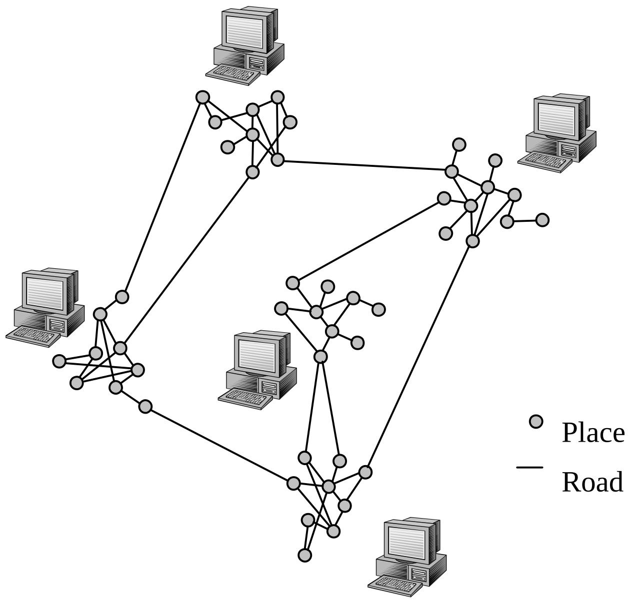
As part of running the virtual environments, it is required that the peer-to-peer system should automatically split the simulated world into "islands" for distribution across machines. This must be done in such a way as to reduce the expected communication between machines. It is expected that in many experiments the virtual world will fall naturally into islands (clumps of interconnected places with few connections with other clumps). The algorithm for deciding the distribution will take into account the total processing power required and available, as well as the virtual world topology.

As a first step, software to run the simulated environment on single machine will be provided, as a contingency, and in order that the work can continue before the completion of this WP.

Training will be provided in the use of the software. This will involve the production of paper and web-based training materials, as well as visiting each of the partners to provide on-site training. Electronic and telephone support will also be provided.

The software will be maintained throughout the life of the project, with regular new releases, fixing bugs and adding new features as required.

Figure 1 – Possibly Efficient Distribution of Simulated World



Workpackage name	Peer-to-peer Infrastructure						
Workpackage number	5	**Start date or starting event:**		1			
Participant id		3	1				
Person-months per participant:		12	9				

Objectives

- To provide the peer-to-peer infrastructure necessary to support the extraordinarily large systems of complex agents required of this project.
- To provide on-site training and electronic support for the software infrastructure to partners in the project, and to maintain the software throughout the life of the project.

Description of work

Task 5.1 Survey the available peer-to-peer technologies

Task 5.2 Produce single machine foundation software

Task 5.3 Specify distribution algorithms

Task 5.4 Produce peer-to-peer foundation software

Task 5.5 Produce training materials

Deliverables

D5.1 (Month 11) Peer-to-peer foundation software (code + documentation)

Milestones and expected result

M5.1 (Month 5) Decision on the underlying technology to use, summarised in interim report

M5.2 (Month 6) Definition of the interface with the simulated environment of WP1

M5.3 (Month 12) Definition of the algorithm for distributing the simulated environment

7.6.6 Integration and Evaluation Workpackage Description

Background

Different partners will develop the software components of Workpackages 1 to 5. This developmental process needs to be efficiently integrated, and it is essential for smooth integration that the interfaces between the software modules are properly specified in advance. This workpackage includes the inter-module (and hence inter-workpackage) tasks that are required to ensure good module interfaces. In order to achieve this we adopt appropriate parts of the IEEE Standard 1058.1-1987 for Software Project Management Plans.

In addition, this workpackage will monitor the integration of the research, and continuously evaluate the progress the project has made towards the objectives described in section 2, using techniques of formative evaluation.

Objectives

The first objective of this workpackage is to specify, and produce if necessary, include the tools required to ensure reliable technical integration.

The second objective is to achieve conceptual integration, ensuring that all partners share a common view and awareness on the project and its components.

The third objective is to provide reliable feedback to partners and the Commission on the current and predicted progress of the project when measured against its objectives.

