INFORMATION SOCIETIES TECHNOLOGY
(IST)
PROGRAMME

Contract for:

Shared-cost RTD

Annex 1 - "Description of Work"

Project acronym: DREAM
Project full title: Distributed Resource Evolutionary Algorithm Machine
Contract no.: *IST-1999-12679*
Related to other Contract no.: n/a

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Proposal number:*IST-1999-12679*
Operative commencement date of contract: *see Article 2.1 of the contract*

Contents

1. Project Summary

Shared Cost RTD CPF Form – Form A2

EUROPEAN COMMISSION
RESEARCH DIRECTORATES
GENERAL
SHARED COST
RTD CPF FORMS

EN C 1 FP5RTD

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Project Acronym [2]	DREAM	Proposal No [3]	IST-1999-12679

A2. Project Summary [20]

Objectives (maximum 1000 characters)

- **To create the software infrastructure necessary to support the next generation of evolving infohabitants in an open and scalable fashion, using existing Internet infrastructure and existing hardware resources.**
- **To unify evolution approaches, so that infohabitants can evolve using a number of complementary mechanisms.**
- **To allow meta-optimisation procedures, so that the algorithms for evolution themselves can be optimised by co-evolving a virtual world with the infohabitants it contains.**
- **To create the software infrastructure necessary to support the emergent virtual economy that will result from the implementation of virtual machine onto physical resources.**
- **To demonstrate the usefulness of the infrastructure by using it to implement two applications which can make full use of it.**
- **To facilitate an improved understanding of the dynamics underlying real-world economic and social systems by simulating these systems with the DREAM.**

Description of the work (maximum 2000 characters)

The project is divided into four distinct phases.

In the first phase, which lasts 14 months, the participants will work together to provide a prototype DREAM infrastructure.

Phase two lasts 13 months, and is concerned with the use of the prototype DREAM for three purposes. During phase two, three teams will be formed, with each participant joining two of the teams, so maintaining the cohesion of the project. Application 1 involves the implementation of a new model of economic and social behaviour; Application 2 concerns distributed data mining with the DREAM; and Application 3 will look at how the DREAM can contribute to distributed scheduling. The result of phase two will be an evaluation report on the prototype DREAM. This phase also includes an iterative process of evaluation and redesign. Required changes identified during implementation of the applications, will results in changes to the DREAM prototype.

The application areas are carefully chosen such that they together span a wide scale. Namely, we cover three types: optimisation (scheduling application), modelling (data mining application), and simulation (economic and social behaviour). The deliberately different focuses are meant to provide feedback on the general underlying paradigm, that is the distributed evolutionary mechanism, from different angles. However, the shared DREAM framework keeps these activities coherent; all findings will be fed back into the general architecture. Therefore, the three applications will illuminate different corners of the DREAM framework, thereby contributing to a widely applicable universal approach.

Phase three is concerned with continuing to re-design and re-implement the DREAM based on the final DREAM evaluation report .

The final phase brings the project to a close, with the all participants working together on the production of user documentation, and a book of scientific reports. This phase will also include the identification of avenues of exploitation, and early discussions with possible beneficiaries. Some work on exploitation will begin as soon as phase one is complete.

Milestonesand expected results (maximum 500 characters)

After the first phase a prototype DREAM infrastructure will be available. In the second phase, trials with the three applications will produce evaluation reports. After the third phase the final DREAM infrastructure will be available. At the end of the project the scientific results will be published in a book including a CD-ROM with the DREAM software and user documentation. The software and user documentation will also be available on the WWW along with summaries of results.

2. Project Objectives

It is hoped that Universal Information Ecosystems "will turn the complex information infrastructure as it is emerging today into a rich, adaptive, responsive and truly open environment" (UIE Objectives). For this to happen there will inevitably be some types of software infohabitant which must adapt and evolve, for example, to model complex distributed systems, such as large groups of humans, or to help solve problems or search out data. The Distributed Resource Evolutionary Algorithm Machine (DREAM) is designed to provide the technology and software infrastructure necessary to allow these infohabitants to exist and evolve in a virtual world.

There are many systems in existence which provide some of the features of the DREAM. Some provide libraries or toolkits for evolution. Some, for example *Swarm*, provide simulations using agents. Others, for example *Creatures* provide artificial life simulations with migration over the Internet. Some systems, for example *Network Tierra* also allow some sharing of CPU time. Further systems, for example Beowulf clusters, allow parallel processing using networks of machines. However, no systems currently in existence provide all the features of the DREAM. In particular, few current systems have been developed with scalability and openness as paramount concerns. The DREAM will go beyond the state-of-the-art by providing all of the following features within the same system:

- A tool that is a framework in which to develop instantiations of applications, rather than having the models or problems hard-coded into it.
- A tool designed to allow both the solutions of industrial optimisation problems and the modelling of the behaviour of large systems.
- A tool which allows for free migration of infohabitants through the internet, thus allowing the formation of diverse niches
- A tool which allows the use of spare CPU cycles in an automated and secure manner
- A tool designed to allow behaviour at the macro level to be observed (whereas, for example, *Creatures* only monitors its habitants at the micro level)
- A tool designed to be scaleable and open

The DREAM project is based on two components, a physical one and a virtual one. The virtual world will necessarily be implemented on physical resources. The owners of those resources, or infohabitants working on behalf of end users, will from time to time have problems that need to be solved using great amounts of computing power. At other times they will have computing power that is idle because the computer is not being used at that time or because the CPU is not being used 100%. The infrastructure proposed here allows the DREAM to be implemented across hardware resources that are shared and distributed. At a global level, this allows much more effective and efficient use of existing hardware. At the local level, individual users are enabled to use much more computer power than they physically possess without having to invest in hardware.

On the virtual side, an evolving population of infohabitants will be able to tackle a problem in an adaptive fashion. Individual infohabitants or sub-populations can compete, thereby enforcing quality pressures on each other. By using Darwinian principles in computer simulations, high quality problem solutions can be evolved. While this competition continues, there is also the possibility for co-operation or negotiation between individual infohabitants or sub-populations. This, it is expected, will provide a collective intelligence that operates effectively by dividing the problem at hand and allowing infohabitants to generate a solution jointly. This is especially important for real, very large problems. It is expected that quality solutions will be obtained for problems of a much larger scale than present technology supports. In addition to applications developed to solve difficult problems, a virtual society can be used to simulate aspects of real world society. Example aspects that might be simulated are: the way in which interactions at a local level lead to emergent behaviour at the macro level; the way that geographical distribution leads to cliques and clusters that share the same information and ideas within themselves; or the ways in which economies arise from the assignment

of resource value to information. Here, the emphasis is on the system as model, rather than the system as problem solver. The DREAM framework provides a virtual environment that, by its intrinsic complexity and variety, matches real environments better than currently used systems. It is expected that non-trivial insights in the complex dynamics of society can be achieved.

The intention is to put forward the microscopic simulation, macroscopic analysis approach. The DREAM framework enables an enormous scale-up in the size of simulated words. The worlds we are going to simulate are derived (i.e. simplified) from real life. Yet, it is an open research question whether this scale-up reaches such a level of fidelity that we could indeed speak of real human scenarios.

The scientific objectives of the DREAM project are:

- To create the software infrastructure necessary to support the next generation of evolving infohabitants in an open and scalable fashion, using existing Internet infrastructure and existing hardware resources.
- To unify evolution approaches, so that infohabitants can evolve using a number of complementary mechanisms.
- To allow meta-optimisation procedures, so that the algorithms for evolution themselves can be optimised by co-evolving a virtual world with the infohabitants it contains.
- To create the software infrastructure necessary to support the emergent virtual economy that will result from the implementation of virtual machine onto physical resources.
- To demonstrate the usefulness of the infrastructure by using it to implement two applications which can make full use of it.
- To facilitate an improved understanding of the dynamics underlying real-world economic and social systems by simulating these systems with the DREAM

3. Participant List

List of Participants

Participant Role	Participant number	Participant name	Participant short name	Country	Status*	Date enter project	Date exit project
CO	1	Napier University	Napier	United Kingdom	C	1	36
CR	2	Universitaet Dortmund	UNIDO	Germany	P	1	36
CR	3	Ecole Polytechnique	EEAAX	France	P	1	36
CR	4	Universiteit Leiden	UL	Netherlands	P	1	9
CR	5	Universidad de Granada	ATC-UGRS	Spain	P	1	36
CR	6	South Bank University	SB	United Kingdom	P	1	36
CR	7	Free University Amsterdam	FUA	Netherlands	P	10	36

*C = Co-ordinator (or use C-F and C-S if financial and scientific co-ordinator roles are separate)
P - Principal contractor
A - Assistant contractor

4. Contribution to Programme/Key Action Objectives

The DREAM sets up the essential components of a technology that can realise a new style of computing: an evolving infohabitant society embodying a collective intelligence. Such a collective intelligence has an intrinsically distributed, adaptive, and self-organising nature. Competition between individual infohabitants or between sub-populations gives a selection pressure which guides evolution towards evolving high quality solutions to problems. Co-operation and negotiation between individual infohabitants and between sub-populations complements the competition to provide a collective intelligence for effective problem solving by division of the problem – a key to solving real, very large problems. The DREAM project contributes to key action objectives by implementing and evaluating an approach to collective intelligence based on evolutionary models with competition, co-operation, negotiation and trading among individual infohabitants and species.

An evolving infohabitant society will be physically placed in a distributed hardware and software environment. Technically, this environment is created by integrating numerous computers through advanced communication technology. Such an infrastructure provides a very natural basis for holding a variety of local environments with different local conditions reflecting different aspects of a problem. The results of individual and collective learning processes on local level can be disseminated globally by migrating and recombining pieces of knowledge. The DREAM project contributes to key action objectives by creating the software infrastructure necessary to support evolving infohabitants in a distributed, open and scalable fashion, using existing Internet infrastructure and existing hardware resources.