Details

Determine and produce tools of integration

a) Determine tools of software integration, such as coding standards, interfaces between software components, the methods of documentation and those of quality assurance.
b) Specify software components, test cases for modules, and test cases for integrated components.
c) Specify version control methods.

Create and maintain conceptual integration

a) Create and maintain awareness of all project components at all partners.
b) Cross educate partners in relevant disciplines that are specialties of other partners.
c) Develop a common framework (including, e.g., common vocabulary) to describe the total project span and to facilitate cross-fertilisation of ideas.

Continuously measure the progress the project is making towards its objectives

a) Evaluate the progress of the project as a whole and broken down to its (sub-)objectives. Apply contingency measures if needed as discussed in section 5.2.
b) Evaluate the progress of individual workpackages, against their objectives, milestones, and deliverables.
c) Monitor the state-of-the-art of the technologies, theories and practices involved in the project, and make recommendations to the management committee of changes that might be necessary to take account of advances.

Workpackage name	Integration and Evaluation							
Workpackage number	6		**Start date or starting event:**			1		
Participant id		1	2	3	4	5		
Person-months per participant:		18	6	3	3	3		

Objectives

- To specify, and produce if necessary, include the tools required to ensure reliable integration.
- To provide reliable feedback to partners and the Commission on the current and predicted progress of the project when measured against its objectives.

Description of work

The work will be divided into the following tasks
Task 6.1 Determine and produce tools of integration
Task 6.2 Create and maintain conceptual integration
Task 6.3 Continuously measure the progress the project is making towards its objectives

Deliverables

D6.1 (Month 12) Software Interface Specifications and Test Software
D6.2 (Month 36) Final Evaluation Report

Milestones and expected result

M6.1 (Month 4) Agreement on tools and version control methods, summarised in interim report

7.6.7 Dissemination and Exploitation Workpackage Description

Background

As every research project, the results of the NEW TIES project have to be disseminated and exploited. We intend to seek exposure via the Internet and (popular) scientific publications and special tracks we organise on conferences about our subject. We will distribute our code through the Internet as a platform that can be used as a test bed for other researchers and we plan to organise a special workshop where we intend to invite leading experts, industrial research groups and (European) research projects.

Objective

The objectives of this workpackage are to distribute the knowledge acquired in this project, to provide other researchers with a working research platform, and to actively seek industry cooperation for further developments.

Details

1. Publish scientific articles in a number of leading journals, conferences and more popular scientific oriented media.
2. Build and maintain a project Web-site providing all available information, free code, challenges and relevant publications. We will put special effort into “marketing” to popular-scientific forums. Ideally we can build a virtual community for users, including students, fellow researchers and interested laypeople.
3. Challenge other scientists to design better populations and provide a test bed for such a challenge. The objective of the challenge(s) will be to allow scientists to compare different models on one platform, which is similar to the objective of the Robocup challenge.
4. Release the research platform and open the source code, such that we provide a platform for other researchers to test agent populations of their own design. This is expected to have an important impact by facilitating a “kick-start” for novices to enter this research area. Therefore, significant effort is allocated to this activity and we are to release the beta version early and seek fedback from a group of enthusiastic early adopters.
5. Organise a demonstration event (workshop, summer school, or alike) for a scientific and industrial audience to investigate how we can further exploit our results. This workshop should disseminate the main results of our project and relate it to advances made by other researchers. The primary goal, however, is to set out directions to be taken to further advance the science and technology of this project. To this end industry involvement is essential.
6. Edit a special journal issue and special tracks during conferences that cover (aspects of) the challenges we set. This allows us to further disseminate our results and attract other scientists to join in on our efforts.
7. Organise tutorials during summer schools and/or conferences. This, too, allows us to disseminate the results and attract other scientists to join in on our efforts.
8. Actively seek contact with larger European initiatives, such as networks of excellence and integrated projects in relevant areas, e.g. Exystence, AgentLink III, and ECAgents, ISCOM, PACE, and others as they become known to us.
9. Maintain the Plan for using and disseminating knowledge. The initial version of this plan is formed by the relevant parts of Annex I.