The first use we will make of the DREAM as part of this project concerns simulating large scale virtual societies. It is expected that the large scale of the DREAM will bring significant improvement over existing simulated experiments in the understanding of real society phenomena. Moreover, such an accurate model in an evolutionary framework allows to try to solve the inverse problem of finding optimal policies to drive the society toward a given direction. The DREAM will provide a powerful tool to underpin a new kind of experimental social and economic research. Proof-of-principle applications in data mining and human resource scheduling are planned to further evaluate this conceptual framework. While each of these applications is relevant on its own right, their main contribution is providing feedback on our approach as a whole.

The mutual use of other people's hardware and software in the distributed environment will give rise to a virtual economy, where some virtual currency unit is needed for periodical clearance among the owners of infohabitants (the participating individual users and organisations). Such a virtual economy is expected to take effect and to have a significant impact on the future information society. Besides the technological and scientific objectives on computational level, the DREAM project constitutes a long term, real life experiment of such a virtual economy. It is hoped that the insights gained can be translated into recommendations regarding future policy measures.

5. Innovation

Evolving systems can be scaled up enormously. Current experimental research in the areas of evolutionary computing, artificial life and artificial societies is based on populations of a couple of dozens, hundreds, or at most thousands. The DREAM provides the technology to use at least millions of infohabitants, and since its design is entirely distributed and scalable, there is no known reason why it should not support trillions of infohabitants. This has two major scientific consequences:

- A big leap regarding the size and complexity of the problems that can be tackled
- The necessity for new tools for scientific analysis of the nature of collective intelligence, self-organisation, emergence, and complexity. By being able to simulate virtual societies at large scale, the DREAM also provides a powerful tool to underpin a new kind of experimental social and economic research.

It is unclear and unpredictable how such a massively distributed, open-ended adaptable information ecosystem will behave over time. The emerging features of the system are likely to be completely innovative, and observation tools need to be designed carefully because we do not know beforehand what kind of information is important to observe. Furthermore, control and steering mechanisms of current evolutionary computation techniques might be insufficient to cope with such a new level of complexity. It hence becomes necessary to have a flexible graphic tool allowing one to design new observables on the fly, in order to verify globally some hypotheses that could only be guessed by partial human observation.

In economic and social simulations, the system is expected to facilitate simulations at a new quality level, with an expected explanatory power which goes far beyond current simulations, approaching capabilities of real-world scenarios.

Classical economy is based on Adam Smith's invisible hand principle: the stable global optimum is reached when all agents look after their own well-being. However, this does not hold in a number of cases, among which are the famous “Tragedy of the Commons” or the “Iterated Prisoners’ Dilemma”. These are paradigms for many current situations, where the concern is the agents’ interaction, rather than the quantity of goods or the price levels.

One limitation of existing economical simulations (for example, J. March, based on models of risk takers and avoiders, or Schelling, using games of life to model, for example, the effects of racism), is that they do not take into account the intrinsic opportunism of social and economical agents: they anticipate other individuals' behaviour, thus modifying their own, which in turn amounts to modifying the rules of the game. Communication among the DREAM infohabitants, as well as the size of the population will allow for such aspect of co-evolution to be taken into account.

At first we will try to see the effect of different culturally-founded behaviours (for example competition-oriented, altruist or diversity-oriented) on the global steady state of the whole infoworld. Further, the inverse problem will be approached: are there some rules that can be enforced in order to modify the final state of the infoworld? In other words, in the case of tax policy for instance, an expected outcome would be to replace the old cultural and historical arguments with new simulation based strategies.

Current distributed data mining applications usually split either the models or the data. In the master-slave model, partial hypotheses are tested against the whole data set. In the pipe-line model the data is distributed, but the hypotheses are tested against every subset of the whole data. This approach leads to speedup if the different data subsets are evaluated in parallel, but still has a search dynamic identical to that of standard sequential data mining. In our innovative approach, it is expected to distribute both the data and the hypotheses in the DREAM; infohabitants representing partial hypotheses being partially evaluated on a subset of the whole dataset. The global communications among infohabitants will allow, for instance, the rapid elimination of unpromising infohabitants, while letting promising ones breed and migrate to other subsets of the dataset.

The proof-of-principle application of distributed human resource scheduling will be innovative in its methods of partitioning scheduling problems for distributed processing. New methods of scheduling and rescheduling by co-operation, negotiation and trading of infohabitants will be developed, that would not be possible without the DREAM infrastructure. New methods of dealing with the competing multi-objectives of the problem will also be developed.

We intend to tackle the problem of accounting for use of computer power by infohabitants and their owners, and for provision of computing power by others or the same owners at different times. This will require the introduction of a currency unit which can be earned and spent by human users. This currency may also be used by infohabitants to trade information, so that an infohabitant has an incentive to find out things that will be useful to other infohabitants. Additionally, migration to, or existence in, some virtual niches, might also involve costs to infohabitants.

Some political issues may become apparent here, such as “should information be free?”. We need to ensure that people feel secure to give their spare CPU time in the knowledge that they can draw on these “banked resources” when required. We must also consider the relationship between hard resources (i.e. those provided by an infohabitant’s owner) and earned resources (i.e. those which an infohabitant had acquired through trading with other infohabitants. The relationship between the resource wealth of an infohabitant and its fitness will also require investigation.

The emergent economy that will result, is not only necessary for the Universal Information Ecosystem to fit into the real world, it will also provide novel insights into the ways in which economies work.

6. Community Added Value and Contribution to EU Policies

This project can draw particular benefit from the European dimension. This is because of the necessarily international nature of the Universal Information Ecosystem that we plan to support. Since the DREAM is designed to be *open* and *universal*, it is very important that researchers from a number of different countries, and a variety of different backgrounds, become involved.

A project such as this, conducted within a particular institution or limited to a particular country would almost certainly result in a framework that was neither open nor universal. Idiosyncrasies in the particular institution or country would inevitably find their way into the framework, making it difficult for others to use, and ultimately making wide take-up of the results unlikely.

By taking a Europe-wide view from the start we will benefit from six different institutions each with a distinct background and specialist research and application area. This, it is hoped, will make providing an open and universal system more natural, since a wide range of languages, protocols, platforms, adaptive schemes and working practices will be represented.

The project will also benefit from being carried out at a European rather than national level, because having the six researchers spread across six research centres will enable the project to stay more up to date with new developments in the field. Each of the participants is involved with other related research projects, and the European perspective will give the DREAM project team the chance to interact with a larger number of other projects.

The project will contribute to EU policies through taking its place as an integral part of the Universal Information Ecosystem.

7. Contribution to Community Social Objectives

Evolutionary computing is ideally suited to contribute to Community social objectives because the aim of evolution is most often to provide solutions in a better or more efficient manner than was previously possible. For example, an evolutionary algorithm might be the best way to optimise the design of an internal combustion engine to use less fuel and produce fewer harmful emissions. Another evolutionary algorithm might design the plan of a new factory, so that it works efficiently, but is also a pleasant place to work. A further evolutionary algorithm might schedule employee's shifts so that they can work more sociable hours, and hours which fit better with their lifestyle, for example, around childcare arrangements. This could directly improve their quality of life.

On completion of this project, the resultant infrastructure will allow scientists to use massive computing resources for short periods of time. This will enable them to evolve much better solutions to much larger problems than has previously been possible, and so the contribution to Community social objectives will be larger still.

The DREAM project is based around the idea of gaining greater computing power by using *existing* hardware infrastructure more efficiently. The evolving infohabitants will seek out otherwise unused or underused hardware to do their processing for them. Greater efficiencies will lead directly to the minimal use of, and conservation of, natural resources – resources that would otherwise be wasted in the production, distribution and maintenance of extra computer hardware. They will also lead to preservation of the environment through decreased production and disposal pollution.

8. Economic Development and S&T Prospects

Dissemination of results

The intermediate and final results of the Distributed Resource Evolutionary Algorithm Machine (DREAM) project will be disseminated by several channels, the most important one being the medium DREAM is focusing on, i.e., the Internet. This dissemination feature will already be inherent, from the very beginning, as a WWW-page will form the cornerstone of the whole project. In inhabiting other computers the DREAM infohabitants will also carry information about the DREAM itself to these machines and therefore further the dissemination of information about DREAM to other computer users. Giving an infohabitant the right to run on a user's machine will always imply that the user receives some basic information about the project from the infohabitant, such that the paradigm itself provides the ideal way of information dissemination. Each infohabitant will provide, with its computation task, an information carrier that informs users about the DREAM. Provided that the infohabitants are attractive enough for WWW users to let them inhabit their computer system, any kind of information they carry can be communicated to the user.

While this is the primary information dissemination method, the more traditional ones will of course be exploited within the project. Exploitation of the scientific results will be sought through high quality scientific channels. The main channel for the final dissemination of project results will be the publishing of a book, edited by the co-ordinator and including contributions by each of the participants. The book will cover each of the research issues that are addressed by the project, and will include guidelines and user tutorials. The partners have a leading role in the Springer book series on Natural Computing that would most probably be very interested in publishing such a volume. Accompanying the book will be a CD-ROM containing all the software necessary to participate, either through use of the DREAM to solve some problem, or by offering spare computing resource or use by others. The CD-ROM materials, user guide and tutorials will also be made available free of charge on the project WWW pages.