Workpackage name	Dissemination and Exploitation						
Workpackage number	7	**Start date or starting event:**	7				
Participant id	1	2	3	4	5		
Person-months per participant	18	6	6	6	6		

Objectives

The objectives of this workpackage are to distribute the knowledge acquired in this project, to provide other researchers with a working research platform, and to actively seek industry cooperation for further developments.

Description of work

Task 7.1 Publish scientific articles

Task 7.2 Build and maintain a project Web-site

Task 7.3 Challenge other scientists and provide facilities for reproducible and comparable experiments.

Task 7.4 Release the research platform, open the source code, and provide training material (cf. task 7.3) .

Task 7.5 Organise a workshop for demonstration and publicity purposes

Task 7.6 Edit a special journal issue and special tracks during conferences.

Task 7.7 Organise tutorials during summer schools or conferences on the subject of ‘artificial societies’.

Task 7.8 Actively seek contact with larger European initiatives.

Task 7.9 Maintain the Plan for using and disseminating knowledge

Deliverables

D7.1 (Month 22) Downloadable package of the research platform (code on the Web-site) and corresponding on-line training material

D7.2 (Month 36) Final plan for using and disseminating knowledge, inlcuding the collection of scientific and popular publications concerning the project

Milestones and expected result

M7.1 (Month 14) First release of the research platform package (beta version on the Web-site)

M7.2 (Month 30) A popular scientific article accepted for publication

M7.3 (Month 33) Demonstration and publicity event

7.6.8 Management and Coordination Workpackage Description

Background
As every research project, NEW TIES requires solid management.

Objective
The main objective of this workpackage is to ensure that the project is carried out according to the plans and the contract with the European Commission.

Details
Management and coordination has three main functions: administrative, executive and technical

The **administrative** project management comprises:

- preparing and distributing non-technical reports (Management Reports, Progress Reports),
- maintaining accurate consolidated records of costs, resources, and time-scales,
- preparing and submitting to the Commission the cost statements of all partners,
- remaining in close contact with the Commission and the Project Officer,
- communicating with other projects and co-ordinating presentations, and
- measuring and reporting the progress of the project in terms of
  - a) the project objectives as outlined in section 2 and
  - b) the key criteria formulated by the Commission

The **executive** project management comprises:

- reviewing project progress,
- ensuring that the project maintains its objectives and relevance within the FET-Open programme,
- resolving any technical, administrative or contractual issues.

The **technical** project management comprises:

- reporting the progress of the project

Specific tasks in this workpackage include:

- to take care of a legal consortium agreement if required,
- interface the consortium with the European Commission via the project officer ,
- to run the (financial) administration,
- monitor progress and act correctively if needed,
- ensure the timely delivery of all necessary documentation.

An important instrument for successful project management is communication. Regular project meetings form the most effective means to this. Besides, meetings always involve periodic progress reports allowing the timely notice of deviations from the planned progress. We also consider team building as part of good management that can help project integration and prevent segregation. To this end a number of instruments will be used, complementing activities under the Integration and Evaluation workpackage:

- A quarterly project Newsletter with a rotating copy editor, made publicly available through the project Web-site, also helping to promote the project worldwide.
- Monthly electronic chat session for the Management Committee, where the chat-log will be only distributed internally.
- Monthly electronic chat session for the Scientific Committee, where the chat-log will be only distributed internally.

Workpackage name	Management and Coordination							
Workpackage number	8	**Start date or starting event:**	1					
Participant id	1							
Person-months per participant	6							

Objectives

The main objective of this workpackage is to ensure that the project is carried out according to the plans and the contract with the European Commission.

Description of work

Specific tasks in this workpackage include:
Task 8.1 take care of a legal consortium agreement if required
Task 8.2 interface the consortium with the European Commission via the project officer,
Task 8.3 coordinate administrative and scientific work,
Task 8.4 monitor progress and act correctively if needed,
Task 8.5 ensure the timely delivery of all necessary documentation (deliverables),
Task 8.6 run the (financial) administration.

Deliverables

D8.1 (Month 36) Full project documentation

Milestones and expected result

M8.1 (Month 3) Project Web-site and information infrastructure (mailing and chat list, workspace, etc.)

M8.2 Periodic progress reports for project meetings and provision of reports as requested by the Commission

M8.3 Chat agendas, logs and decision lists

M8.4 Quarterly newsletters

Literature

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8 Project resources and budget overview

8.1 Efforts for the project (person-months)

Full duration of project

	VUA	ELU	Napier	UniS	UTIL	TOTAL ACTIVITIES
RTD/innovation activities						
Environments and challenges			9	12		21
Agents and Learning	12	12	6	9	6	45
Language, Communication and Co-operation	6				21	27
Emerging world models and culture	9	12		6		27
Peer-to-Peer Infrastructure	9		12			21
Integration and Evaluation	18	6	3	3	3	33
Total research	54	30	30	30	30	174
Demonstration activities						
Dissemination and Exploitation	18	6	6	6	6	42
Total demonstration	18	6	6	6	6	42
Management activities						
Management and Coordination	8					8
Total management	8					8
TOTAL per Participant	80	36	36	36	36	
Overall TOTAL EFFORTS						224

8.2 Overall budget for the project (forms A3.1 & A3.2 from CPFs)

8.3 Management level description of the project

9 Ethical issues

A. Proposers are requested to fill in the following table

Does your proposed research raise sensitive ethical questions related to:	**YES**	**NO**
Human beings		X
Human biological samples		X
Personal data (whether identified by name or not)		X
Genetic information		X
Animals		X

B. Proposers are requested to confirm that the proposed research does not involve:

Research activity aimed at human cloning for reproductive purposes,

Research activity intended to modify the genetic heritage of human beings which could make such changes heritable[15]

Research activity intended to create human embryos solely for the purpose of research or for the purpose of stem cell procurement, including by means of somatic cell nuclear transfer;

Research involving the use of human embryos or embryonic stem cells with the exception of banked or isolated human embryonic stem cells in culture[16]

	YES	**NO**
Confirmation : the proposed research involves none of the issues listed in section B	X	

Further information on ethics requirements and rules are given at the science and ethics website at http://europa.eu.int/comm/research/science-society/ethics/ethics_en.html.

[15] Research relating to cancer treatment of the gonads can be financed

[16] Applicants should note that the Council and the Commission have agreed that detailed implementing provisions concerning research activities involving the use of human embryos and human embryonic stem cells which may be funded under the 6th Framework Programme shall be established by 31 December 2003. The Commission has stated that, during that period and pending establishment of the detailed implementing provisions, it will not propose to fund such research, with the exception of the study of banked or isolated human embryonic stem cells in culture.

10 Other issues

The project touches on a number of important horizontal issues:

1. Ethical issues

The project has no *direct* ethical issues for it does not involve experimentation with human or animal participation - all experiments will be carried out in simulation. However, the sociological inspiration and context (environments and challenges) allow popular – and perhaps incorrect – interpretation of our findings. The management committee will consider such aspects and review them regularly, taking action if necessary.

2. Engagement with the wider community

As noted in section 5 the project has the opportunity (and the responsibility) to inform the wider public of the possible implications of the creation of large-scale communities of autonomous virtual agents. We shall do this through the popular science media, endeavouring to provide a fair and objective view of future scenarios, without encouraging scare-mongering.

3. Privacy and data protection

Privacy issues generated by using p2p computing will be addressed from the beginning with great care. Data from participating institutions and individuals will be handled taking relevant data protection guidelines and regulations into account. The management committee will pay attention to national and international laws and regulations concerning file sharing, communication protocols, and the remote control of computing infrastructure.

4. **Gender issues**

It is regrettable that the proportion of women in the field seems to be decreasing and while we are not in a position to make any major impact on this, we shall do our best to recruit female researchers to the project (we are well aware that all the proposers are male). This we shall do by positively drawing the job opportunities to the attention of suitable female candidates and favouring female applicants to the extent possible within the anti-discrimination laws of the partners' countries and the European Union.