The DREAM consortium is represented on the editorial boards of major international journals in the area. Special issues of these journals form an excellent forum for scientific exploitation too. Furthermore, the project partners are members of organising committees of the major international conferences in the field. Organising of special sessions of leading conferences around DREAM related activities can be undertaken already during the project. Additionally, offering DREAM related self-supporting workshops targeting both academia and industry seems an efficient way to disseminate results and generate further activities. Conferences and journals which may be targeted are listed below (note that where a conference is part of a series, only the most recently advertised conference is given):

General EC conferences

- Parallel Problem Solving from Nature (PPSN) Paris (France), Sept. 17-20 2000
- Genetic and Evolutionary Conference (GECCO) Las Vegas (USA), July 8-12 2000
- Congress on Evolutionary Computation (CEC) San Diego (USA), July 16-19 2000

Other General-Purpose Conferences

- AI conferences - IJCAI (International Joint Conference on AI, in Stockholm last July) and ECAI (European Conference on AI, in Berlin next summer) are places where to advertise and demonstrate the DREAM possibilities.
- 7th European Conference on Intelligent Techniques and Soft Computing (EUFIT) Aachen (Germany), 13 - 16 September 1999
- Complex Systems - a series of conferences. In 98, subtitled Complexity Between the Ecos - From Ecology to Economics Sydney (Australia), November 30th-December 3rd 1998

Artificial Life Conferences

- European Conference on Artificial Life (ECAL) EPFL (Lausanne, Switzerland), 13 - 17 September 1999
- ALife
- Fifth International Symposium on Artificial Life and Robotics AROB2000 Oita, Japan, 26 - 28 January 2000
- Virtual Agents 99 - Workshop prior to the UK Virtual Reality SIG Conference University of Salford (UK), 13 September 1999
- Second International Conference on Virtual Worlds Paris (France), 5 - 7 July 2000

High Performance Computing Conferences

- International Parallel and Distributed Processing Symposium (IPDPS) special track: Bio-Inspired Solutions to Parallel Processing Problems (BioSP3) Cacun, Mexico, 1 May 2000
- International Symposium on Handheld and Ubiquitous Computing (HUC 99) Karlsruhe, Germany, September 27-29, 1999 Note: from the themes on the Web page "Linking virtual worlds with physical worlds"
- International Conference on Parallel Processing Aizu-Wakamatsu, Japan, 21 - 24 September 1999

Information Technology Conferences

- Conference on Information Technology Bhubaneswar, India, December 20-22 , 1999.
- 1st Asia-Pacific Conference on Intelligent Agent Technology Hong Kong, China, 15 - 17 December 1999

Application Oriented Conferences

- 3rd International Conference on the Practice And Theory of Automated Timetabling Constance, Germany, 16 - 18 August 2000
- Knowledge Discovery and Data Mining (KDD) Boston (MA, USA), August 20-23, 2000

WEB sites

- EvoWeb, EvoNet Web site - http://www.dcs.napier.ac.uk/evonet/
- Artificial Life Online - http://alife.santafe.edu/
- Complexity On-Line - http://complex.csu.edu.au/complex/
- MLNet Online Information service - http://www.mlnet.org/
- The Quantitative Macroeconomics Home Page - http://ideas.uqam.ca/QMRBC/

Journals

- Evolutionary Computation (MIT Press) - Thomas Baeck is associate editor
- IEEE Transactions on Evolutionary Computation - A. E. Eiben, Thomas Baeck and Marc Schoenauer are associate editors
- Genetic Programming and Evolvable Machines (Kluwer Academic) - Marc Schoenauer and A. E. Eiben are associate editors
- Complex Systems (Complex Systems Inc.) - see also Complexity On Line Artificial Life (MIT Press)
- Evolutionary Ecology (Chapman-Hall)
- Ecological Modelling (Elsevier Science)
- Journal of Evolutionary Economics (Springer)
- Computational Economics (Kluwer)
- Journal of Scheduling (John Wiley)
- Data Mining and Knowledge Discovery (Kluwer)

- Journal of Economic Dynamics and Control (North Holland)
- Review of Economic Dynamics (Academic Press)

Books

A volume of the Natural Computing Series - A. E. Eiben and Thomas Baeck are series editors.

Exploitation of results

As soon as the prototype is complete companies and institutions that might make use of the DREAM infrastructure will be approached in order to disseminate information and to identify exploitation routes. These bodies will be asked for their feedback on the approach, and if considered appropriate, their comments may result in changes during workpackage 5. These early discussion will allow for more effective exploitation of the final DREAM infrastructure.

A special version of the DREAM infrastructure could be sold as a distributed, problem solver for a company's intranet, because many companies now have up to several thousand interconnected machines.

Problem oriented project exploitation will focus on application potential in the areas addressed during this project: optimisation, modelling, and simulation. Companies and institutions that deal with problems within the application areas of DREAM are possible targets for utilisation of the DREAM framework, particularly if current technology cannot provide them with satisfactory solutions.

In the case of optimisation, the improved optimisation qualities of the DREAM will be offered to industrial partners to solve their optimisation problems, an attractive option to industrial partners due to the high-quality solutions promised by the massively parallel, distributed optimisation paradigm.
The results of the distributed scheduling application will be exploited in three ways. Firstly through the identification of companies involved in providing scheduling solutions. These companies can then be approached in order to transfer new the technology to their products, so incorporating an interface to a DREAM in them. Secondly the possibility of producing a product from the scheduling software developed will be investigated, with a view to the possible sale of this product. Thirdly it is likely that the technology will be incorporated into existing human resource scheduling software currently produced and owned by Napier University and its authors.

As for modelling applications, data mining is a most promising area at the moment. Namely, the amount of data collected is growing everywhere, but the tools to utilise these data are not able to keep up with the pace of this growth. Therefore, we expect a rather immediate interest from data intensive sectors, such as marketing, banking, finance, insurance, etc. Such companies are easy to identify at national levels and typically are quite open (and rich) for investing in developments leading to competitive advantages.

Approaching companies that are maintaining huge amounts of data, and therefore would be interested in the extra possibilities we can offer, is the first channel for exploitation. Our policy will be based on offering a primary analysis of external data free of charge, followed by a contractual co-operation aiming at deploying the technology at the given site. In this way we hope to achieve concrete on-site applications that are integrated in the given organisations' existing set-up. Practically, this means separate projects between project participants and companies. Turning the data mining DREAM software into a product forms the second possibility of exploiting the outcomes. This could be realised in the form of an agency responsible for marketing and selling this product. Issues of clearing among DREAM participants and the Commission need to be elaborated

for this option. The third option is the application of the software at the participating institutes themselves. The current academic practice does include collecting and managing data on, for instance, secondary schools to attract students. Such activities could be supported by intelligent data analysis facilitating more efficient campaigns.

Socio-economic simulations form the third application area. Social and economic systems are even today still weakly understood and are of paramount importance for the future sustainable growth on all levels of economy and society. Simulating these systems with a distributed evolutionary machine will provide a new quality of computer models, because a critical mass can be reached with the large number of infohabitants so as to show typical emerging features which are also reminiscent of real-world systems.

The primary targets for applying the socio-economic simulation tools are governmental institutions. Departments responsible for long term planning, for instance infrastructure or tax and welfare, may be interested in the novel technology. It should be noted, however, that implementation of policies resulting from such simulations can only be expected if the reliability of the system is sufficiently proven. To this end, it is crucial that the project partners seek contact with such institutions in an early phase (after having a running prototype) and involve them into further development. Such co-operation would be inevitably of a long-term character, and therefore would go beyond the DREAM framework, but it is essential to initiate activities into this direction as early as possible.

Such simulations can also be useful e.g. for banks and insurance companies requiring predictions about the behaviour of large, interacting societies of intelligent entities. At this moment, however, it is hard to foresee whether the commercial sector would be prepared to invest in long term return technology.

9. Workplan

9.1 General Description

The project will last 36 months and will employ one researcher with each of the six participants. The two at Napier University and South Bank University will spend 25% of their time on project co-ordination and management.

The project is divided into four distinct phases.

In the first phase, which lasts 14 months, the participants will work together on Workpackage 1 to provide a prototype DREAM infrastructure.

Phase two lasts twelve months, and is concerned with the use of the prototype DREAM for three purposes. During phase two, three teams will be formed, with each participant joining two of the teams, so maintaining the cohesion of the project. The three teams will work on Workpackages 2, 3 and 4. Workpackage 2 involves the implementation of a new model of economic and social behaviour; Workpackage 3 concerns distributed data mining with the DREAM; and Workpackage 4 will look at how the DREAM can contribute to distributed scheduling. The result of phase two will be an evaluation report on the prototype DREAM. This phase also includes an iterative process of evaluation and redesign in workpackage 5. Required changes identified during implementation of the applications, will results in changes to the DREAM prototype.

The application areas are carefully chosen such that they together span a wide scale. Namely, we cover three types: optimisation (scheduling application), modelling (data mining application), and simulation (economic and social behaviour). The deliberately different focuses are meant to provide feedback on the general underlying paradigm, that is the distributed evolutionary mechanism, from different angles. However, the shared DREAM framework keeps these activities coherent; all findings will be fed back into the general architecture. Therefore, the three applications will illuminate different corners of the DREAM framework, thereby contributing to a widely applicable universal approach.

Phase three contains the remaining part of Workpackage 5. It is conducted by all participants. This phase is concerned with continuing to re-design and re-implement the DREAM based on the final DREAM evaluation report .

The final phase brings the project to a close, with the all participants working together on the production of user documentation, and a book of scientific reports in Workpackage 6. This phase will also include the identification of avenues of exploitation, and early discussions with possible beneficiaries. Some work on exploitation will begin as soon as phase one is complete.

9.2 Workpackage List

B1. Workpackage list

Work-package No[1]	Workpackage title	Lead contractor No[2]	Person-months[3]	Start month[4]	End month[5]	Phase[6]	Deliv-erable No[7]
WP1	Prototype Construction	1	77	0	13		D2 D3 D4
WP2	Economic and Social Behaviour	7	23.4	14	26		D5 D7
WP3	Distributed Data Mining	3	15.6	14	26		D8
WP4	Distributed Scheduling	1	18.2	14	26		D9
WP5	Evaluation and Redesign	5	41.8	14	33		D6 D11 D12
WP6	Documentation, Dissemination and Exploitation	1	22	14	35		D10 D13 D14 D15 D16
WP7	Project Co-ordination	1	18	0	35		D1
	TOTAL		216				

[1] Workpackage number: WP 1 – WP n.
[2] Number of the contractor leading the work in this workpackage.
[3] The total number of person-months allocated to each workpackage.
[4] 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.
[5] Relative end date, month 0 marking the start of the project, and all end dates being relative to this start date.
[6] Only for combined research and demonstration projects: Please indicate R for research and D for demonstration.
[7] Deliverable number: Number for the deliverable(s)/result(s) mentioned in the workpackage: D1 - Dn.

9.3 Workpackage Descriptions

Workpackage 1 – Prototype Construction

This workpackage is concerned with the construction of a prototype DREAM infrastructure. The workpackage is led by Napier University, but four strands have been identified, each of which will be led by one of the other participants. These strands are: methodology (leader - UL/FUA), infoworld evolution (leader - UNIDO), infoworld properties (leader ACT-UGR) and human-infoworld interface (leader EEAAX).

In the methodology strand we will concentrate on the definition of infohabitants and infoworlds as objects. The infohabitant/infohabitant, infoworld/infoworld and infohabitant/infoworld interfaces will be defined.

In the infoworld evolution strand we will concentrate on the evolution both of infohabitants and their infoworlds. A unified framework for evolution will be developed which includes all major elements of evolutionary computing.

In the infoworld properties strand we will consider the interface between infoworlds and the physical machines on which they run.

In the human-infoworld interface strand we will consider both the input and output interfaces between the user and the infoworlds, and infohabitants.

The strand are described in more detail below:

Methodology
This strand is the basis for the rest of the work; its goal is to create the infrastructure to make possible the evolution of infohabitants within infoworlds. The infrastructure must allow:

- control by the user,
- the communication from one infoworld to another
- the communication from the infohabitants to the infoworld
- the design of infoworlds so that they perform the function desired by the user
- the ability for an internal economy to develop.

First an analysis of current solutions to distributed problems over the Internet will be conducted. Architecture and operating system independent object frameworks will be also examined, to see which one suits the problem best.

This strand will consider issues related to the emergent economy that is likely to emerge as a result of infohabitants using hardware resources owned by someone other than the infohabitant's owner. Some political issues may become apparent here, such as "should information be free?". We need to ensure that people feel secure to give their spare CPU time in the knowledge that they can draw on these "banked resources" when required.

This strand must also consider the relationship between hard resources (i.e. those provided by an infohabitant's owner) and earned resources (i.e. those which an infohabitant had acquired through trading with other infohabitants). A separation of hard resources and the internal currency of the infohabitants may be required. The relationship between the resource wealth of an infohabitant and its fitness will also require investigation.

When these decisions have been made, the universal evolution of infohabitants within infoworlds to solve problems will be approached. A methodology for creating infoworlds, infohabitants and the

rest of the evolution operators will be created, by defining the interfaces (the glue) that allow all these elements to communicate.

The participants feel that decisions about specific technologies (platforms, languages, etc.) cannot be made in advance of the project. However, it is expected that the major platforms (e.g. machines running Windows, Unix or Linux) will be supported and that the preference will be for object oriented languages.

The DREAM as a framework for applications has two separate parts: the infoworld and its infohabitants. The infoworld must deal with generic infohabitants, and be able to make them evolve independently of their internal representation. This means that the infohabitants must have a generic interface that allows them to evolve, or at least that the infoworld must know how to make them evolve. To make that possible, and infohabitant abstract data type (ADT) will be designed; all real infohabitants should be instances of this data type.

The rest of the elements intervening in evolution, such as selection, replacement, mutation and recombination operators, must also be cast in that framework, so that they are generic, easy to use, and applicable to a wide range of problems or else extended so that they can be suited to a particular problem.

A third part is a user interface that allows design of infoworld and infohabitants easily, and also visualisation of the evolution process from the computer that hosts the virtual machine or other computers.

These elements must be able to work in a wide range of platforms and operating system, and thus they must be based on standard industrial tools. As a result we propose to use object frameworks to implement all objects (infohabitants, infoworld, evolution operators). Such frameworks allow one to define the interface of objects using Interface Definition Languages, without taking care of actual implementation, and also allow to program object in a variety of languages, since the IDL can be compiled to many different languages. This would allow to program different parts of the infoworld in different languages, and also would allow the user to work with the language with which he or she is more familiar, enhancing the openness and universality.

Identifiable sub-tasks for workpackage 1 methodology strand:

- Survey current solutions
- Conduct investigation of hard and soft currency and resource issues
- Identify object requirements
- Define necessary objects
- Write software for deliverables

Infoworld Evolution

Evolution is a central component of natural and artificial adaptive systems. The main objective of this strand is to achieve this property also within the infoworld by incorporating the feature of evolution. By means of evolutionary processes in combination with huge numbers of infohabitants, the system as a whole is expected to produce qualitatively new behaviour yielding new solutions or new insight into real-world problems and into simulations of real-world scenarios.

Evolutionary aspects - mostly based on theoretically well-founded knowledge from evolutionary computation – will be incorporated into the infohabitants as well as on the level of spatial infohabitant interaction structures.

The evolutionary component of the infoworld essentially splits into variation operators (mutation, crossover of infohabitants), co-evolutionary operators on the level of sub-populations of infohabitants, and evolutionary processes across different niches. The variation operators will be defined for each class of infohabitants; these might go beyond the well-known standard

representations such as real-valued vectors (evolution strategies), binary or discrete-valued vectors (genetic algorithms), permutations of integers (order-based genetic algorithms), or even computer programs in LISP-like languages (genetic programming).

For the standard representations, the corresponding mutation and recombination operators can be taken from existing work on evolutionary algorithms, while a more complex representation of e.g. an infohabitant's survival strategy, an infohabitant's foraging strategy, an infohabitant's norms and values, or others, will require an internal language with corresponding specialised variation operators. Based on the partners' experience of the above mentioned evolutionary algorithms, new operators or operator combinations (for mixed representations) will be designed, implemented and experimentally tested within this workpackage.

In addition to the variation operators, also corresponding selection operators need to be realised. By design of the infoworld, these selection operators are necessarily local and become active among a local group of infohabitants only. Criteria for differentiating fitness or survivability among infohabitants as well as local strategies for selection need to be developed and implemented within this workpackage.

A major aspect of the work is to incorporate the feature of self-adaptation into the evolving aspects of the system. By means of self-adaptation, collective intelligence is known to emerge from the interaction of few individuals in evolution strategies already, such that self-adaptation in a system with large number of heterogeneous infohabitants is a fundamental issue to achieve qualitatively new behaviour on the level of the whole system.

As result of this strand, the system is extended by basic evolutionary principles -- variation and selection - facilitating adaptation of the system, self-adaptation within the system, and emergence of new system properties and qualities.

Locally evolving populations can benefit strongly from segregation into sub-populations with different goals, which co-evolve by competition between the corresponding sub-populations (e.g., a population of test cases might co-evolve with a population of problem solvers so as to find improved solvers as test case hardness increases in the co-evolving population). Also, different populations might exhibit different goals, such that an additional feature of high-level evolution can be incorporated into the system by modelling co-evolution. Incorporating this feature into the infoworld guarantees that different goals of infohabitants can be taken into account by segregated, but interacting populations.

The infoworld is naturally spatially distributed over the Internet, with an interconnection structure among the infohabitants which is neither predefined nor static over time. Instead, the interconnection structure (an underlying graph) randomly emerges and evolves over time, depending on processes of birth, dead, migration, variation, and selection. It is this open structure of the infoworld which forms one of its fundamentally new capabilities.

Existing work on spatially distributed populations is completely focused on fixed, regular and static interconnection topologies and is therefore a restricted version of the infoworld. The corresponding literature will be used as a starting point for implementing the free interconnection structure feature of the infoworld. The specification and implementation of the control mechanisms of the infohabitants over their spatial interconnection forms the next step of the work, including the implementation of the essential operators to build the spatial structure. Currently, we expect operators allowing migration of infohabitants, communication between infohabitants, recombination between infohabitants, and selection among infohabitants as essential for building and changing this structure. These operators will be implemented in this workpackage, and the system tested.

This work will make use of existing software, for example the EO library already developed by two of the participants, where such use does not compromise the objectives of the project.

Identifiable sub-tasks for workpackage 1 infoworld evolution strand:

- Survey existing operators
- Identify key infohabitant behaviours and interactions
- Identify key island interconnection attributes
- Identify key population and migration strategies
- Define new operators based on above

Infoworld Properties

Each virtual machine or infoworld is by itself an implementation of a machine-within-a-machine; so we must understand and design it as such. We must create a toolbox to design these machines so that:

- They work as intended (that is, they carry out the problem they were designed to solve).
- They do not affect their hardware environment (that is, they carry out their work safely).
- They use the resources they are given, and at the same time, by using them, they generate resources (they use "virtual currency" to run, and generate virtual currency if lent for a certain project).
- The user knows their state and what they are doing in each moment (a proper user interface should be designed, that allows proper visualisation of the evolution process and the infohabitants, and allows the user to affect it).
- They must all work in the same way, like all cars do (they must have common interfaces that can be used independently of the inner workings).

All these components must be in an easy-to-use toolbox, and must be compatible with any kind of evolving infohabitant.

The infoworld must be designed to have the following properties:

- It must be defined as an environment in which the user's desired evolution is taking place. To that end, it can be a co-evolutionary environment (the infohabitants themselves define fitness), or a pure optimisation environment, in which a (possibly complex) function is going to be optimised.
- The infoworld exists also as an infohabitant in a universal ecology of many infoworlds. It should be possible to parameterise its workings to make it evolve along with the infohabitants it holds. This would allow to users to pursue complex optimisation problems like meta-optimisation (find the best algorithm for an optimisation task) or changing fitness environments (the fitness, which is defined by the infoworld, could be defined according to external inputs).
- The infoworld must communicate with other infoworlds and with the user; the interface must show some infoworld properties that can be read and/or changed by the user. The infoworld, for security reasons, must define with which infoworlds it is able to communicate and which infohabitants it is able to accept. It should not be possible for any infohabitant to migrate to any infoworld.
- The infoworld must provide a distributed and scalable accounting and clearing mechanism for resources as provided by infohabitant owners and used and traded by infohabitants.
- The infoworld must contain completely the infohabitants it holds; security measures will be implemented to avoid problems, such as an infoworm escaping from the infoworld and affecting the host machine.

This strand will, at the end, detail the components of an infoworld and release a prototype that can be used to design infoworlds and to solve problems with them.

Identifiable sub-tasks for workpackage 1 infoworld properties strand:

- Conduct investigation to establish security issues
- Design infoworld-host machine interface.
- Design infoworld-infoworld interface.
- Design required security measures.
- Program machine-independent class library.
- Security assessment of the virtual machine and infohabitants.