5. **Education**

Some of the senior researchers are teaching related courses on their universities. Exciting outcomes will be naturally included in these lectures. Moreover, smaller research and experimentation tasks from NEW TIES can be used for Master Thesis student projects.

Towards the end of the project, we shall organise a one week *Summer School* on the subject of 'artificial societies' for PhD students and post-doctoral researchers from Europe. From our experience with running summer schools and tutorials in this area over the last few years, we expect there to be considerable interest in the topic and do not anticipate difficulty in attracting at least 30 students. We shall aim to run the Summer School in conjunction with an existing organisation or network to minimise expense and to make it as easy as possible for students to attend.

Following the summer school, we shall make the *syllabus and course notes* available to all from the project web site. This will help educators in European universities incorporate ideas and results from the project in their courses (e.g. graduate level courses on social simulation, agent technologies, information management and the like).

Appendix A

The ambitious project objectives can only be achieved in the required timescale if the project draws on the best talent and expertise available in Europe as a whole. The multi-disciplinary character of the project, involving linguists, computer scientists and social scientists, would make it very difficult to recruit a suitable team from one country alone. Hence it is appropriate that the project should be conceived and carried out at the European level. The actual consortium consists of five partners (including the coordinator) from two EU countries and one new member state. Each of the partners represents an essential competence and all together the consortium is a unique combination of these. A detailed description of each participant is given later in this section.

Project resources are determined according to the targeted objectives. The human resources are customary, one senior researcher and one postdoc at each node, extended with a scientific programmer at the coordinating node. Funding is only required for the postdocs and the scientific programmer. Travel budgets are determined in line with the importance of making and keeping the activities integrated. To this end we need to cover 3 meetings a year for everybody. The equipment budget is determined by the requirements of large-scale p2p experimentation using 10 computers per partner institution. It is our intention to set up a heterogeneous network with racked clusters, LAN and Internet connected groups of PCs to match the variety of infrastructures of possible future roll-outs. Development, deployment, maintenance, and troubleshooting will belong to the core tasks of the scientific programmer. Considering the complexity of such a computer network, our experimental software platform, and the regular overload of local system administrators, such a person is inevitable. Furthermore, the technical side of integration (which is given a prominent place in a separate workpackage) will be an essential task for him/her. We also request subsidy for organising a European workshop centred around our and related subjects to boost dissemination and project impact and to exploit the project results through involving industry. The related budget covers organisation costs, invited speakers, and a number of travel grants. Finally, the consortium has obtained the agreement of Professor Sander van der Leeuw, an anthropologist of international repute, that he will act as an advisor to the project. Our budget contains provisions for his travel and subsistence costs for attending 6 project meetings.

The following table gives an overview of the consortium.

Participant no.	Abbrev.	Name of institution	Name of senior researcher
1	VUA	Vereniging voor Christelijk Wetenschappelijk Onderwijs, Department of Computer Science, Artificial Intelligence Section	Prof.Dr. A.E. Eiben
2	ELU	Eötvös Loránd University, Faculty of Informatics, Department of Information Systems	Prof.Dr. A. Lőrincz
3	Napier	Napier University, School of Computing, Centre for Emergent Computing	B. Paechter
4	UniS	The University of Surrey, School of Human Sciences, Centre for Research on Social Simulation	Prof.Dr. N. Gilbert
5	UTIL	Stichting Katholieke Universiteit Brabant, Computational Linguistics, Induction of Linguistic Knowledge Group	Dr. P. Vogt

A.1 Participants and consortium

Vereniging voor Christelijk Wetenschappelijk Onderwijs, Department of Computer Science, Artificial Intelligence Section

The AI Section (about 25 people) within the CS Department of the VUA has a strong tradition in knowledge-based systems, agent technology, and computational intelligence. The agent group and the computational intelligence group have a joined research track that lies on the intersection of both fields. The NEW TIES project is initiated by the Computational Intelligence Group, headed by Prof.Dr.A.E. Eiben and it lies entirely in this intersection. The CI group (8 persons) has great experience in adaptive techniques, especially evolutionary computing and machine learning and data mining belong to the two major areas. In evolutionary computing it belongs to the leading European groups. Prof. Eiben is editorial board member of all major EC journals (EC, IEEE ToEC, GPEH) and several others in related areas (e.g. Natural Computing). He has experience with European projects since 1995, he is one of the founders and executive board members of the European Network of Excellence on EC, EvoNet.