Human-Infoworld Interface

The objective of this strand is to build the Human-Machine Interface for the infoworld and the infohabitants. This includes the settings of the infoworld and infohabitants (input interface), as well as the definitions and visualisation of the observables (output interface). It is crucial to be able to detect emergent behaviours and properties through this output interface.

The input interface will allow the user to define precisely the characteristics of the target infoworld, and the kind of infohabitants that will evolve in that world. For the infoworld, this includes the description of the time and space scales, the resources that are available to the infohabitants as well as the response of the infoworld to the existence and actions of the infohabitants. The design of the infohabitants will include their class, their genotype (what are they made of?), their phenotype, especially their interfaces with the infoworld (how do they act on their environment, and react to environmental changes?) as well as with the other infohabitants (how do they communicate?) and the diversity-modification operators (how do they evolve?).

Some basic building blocks will be chosen in some predefined list of standard types, then assembled and structured using simple graphical moves. This construction will be totally recursive, i.e. newly created building blocks can immediately be used among the original ones to build even more complex ones.

The output interface will allow the user to monitor different observables, at the infohabitant level, at the infoniche level, and at the infoworld level. Any feature defined in the input interface is eligible to become an observable, and should be made available either directly for each infohabitant or through statistical measures for the infoniches and the infoworld.

Candidate measures include those from standard statistics - from simple means and averages to Principal Component Analyses and non-linear multi-regressions, in order to detect emergent correlations. But more recent measures that were specifically designed and/or used in Evolutionary Computation will also be considered, addressing fitness landscape description, genetic diversity or operator usefulness, for example.

The user should be able to select any measure of any topic at any time and at any level. For instance, he can ask for some existing observables for a given infohabitant, or summaries of some observables for certain types of infohabitant at a given infoniche, or global summaries of such observables over the infoworld. All these features will then be displayed in real time, or stored to be later examined off-line.

As the chances are high that specific measurements will be required to assess and validate some early detected emergent properties, it should be again possible to easily directly program forgotten measures. Here again, the first beta-testers will be the partners working on WP 2, 3 and 4, whose reactions will in turn will result in modifications of the specifications of the output interface, thus pushing further the usability limits of the graphical interface.

A user-friendly mouse-driven input interface, covering most of possible current requirements for the properties of infoworlds and infohabitants will allow easy and quick experimentation. A set of predefined simple examples, as well as some tutorial-like user guide will contribute greatly to the wide dissemination of the whole DREAM package.

Similarly, the expected result from the graphical output interface is to facilitate the detection of emergent properties of the infoworlds/infohabitants. It is well known that graphical plots can make things more visible. The underlying hope is that yet unknown emerging properties will be first detected by human analysis of a very small number of infohabitants. The subsequent possibility of immediate and easy monitoring of interesting measures of a higher grain (without having to compile or reprogram anything) allows one easily to confirm (or deny) early hypotheses.

Note that all facilities offered through the graphical input and output interface will nevertheless be available through some open library using standard programming languages - and this might be especially useful for the partners working on WP 2, 3 and 4. Reciprocally, these first applications will most probably retro-act on the design of the interface, pointing out the misconception errors.

Identifiable sub-tasks for workpackage 1 human-infoworld interface strand:

- Identify input interface user requirements
- Design input user interface
- Program prototype input user interface
- Define observables at three levels
- Identify output interface user requirements
- Design output user interface
- Program prototype output user interface

Workpackage 2 - Economic and Social Behaviour

The objective of this workpackage is to apply the DREAM as a simulator for human societies, focusing on economic and social aspects and restricted to macro-scale analyses. This simulator is meant to evaluate a given policy (direct problem), and to support the design of new policies (inverse problem).

A typical example might concern road traffic load balancing: the direct problem is to determine how the construction of a new road will impact the overall traffic; the inverse problem deals with designing new roads (or toll policies etc.) in order to minimise the overall travel time of the population under a range of load conditions.

Another example application concerns tax and welfare policies. The infoworld can be initialised with infohabitants representing groups that differ regarding their wealth status and wealth-gaining behaviour. The effects of various tax collection and redistribution (welfare) policies can then be monitored on-line and aggregated in relevant statistics. An evolutionary approach also facilitates the emergence of individual responses to various policies, such as tax paying/not paying behaviour.

The evolutionary approach is well suited to modelling economic and social processes on the large scale: DREAM will allow one to simulate the actual behaviour of a huge number of infohabitants, as opposed on the one hand to econometric models dealing with distributions, and on the other hand with small discrete models. As individuals affect each other in achieving their goals, anticipate other individuals' choices and modify their own choices accordingly, evolution offers the infohabitants an opportunity to create bunches of "niches". This fragmentation of the milieu should allow more precise characterisations of the possible drifts of the infoworld (how could a sub-population side-step or subvert a general directive). Typically, any policy might produce some counter intuitive effects, due to the opportunism of economic/social agents.

The work in this project is based on the project partners' experiences with agent-based simulations following the research of Epstein and Axtell ("Growing Artificial Societies", MIT Press, 1996) and the "Bounded Rationality Model" described by H. Simon (MIT Press, 1982). Using a cellular-automata based approach with a regularly arranged, 2-dimensional spatial structure, numerous experiments have recently been conducted at Leiden University within a student project seminar on Evolutionary Economics, supervised by A. E. Eiben and Thomas Baeck. In particular, the

experiments focused on an empirical investigation and comparison of various taxation schemes in trade networks. The implementation was based on the SWARM simulation software developed at the Santa Fe Institute.

At Ecole Polytechnique, two MSc theses in Evolutionary Sociology have been supervised by Michele Sebag and Marc Schoenauer since 1997: the theses focused on the modelling of car drivers with different behavioural preferences (competition-oriented, altruist, diversity-oriented) and the impact of the individual preference distribution on the overall traffic jam.

These simulations, although somewhat related to reality, suffered from the limitations of the model and the available computing power. In particular, too small a number of interacting agents seems to prevent the system from reaching a 'critical mass' where synergistic effects on the macroscopic level can be observed. Furthermore, some aspects in the individual or interaction models were forcedly simplified: In the trade network study, only von-Neumann or Moore-neighbourhoods have been considered, which means that individuals interact with only four or eight direct neighbours; furthermore they all follow the same strategy; In the traffic network case study, individuals plan their trajectory on the basis of the previous day traffic, and do not modify their trajectory on the fly. The models were thus severely restricted in contrast to the evolving diversity of behaviours in real-world societies.

This workpackage may also draw on work currently being carried out at Napier University into agent based modelling of commuters choosing their method of travel to work. Commuters are influenced in their choice by the current state of the environment (e.g. how busy the buses are) and also by social factors.

A DREAM model will consist of two parts: at the local level, the infohabitant is modelled through a set of possible actions, preferences and beliefs. At the global level, the infoworld is described by the communication and perception facilities, and the general information shared by the infohabitants. These notions are borrowed from multiple agent systems and artificial life on one hand, computational economy and management research on the other hand. The DREAM project will benefit from the close working relationship of Prof. Eiben with the economics department of the Free University of Amsterdam, and the privileged relationships between EEAAX at Ecole Polytechnique and the Management Research Centre in Ecole des Mines de Paris.

The first part in this work package is thus to provide accurate and robust simulators, in order to predict the behaviour of the population under a given policy/environment. Realistic test cases in the field of economic and social applications will be identified. The relevance of the models will be evaluated from their adequacy with observed scenarios (e.g. prediction of perturbations due to environmental changes).

The natural follow-up of such model is to determine the policy leading the infoworld into a target state (equilibrium, periodic, or even chaotic!). The second part of the work package is thus concerned with the policy optimisation. The interest of this second phase derives from the fact that the global optimum of the population is not necessarily reached when each infohabitant pursues its individual optimum. This discrepancy, contradicting the key axiom of classic economics (the "invisible hand" metaphor), arises most frequently in domains concerned with resources sharing (the Tragedy of the Commons).

The first task in the work will be a concise literature overview performed on related areas: agent-based computational economics, evolutionary economics and artificial life. This will provide a catalogue of approaches in current practice, relevant research questions and will indicate the cutting edge of present computational techniques. Particular attention will be given to the communication and migration aspects of all models, as these are expected to be a major innovation brought by the DREAM framework. A selection of modelling principles and specific research goals that will be adopted for this WP will conclude this overview.

The second task is to identify two realistic case applications and models in the field of economic and social studies. The models (for the infohabitants and the infoworld) are parameterised with the communication and migration facilities, and the level of anticipation of other infohabitants' actions. These models will be implemented in the general DREAM framework.

The third task is to evaluate the models regarding the simulator performances. The primary evaluation of the models will take into account their ability to describe relevant aspects of society (how realistic they are), and provide accurate predictions. These models will be used to compare different scenarios in different infoworlds, and the impact of the communication facilities and the degree of anticipation onto the dynamics of the whole system (both the transient and the asymptotic states will be considered).

The final task is to investigate the inverse problem aspects, i.e. the model usefulness in answering questions at policy forming level. The policy search space needs to be carefully delineated. Again, the influence of the different parameters of the model (communication facilities, migration rates) on the resulting optimal policy will be investigated.

It is expected that while working on these implementations several improvements of the general DREAM framework will be proposed. It is essential that these proposals be merged with similar findings within WP 3 and WP 4 and fed back to the highest design level of the whole software infrastructure.

Identifiable sub-tasks for workpackage 2:

- Survey previous work
- Identify two complementary test cases
- Implement the test cases on the DREAM
- Investigate the direct problem
- Investigate the inverse problem

Workpackage 3 - Distributed Data Mining

A clearly visible trend in the last decade is that more and more organisations are collecting and utilising more and more data. Storing, organising and effectively retrieving data can certainly provide improvements in management and operational activities. A higher level of support can be achieved by processing the data and discovering more or less hidden relationships among data records and attributes. Such activities, commonly called data mining, require advanced techniques from statistics and machine learning. Usually there are two technical bottlenecks data mining applications have to face: the huge amount of data (many records and/or many attributes), and the very complex, hardly comprehensible relationships between data features. The next generation of data mining tools has to be able to both types of problems. To put it simply, a high level of both efficiency and expressive power needs to be achieved simultaneously. The main objective of this workpackage is to use the DREAM framework to perform data mining efficiently, while maintaining a model syntax with a high expressive power.

Distributed data mining allows for a significant gain in efficiency compared to sequential approaches. Current distributed data mining applications usually split either the models or the data. In the master-slave model, partial hypotheses are tested against the whole data set. In the pipeline model the data is distributed, but the hypotheses are tested against every subset of the whole data. This approach leads to speedup if the different data subsets are evaluated in parallel, but still has a search dynamic identical to that of standard sequential data mining. The DREAM framework allows us to distribute both the data and the hypotheses. Infohabitants can represent partial hypotheses, and they can be partially evaluated on a subset of the whole dataset. The global communications among infohabitants will allow, for instance, the rapid elimination of unpromising infohabitants, while letting promising ones breed and migrate to other subsets of the dataset. Different models of distributed data mining will be implemented in the infoworld framework. The basis of the pursued

approach is to distribute both the data and the population of models trying to describe the data. A merger of techniques from distributed evolutionary computing and distributed data handling needs to be developed. The main objective is to create the technology to analyse very large amounts of data (millions of records).

Another strength of the DREAM based approach to data mining is the high flexibility concerning model formats. An evolving population of models is applied to create models that describe the given data at an appropriate level of accuracy. This, however, does not imply that we restrict ourselves to genetic programming - the most commonly practised evolutionary approach in data mining applications. Rather than seeing evolutionary data mining as a competitor to other approaches, we aim at coexisting and co-operating sub-populations of infohabitants of different styles, such as species of decision trees, ensembles of neural networks, rough data models etc. The two main tasks here are to prevent overfitting and to find the right balance between expressive power of the models (i.e. flexible formalisms facilitating high quality) and simplicity (facilitating "readability" to humans).

This implementation will be tested on very large real-world data sets from the area of marketing and finances. We expect that access to real world data will be only granted under clear security and confidentiality conditions. This workpackage will therefore also provide experience on such aspects of working within the DREAM framework.

It is expected that while working on these implementations several improvements of the general DREAM framework will be proposed. It is essential that these proposals be merged with similar findings within WP 2 and WP 4 and fed back to the highest design level of the whole software infrastructure.

Identifiable sub-tasks for workpackage 3:

- Survey existing distributed data-mining techniques and sampling mechanisms
- Design different partial rewards of hypotheses and aggregation procedures
- Implement the fully distributed model
- Run comparative validations on really large databases

Workpackage 4 - Distributed Scheduling

This is the third workpackage that aims to demonstrate proof-of-principle of the DREAM technology and infrastructure through its use for a real world application. In this case the application is the scheduling of distributed human resources using distributed evolutionary techniques. The requirement is to schedule the distributed human resources in a manner that uses those resources, and associated physical resources, in a more effective and efficient manner, and in a manner that improves the quality of life of the people involved.

The first task will be to discover the nature of the partial partitioning of distributed human resource scheduling problems, so that effective partitioning of the problem space between infohabititants and infohabitant communities can be achieved. Partial partitioning occurs in problem such as these when resources are link far more tightly to a particular group than to others outside the group, but there is not a total partitioning. For example, suppose we wish to schedule the meetings of all academics in Europe. Most meetings will involve academics from only one institution, however some meetings will involve an academic from another institution and occasionally meetings will involve people from several institutions. We will therefore investigate the possibility of scheduling by allowing different infohabitants to take ownership of different partial partitions of the problem (for example the schedule for a particular institution). The infohabitants will then and co-operate, negotiate and possibly trade to attempt to resolve conflicts between schedules.

Human resource scheduling is a multi-objective optimisation problem. There are generally a number of different competing objectives that need to be taken into account. For example, we may want to maximise the number of completely free days a person has, while minimising travel costs, and

maximising availability of people at each meeting. Research will therefore be carried out to investigate the possibility of different infohabitants having different objective functions, some thinking that free days is most important while others consider that travel costs are paramount. These different objective functions could also be applied to different infoniches, so that an infohabitant that has a good schedule so far as costs are concerned might not do so well if it travelled to an infoniche where costs were not considered particularly important.

Another aspect that will be considered is that of re-scheduling when changes occur. This will involve infohabitants renegotiating with each other when some aspect of the problem changes, for example somebody remembers that their partner's birthday is coming up and they cannot travel abroad on that day.

The final scheme will be tested on real world data, and the results of experiments published.

It is expected that while working on these implementations several improvements of the general DREAM framework will be proposed. It is essential that these proposals be merged with similar findings within WP 2 and WP 3 and fed back to the highest design level of the whole software infrastructure.

Identifiable sub-tasks for workpackage 4:

- Survey existing techniques for distributed scheduling
- Investigate partial partitioning
- Design adaptations of techniques for the DREAM environment
- Implement algorithm
- Investigate differing objective functions
- Test with real world data

Workpackage 5 - Evaluation and Redesign

The DREAM infrastructure is an iterative process since the initial prototype will inevitably have shortcomings. It is the purpose of this workpackage to implement an iterative process of redesign and rebuild. It is not possible to describe exactly the work that will be done at this stage, as it is dependent on the outcomes and progress of workpackages 2, 3 and 4.

The goal of this workpackage is to produce interim and final evaluation reports on the DREAM prototype as experienced in workpackages 2, 3 and 4 and redesign and rebuild the DREAM infrastructure to take account of these. The reports will pull together issues identified by workpackages 2, 3 and 4 and recommend appropriate action. The reports will also consider progress towards meeting the scientific objectives of the whole project.

Major issues will be addressed by redesign and re-implementation of the DREAM prototype, followed by re-implementation of software from workpackages 2, 3 and 4 in the light of the new design. Any software bugs or security issues will also be addressed.

At the end of this workpackage the final DREAM infrastructure will be ready.

Identifiable sub-tasks for workpackage 5:

- Identify infrastructure problems and bugs
- Produce interim evaluation report
- Produce final evaluation report
- For each problem:
  - Decide on course of action to solve problem
  - Update relevant documentation
  - Implement changes in prototype
  - Implement changes to applications to reflect changes to prototype.

Workpackage 6 – Documentation, Dissemination and Exploitation

There are two main goals of this workpackage. The first is to document the DREAM infrastructure to allow easy use both by those wishing to implement some system on the model and by those simply wishing to allocate their spare CPU time to the DREAM. The user documentation of the DREAM infrastructure will already have been completed to some extent in the process of the project. The main task here will be to make it complete and in a form suitable for publication as wide access.

The other main goal is to make sure that the project's research findings are widely disseminated and that exploitation routes are identified. While some research findings will be disseminated through refereed paper publications in international conferences and journals, the final dissemination of project results will be published in a book, edited by the co-ordinator and including contributions by each of the participants. The book will cover each of the research issues that are addressed by the project, and will include guidelines and user tutorials. Accompanying the book will be a CD-ROM containing all the software necessary to participate, either through use of the DREAM to solve some problem, or by offering spare computing resource or use by others.

The project's WWW pages will be finalised, and a summary of results published there, although it is expected that the pages will continue to evolve after the end of the funded project.

While this workpackage does not include actual implementation of exploitative applications, work will be done to identify possible exploitation routes. At an early stage in the workpackage, (i.e. as soon as the DREAM prototype is complete) organisations that may benefit from the DREAM will be identified and contacted. Their feedback on the DREAM approach will be sought, and discussions about exploitation opportunities will be held.

Identifiable sub-tasks for workpackage 6:

- Produce DREAM documentation.
- Produce book.
- Finalise WWW pages.
- Identify exploitation routes.

Workpackage description

Workpackage number :	1						
Start date or starting event:	Month 0						
Participant number:	1	2	3	4	5	6	7
Person-months per participant:	10.5	14	14	10	14	10.5	4

Objectives

To create a methodology for designing infohabitants and to abstract their common characteristics so that they can be later evolved within infoworlds using virtual machines.

To investigate the relationship between hard resources and infohabitant currency and fitness.

To provide a unified object framework for evolutionary methods.

To allow evolutions of infoworlds long with their infohabitants.

The design and define the infoworlds in which the infohabitants are going to evolve, and their implementation on hardware, and address related issues of security.

To address to problems of accounting for CPU time used and offered by infohabitants and their owners, and the emergent economy of resources that might develop.

To build the Human-Machine Interface for the infoworld and the infohabitants.

Description of work

This workpackage is concerned with the construction of a prototype DREAM infrastructure. The workpackage is led by Napier University, but four strands have been identified, each of which will be led by one of the other participants. These strands are: methodology (leader – UL/FUA), infoworld evolution (leader - UNIDO), infoworld properties (leader ACT-UGR) and human-infoworld interface (leader EEAAX).

In the methodology strand we will concentrate on the definition of infohabitants and infoworlds as objects. The infohabitant/infohabitant, infoworld/infoworld and infohabitant/infoworld interfaces will be defined.

In the infoworld evolution strand we will concentrate on the evolution both of infohabitants and their infoworlds. A unified framework for evolution will be developed which includes all major elements of evolutionary computing.

In the infoworld properties strand we will consider the interface between infoworlds and the physical machines on which they run.

In the human-infoworld interface strand we will consider both the input and output interfaces between the user and the infoworlds, and infohabitants.

Deliverables

D2 – Architectural Overview of the DREAM (month 10)

D3 – Interim DREAM Prototype (month 11)

D4 – DREAM Prototype (month 13)

Milestones and expected result

- Completion of the survey of existing solutions
- Resolution of matters relating to hard and soft currency, and relationships with fitness.
- Existing evolution operators survey
- Key infohabitant behaviours and interactions identified
- Key island interconnection attributes identified
- Key population and migration strategies identified
- Definition of new operators based on above
- Design of infoworld interface, including infoworld-infoworld and infoworld-host machine.
- Machine-independent class library to be able to program infohabitants and infoworlds in several languages. Will be also licensed as open source under the GPL.
- Security assessment of the virtual machine and infohabitants.
- Implementation of security measures.
- Set up of a distributed code repository that holds the source for the various DREAM software packages, and to which all the DREAM researchers can contribute.
- Input interface user requirements identified
- Input user interface designed
- Prototype input user interface programmed
- Observables defined
- Output interface user requirements identified
- Output user interface designed
- Prototype output user interface programmed

Workpackage description

Workpackage number :	2				
Start date or starting event:	Month 14				
Participant number:	7	1	3	5	6
Person-months per participant:	5.2	3.9	5.2	5.2	3.9

Objectives

To apply the DREAM as a simulator for human society focusing on economic and social aspects. Economic and social processes emerge from a huge number of individuals effecting each other in achieving their goals. We will use concepts from agent-based computational economics and sociology, and from artificial life to offer a way to create more realistic models than current technology supports. The main objectives are twofold: developing realistic models and utilising such models to answer questions arising in economy and sociology. Example applications will be developed (e.g. in road traffic load balancing and welfare policy) firstly to study the effect of different parameters (e.g. selfish vs. competition oriented behaviours, level of anticipation or memory capacities of the infohabitants, etc.) on the global dynamics of the infoworld (both transient and asymptotic), and secondly to define optimal policies (e.g. toll or tax regimes) to guide the infoworld toward some target dynamic state.