The main contribution of the group to NEW TIES is the experience in evolutionary computing, p2p computing (the group was one of the participants of the DREAM project), and machine learning, especially distributed data mining, social simulation, communication and cooperation in SugarScape and other artificial worlds.

Eötvös Loránd University, Faculty of Informatics, Department of Information Systems

The Intelligent Systems Group of Professor András Lőrincz is a young group of five years history. The group has 4 staff and 12 PhD students at present. The quality of these students can be illustrated by the three Pro Scientia Golden Medals, awarded in every other year only to 3 or 4 students of Informatics in Hungary (2000 students/year), which are owned by members of the group. The group is engaged in research on machine learning [1,2], functional models of the brain [2,3,7], and in the development of relevant benchmark problems to test the algorithms. Such benchmarks include (i) human-computer interfaces embedded into cognitive research, (ii) distributed robotic searching and filtering Internet materials under human supervision [6], and (iii) the development of anonymous but accountable self-organizing communities for medical purposes [3]. One of the main strengths of this group is in its efficient networking with other research groups. Point (i) concerns augmentative and alternative communication for persons of severe physical disabilities (together with the Hungarian Bliss Foundation) and cognitive development of (handicapped) children (together with the Institute of Psychology of the Hungarian Academy of Sciences). Concerning point (ii) the work is supported by the European Office of Aerospace Research and Development. The work aims at, amongst other things, the robotic gathering of Internet materials and robotic collaboration with humans to make the gathered material amenable for the supervising human. Point (iii) is executed in collaboration with the Technical University of Budapest and the University of North Carolina and is supported by the Hungarian Academy of Sciences and the NSF jointly. It concerns data collection, information filtering and knowledge developing for communities of special needs, e.g., communities of patients and doctors under constraints of pro-active threshold cryptography and survivable storage. Point (iii) includes also the development, the evaluation and the added-value estimation of teaching and training materials on the Internet, including, e.g., Open CourseWare materials of MIT and alike. This project is executed in collaboration with other groups of the University. Another aspect of Point (iii) is the development of pro-active distributed methods for RF-MEMS in collaboration with the Department of Control Engineering and Information Technology of the Technical University of Budapest [8].

Napier University, School of Computing, Centre for Emergent Computing

Since becoming a university in 1992, Napier University has become one of the largest universities in Scotland with approximately 11,500 students, employing 1560 staff. The School of Computing at Napier University is the largest computing department in Scotland.

The Centre for Emergent Computing (16 people) is led by Ben Paechter and studies how ideas of simulated evolution can be used to solve many hard computational problems. The centre also studies a variety of other nature-inspired techniques such as immune-system models and ant-colony optimisation. Most recently the centre has looked at methods of distributing processing of such systems across peer-to-peer networks, and Ben Paechter coordinated the FET ***DREAM*** Project in this area.

Other FET projects that the centre collaborates in are ***Metaheuristics*** – a training network studying nature inspired algorithms for combinatorial optimisation; ***SIGNAL*** – investigating how robots might "grow up'" through their own experience of the world as they move about; and ***EvoNet*** – a Network of Excellence in Evolutionary Computing with the administrative hub at Napier.

Nationally funded projects include ***Hyperheuristics*** – a study a how to evolve heuristics to solve problems; "Proof of Concept" funding to develop the commercial potential of an application of evolutionary computing techniques for modelling the buying and selling behaviour of stock-market traders; and, most recently, ***Specked Computing*** a four year study to develop "smart dust" technologies, and methods for self organisation and collective processing in systems composed of large numbers of communicating $1mm^3$ specks of silicon.

The centre maintains strong links with the Distributed Systems and Mobile Agents research group in the same School, which will provide useful input in this area.