Description of work

A concise literature overview will be performed on related areas such as agent-based computational economy, evolutionary economy, artificial life. This will provide a catalogue of approaches in current practice, relevant research questions and will indicate the cutting edge of present computational techniques and will provide a selection of modelling principles and specific research goals that will be adopted .

Next, two test models will be chosen, and implemented in the general DREAM framework. The primary evaluation of the models will take place by assessing their ability to describe relevant aspects of society (how realistic they are).

Last, the mechanism to solve the inverse problem will be set up in the DREAM framework, and tested on the two chosen test cases to answer questions at policy forming level, such as what tax system is the most fair, or what policies facilitate co-operation among members of society.

It is expected that while working on these implementations several improvements of the general DREAM framework will be proposed. It is essential that these proposals be merged with similar findings within WP 3 and WP 4 and fed back to the highest design level of the whole software infrastructure through WP5.

Deliverables

D5: Overview of computational models of societies (month 15)
D7: Draft Report on the emergence of behaviour patterns in the two instantiations (month 23) (final version of report is produced in WP5)

Milestones and expected result

- Survey of previous work
- Identification of two complementary test cases
- Implementation of the test cases on the DREAM
- Results of investigation of the direct problem
- Results of investigation of the inverse problem

Workpackage description

Workpackage number :	3		
Start date or starting event:	Month 14		
Participant number:	2	3	7
Person-months per participant:	5.2	5.2	5.2

Objectives

The main objective is to support the analysis of very large amounts of data (millions of records). The technology should meet three sub-objectives, efficiency of the data mining process, furthermore high accuracy and transparency of the models that are developed. This latter objective is crucial for having the models validated and accepted by experts and/or users in any given application area.

Description of work

An evolving population of models will be applied to create models that describe the given data at an appropriate level of accuracy. For the sake of efficiency, the implementation will be based on distributed data mining concepts. The basis of the pursued approach is to distribute both the data and the population of models trying to describe the data. A merger of techniques from distributed evolutionary computing and distributed data handling needs to be developed. For the sake of high quality models, the population will contain models (infohabitants) with different internal representation (e.g. neural nets, decision trees). Preventing overfitting is a major task here. Additionally, model formalisms need to be developed that combine flexibility (facilitating high quality) and simplicity (facilitating "readability" to humans). This implementation will be tested on very large real-world data sets from the area of marketing, finance and economics.

It is expected that while working on these implementations several improvements of the general DREAM framework will be proposed. It is essential that these proposals be merged with similar findings within WP 2 and WP 3 and fed back to the highest design level of the whole software infrastructure through WP 5.

Deliverables

D8: Draft Description of the distributed-population-distributed-data framework and report on the experiments (month 23) (final version of report is produced in WP5)

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Milestones and expected result

- Survey of existing distributed data-mining techniques and sampling mechanisms
- Novel distributed-population-distributed-data framework.
- Design of a flexible and transparent model formalism.
- Design of different partial rewards of hypotheses and aggregation procedures
- Implementation the fully distributed model
- Results of comparative validations on really large databases

Workpackage description

Workpackage number :	4			
Start date or starting event:	Month 14			
Participant number:	1	2	5	6
Person-months per participant:	3.9	5.2	5.2	3.9

Objectives

- To demonstrate proof-of-principle of the DREAM technology and infrastructure through its use for a real world application.
- To schedule distributed human resources using distributed evolutionary techniques within the DREAM infrastructure.
- To schedule those distributed human resources in a manner that uses those resources, and associated physical resources, in a more effective and efficient manner, and in a manner that improves the quality of life of the people involved.

Description of work

The first task will be to discover the nature of the partial partitioning of distributed human resource scheduling problems, so that effective partitioning of the problem space between infohabititants and infohabitant communities can be achieved. Partial partitioning occurs in problem such as these when resources are link far more tightly to a particular group than to others outside the group, but there is not a total partitioning. We will therefore investigate the possibility of scheduling by allowing different infohabitants to take ownership of different partial partitions of the problem (for example the schedule for a particular institution). The infohabitants will then and co-operate, negotiate and possibly trade to attempt to resolve conflicts between schedules.

Human resource scheduling is a multi-objective optimisation problem. There are generally a number of different competing objectives that need to be taken into account. Research will therefore be carried out to investigate the possibility of different infohabitants having different objective functions. These different objective functions could also be applied to different infoniches, so that an infohabitant that has a good schedule according to one objective might not do so well if it travelled to an infoniche where that objective were not considered particularly important.

Another aspect that will be considered is that of re-scheduling when changes occur. This will involve infohabitants renegotiating with each other when some aspect of the problem changes.

It is expected that while working on these implementations several improvements of the general DREAM framework will be proposed. It is essential that these proposals be merged with similar findings within WP 2 and WP 4 and fed back to the highest design level of the whole software infrastructure through WP 5.

Deliverables

D9 – Draft Report on the most effective way to partition distributed human resource scheduling problems according to the partitioning of the problem and the distribution of the data, and results of experiments with real data (month 23) (final version of report is produced in WP5)

Milestones and expected result

- Specification of how existing techniques can be adapted for distributed scheduling using the DREAM
- Implementation of distributed scheduling evolutionary algorithm
- Software for distributed human resource scheduling using the DREAM
- Tests with real world data

Workpackage description

Workpackage number :	5					
Start date or starting event:	Month 14					
Participant number:	5	1	2	3	7	6
Person-months per participant:	7.6	5.7	7.6	7.6	7.6	5.7

Objectives

- To identify the major issues concerning the DREAM prototype raised during the work of workpackages 2,3, and 4.
- To evaluate the extent to which the objectives of workpackage 1 have been met.
- To evaluate the extent to which the scientific objectives of the whole project are likely to be met.
- To produce interim and final evaluation reports on the DREAM prototype as experienced in workpackages 2, 3 and 4 and and redesign and rebuild the DREAM infrastructure to take account of these.
- To re-implement software from workpackages 2, 3 and 4 in the light of the new design
- To implement any features of workpackages 2, 3 and 4 which were not originally implemented due to errors in the original DREAM design.

Description of work

It is not possible to describe exactly the work that will be done at this stage, as it is dependent on the outcomes of workpackages 2, 3 and 4.

Interim and final evaluation reports on the DREAM prototype as experienced in workpackages 2, 3 and 4 will be produced. The reports will pull together issues identified by workpackages 2, 3 and 4 and recommend appropriate action. The reports will also consider progress towards meeting the scientific objectives of the whole project.

Major issues will then be addressed by redesign and re-implementation of the DREAM, followed by re-implementation of applications where necessary.

In this stage, also the majority of the bugs and security problems of the existing implementation will be addressed and eliminated.

Deliverables

D6: Interim evaluation report on the general DREAM framework and methodology (month 19)

D11: Evaluation report on the general DREAM framework and methodology. (month 25)

D12: The final DREAM infrastructure, including final versions of the application reports D7, D8 and D9 (month 32)

Milestones and expected result

- Specifications for required changes
- Changes to documentation to reflect prototype changes
- Changes to software

The final DREAM infrastructure.

Workpackage description

Workpackage number :	6					
Start date or starting event:	Month 14					
Participant number:	1	2	3	7	5	6
Person-months per participant:	3	4	4	4	4	3

Objectives

To document the DREAM infrastructure to allow easy use both by those wishing to implement some system on the model and by those simply wishing to allocate their spare CPU time to the DREAM.

To disseminate widely the research findings of the project.

To identify possible avenues for exploitation at an early stage.

Description of work

The user documentation of the DREAM infrastructure will already have been completed to some extent in the process of the project. The main task here will be to make it complete and in a form suitable for publication and wide access.

The project's WWW pages will be finalised, and the major results published there, although it is expected that the pages will continue to evolve after the end of the funded project.

While some research findings will be disseminated through refereed paper publications in international conferences and journals, the final dissemination of project results will be by the publishing of a book, edited by the co-ordinator and including contributions by each of the partic ipants. The book will cover each of the research issues that are addressed by the project, and will include guidelines and user tutorials. Accompanying the book will be a CD-ROM containing all the software necessary to participate, either through use of the DREAM to solve some problem, or by offering spare computing resource or use by others.

While this workpackage does not include actual implementation of exploitative applications, work will be done to identify possible exploitation routes. At an early stage in the workpackage, (i.e. as soon as the DREAM prototype is complete) organisations that may benefit from the DREAM will be identified and contacted. Their feedback on the DREAM approach will be sought, and discussions about exploitation opportunities will be held.

Deliverables

D10 – Interim Report on contacts and progress made with companies with regard to possible exploitation (month 23)

D13- DREAM User Documentation (month 35)

D14 - Final WWW pages describing the project and its results (month 35)

D15 - Book containing research results with CD-ROM (month 35)

D16 – Report on contacts and progress made with companies with regard to possible exploitation (month 35)

Milestones and expected result

- Individual chapters of book

Workpackage description

Workpackage number :	7	
Start date or starting event:	Month 0	
Participant number:	1	6
Person-months per participant:	9	9

Objectives

To co-ordinate the administrative and scientific work of the project.

To ensure that the management plan is carried out.

To ensure that the interface with the Commission runs smoothly.