The University of Surrey, School of Human Sciences, Centre for Research on Social Simulation

The University of Surrey is a research-focused University founded in 1967 with a mission that emphasises professional and applied research. It has strong research groups in engineering (especially space science and communications), environmental science (especially life cycle analysis) and the social sciences.

The University is situated on a green field campus in Guildford, an ancient market town about 30 miles from London's Heathrow and Gatwick airports and 30 minutes from the centre of London by rail. It has about 9000 students, one third of which are postgraduate.

It owns and manages a very successful science park adjacent to the campus and derives substantial income from industrial collaborations. In proportion to its size, it has the third greatest proportion of its income from research grants and contracts of all the British Universities. Its close links with industry and business are also reinforced by the fact that the great majority of its undergraduate students spend their third year on placement with graduate employers.

The group that will be contributing to this project is from the Centre for Research on Social Simulation (CRESS). Professor Nigel Gilbert is Director of the Centre. The centre is involved in a number of research projects applying simulation to policy concerned with the governance of science, to issues relating to the environment, including water resource management and ecological tax reform and to understanding the growth of the internet.

Professor Nigel Gilbert, PhD, ScD, MBCS, FREng, AcSS has a first degree in Engineering, and a doctorate in Sociology. He has been involved in Framework projects since 1989 under the ESPRIT, SEER, TSER, FAIR and IST programmes. His doctoral research was in the sociology of science and he has since made many contributions to this area. He has also worked on the sociology of the environment and on science policy. He is Academic Director of the Digital World Research Centre, Director of the Centre for Research on Social Simulation and Editor of the *Journal of Artificial Societies and Social Simulation*.

He has contributed in a number of roles to the UK Research Councils, including chairing programme committees. He has written and edited eighteen books and about 120 academic papers on topics ranging from the sociology of science to the computerisation of social security benefits and human computer interaction. He is also a Pro Vice-Chancellor at the University of Surrey.

Stichting Katholieke Universiteit Brabant, Computational Linguistics, Induction of Linguistic Knowledge Group

The Computational Linguistics department, headed by Prof. Dr. Harry Bunt, is part of the Faculty of Arts and currently consists of about 25 researchers. The department has two main focal points of research: computational semantics and machine learning of language. The project will be based within the Induction of Linguistic Knowledge group (ILK, 14 researchers), which is recognised worldwide as a leading research ground in machine learning of linguistic knowledge and is headed by two distinguished researchers Prof. Dr. Walter Daelemans and Dr. Antal van den Bosch. The group was recently extended with an 'Innovational

Research Incentives Scheme' project (VENI) funded by the Netherlands Organization for Scientific Research (NWO) on language evolution and computation, headed by Dr. Paul Vogt.

Dr. Vogt has a great experience in the field of language evolution and computation, and is well known for his work on language evolution and symbol grounding. He received his Ph.D. at the AI Lab of the Vrije Universiteit Brussel (promotor: Prof. Dr. Luc Steels). Before joining ILK, he has held a lecture position at the Institute of Knowledge and Agent Technology of the University of Maastricht, and he was Visiting Research Fellow of the Royal Society of Edinburgh and the Caledonean Science Foundation at the Language Evolution and Computation Research Unit of the University of Edinburgh.

The main contribution of the group will be on language evolution, multi-agent technology, machine learning and symbol grounding.

Special Advisor Professor Sander van der Leeuw

The consortium has obtained the agreement of Professor Sander van der Leeuw, an anthropologist of international repute, that he will act as an advisor to the project. Professor van der Leeuw has published widely on archaeological theory, historical ecology and European prehistory, including *Archaeological approaches to the study of complexity* (1981) and *Time, process, and structured transformations in archaeology* (1997). He is External Faculty Member at the Santa Fe Institute in the US, and has been coordinating the ARCHAEOMEDES Research Programme under contract with DG XII of the European Union since 1992. He will be become the Chair of the Department of Anthropology at Arizona State University from January 1, 2004.

Professor van der Leeuw will be consulted on the environmental challenges to be constructed in WP1 and their relevance to understanding human societies. He will also acct as the point of contact between the project team and the Santa Fe Institute, especially their current programmes on Robustness and Social Scaling