To continually evaluate the project's progress against project and workpackage objectives – quickly reporting any problems to management.

To provide evaluation reports to the Commission as required

Description of work

This workpackage must provide co-ordination of administrative and scientific work, including the arranging and recording of meetings. Providing the interface with the Commission in all matters. To provide publicity and information about the project, both to the media and globally through the World Wide Web.

Staff in this workpackage are responsible for the evaluation of the project in a continuous fashion through assessment against both project objectives and against the objectives of individual workpackages. They should monitor the reaching of milestones, and the delivery of deliverables, and report to management is any problem arises or is foreseen.

Deliverables .

D1 Project Presentation Web Site (month 1)

Milestones and expected result

Provision of reports as required to the Commission.

9.4 Deliverables List

Deliverables list

Deliverable No[8]	Deliverable title	Delivery date [9]	Nature [10]	Dissemination level [11]
D1	Project Presentation Web Site	1	O	PU
D2	Architectural Overview	10	R	PU
D3	Interim DREAM prototype	11	O	PP
D4	DREAM Prototype	13	P	PP
D5	Society Models Overview	15	R	PU
D6	Interim Evaluation Report	19	R	PP
D7	Draft Behaviour Modelling Report	23	R	PU
D8	Draft Distributed Data Mining Report	23	R	PU
D9	Draft Distributed Scheduling Report	23	R	PU
D10	Interim Exploitation Report	23	R	PP
D11	Evaluation Report	25	R	PP
D12	Final DREAM Infrastructure and Application Reports	32	O	PU
D13	User Documentation	35	R	PU
D14	Final WWW Pages	35	O	PU
D15	Book and CD-ROM	35	O	PU
D16	Exploitation Report	35	R	PP

[8] Deliverable numbers in order of delivery dates: D1 – Dn

[9] Month in which the deliverables will be available. Month 0 marking the start of the project, and all delivery dates being relative to this start date.

[10] Please indicate the nature of the deliverable using one of the following codes:

R = Report
P = Prototype
D = Demonstrator
O = Other

[11] Please indicate the dissemination level using one of the following codes:

PU = Public
PP = Restricted to other programme participants (including the Commission Services).
RE = Restricted to a group specified by the consortium (including the Commission Services).
CO = Confidential, only for members of the consortium (including the Commission Services).

9.5 Project Planning and Timetable

Whole Project	%	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
WP1 – Prototype Construction	91.7																																				
WP2 – Economic and Social Behaviour	30																																				
WP3 – Distributed Data Mining	20																																				
WP4 – Distributed Scheduling	23.3																																				
WP5 – Evaluation and Redesign	9.2 73.3																																				
WP6 – Documentation, Dissemination and Exploitation	9.2 82..5																																				
WP 7 – Project Co-ordination and Management	8.3																																				

Napier	%	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
WP1 – Prototype Construction	75																																				
WP2 – Economic and Social Behaviour	30																																				
WP4 – Distributed Scheduling	30																																				
WP5 – Evaluation and Redesign	7.5 60																																				
WP6 – Documentation, Dissemination and Exploitation	7.5 67.5																																				
WP 7 – Project Co-ordination	25																																				

UNIDO	%	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
WP1 – Prototype Construction	**100**																																				
WP3 – Distributed Data Mining	**40**																																				
WP4 – Distributed Scheduling	**40**																																				
WP5 – Evaluation and Redesign	**10** **80**																																				
WP6 – Documentation, Dissemination and Exploitation	**10** **90**																																				

EEAAX	%	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
WP1 – Prototype Construction	100																																				
WP2 – Economic and Social Behaviour	40																																				
WP3 – Distributed Data Mining	40																																				
WP5 – Evaluation and Redesign	10 80																																				
WP6 – Documentation, Dissemination and Exploitation	10 90																																				

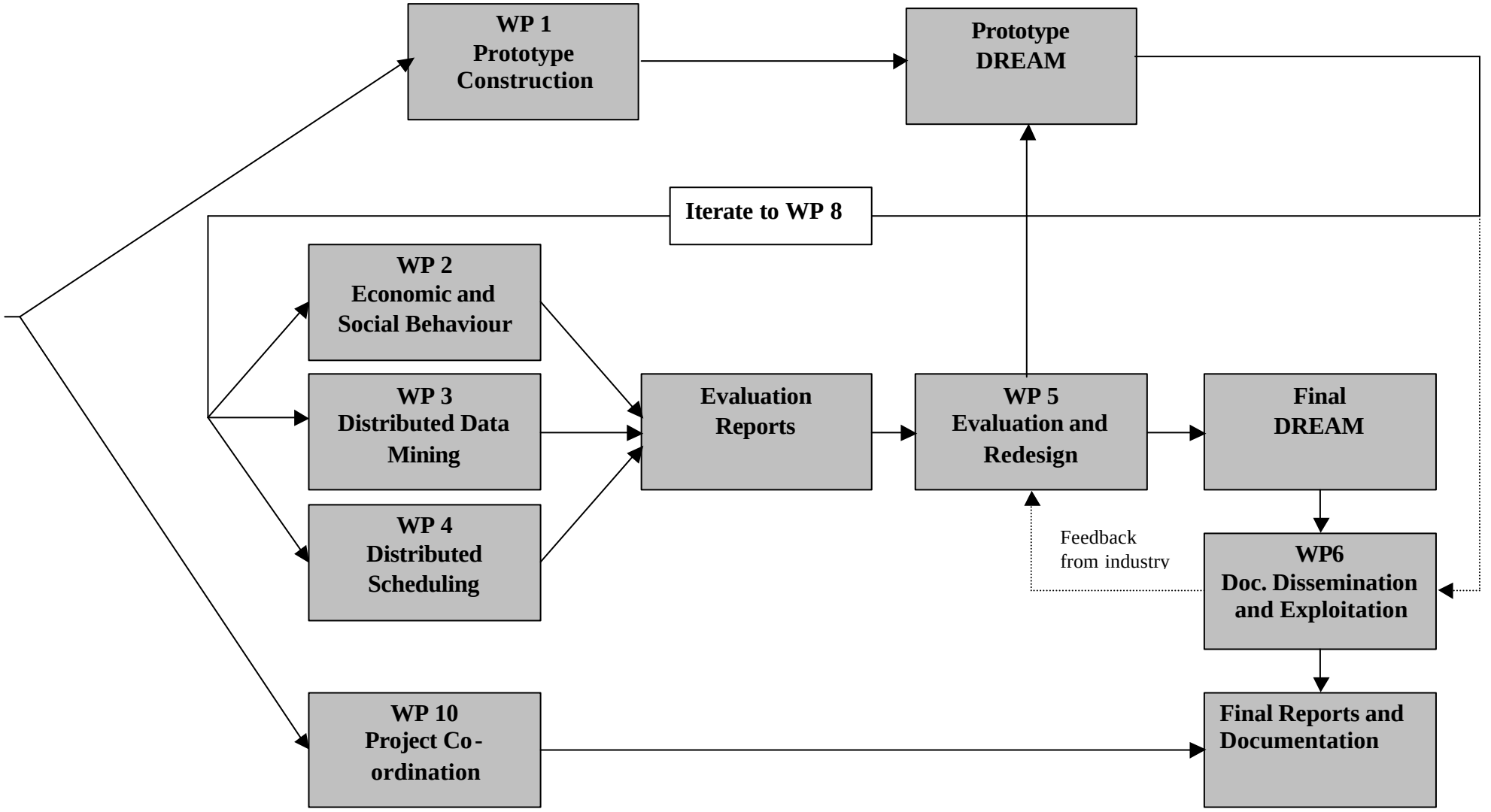
UL	%	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
WP1 – Prototype Construction	**100**																																				

ATC-UGR	%	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
WP1 – Prototype Construction	**100**																																				
WP2 – Economic and Social Behaviour	**40**																																				
WP4 – Distributed Scheduling	**40**																																				
WP5 – Evaluation and Redesign	**10** **80**																																				
WP6 – Documentation, Dissemination and Exploitation	**10** **90**																																				

SB	%	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
WP1 – Prototype Construction	75																																				
WP2 – Economic and Social Behaviour	30																																				
WP4 – Distributed Scheduling	30																																				
WP5 – Evaluation and Redesign	7.5 60																																				
WP6 – Documentation, Dissemination and Exploitation	7.5 67.5																																				
WP 7 – Project Co-ordination and Management	25																																				

FUA	%	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
WP1 – Prototype Construction	100																																				
WP2 – Economic and Social Behaviour	40																																				
WP3 – Distributed Data Mining	40																																				
WP5 – Evaluation and Redesign	10 80																																				
WP6 – Documentation, Dissemination and Exploitation	10 90																																				

9.6 Graphical Presentation of Project Components



9.7 Project Management

As project co-ordinator, Napier University 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 Napier University. Napier University's role as co-ordinator will be assisted in equal effort by South Bank University.

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. Each member will provide a progress and budget report to the co-ordinator 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 Management Committee is expected to meet five times in the course of the project at approximately equal intervals, but the frequency may change according to circumstances. It is expected that one meeting will be held at most of the participating institutions, although other venues may prove more efficient, for example, if several members are already attending the same conference.

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 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. Each member will provide a scientific progress report to the co-ordinator 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.

It is anticipated that the Scientific Committee will meet five times during the course of the project at approximately equal intervals, but the frequency may change according to circumstances. It is expected that one meeting will be held at most of 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.

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.

In addition to intra-project communication, it is expected that inter-project communication can be established between all the projects contributing to the Universal Information Ecosystem. The nature of these communications will not be clear until it has been decided which projects will run, and if a co-ordinating network will be established. However, this project has made provision in its budgets for travel and subsistence to maintain links and share ideas and plans with other related projects.

10. Clustering

It is anticipated that three other projects will be funded under the Universal Information Ecosystems proactive initiative. These are:

- ALFEBIITTE
- ICITIES
- DIET

Much co-operation is expected between the projects. Communication will largely be electronic, although some funds have been set aside for face-to-face meetings.

The most important way in which the DREAM project can benefit from the other projects is through their knowledge and experience with the simulation of societies. Working with the other projects on this matter will form part of the initial work of workpackage 2. The most important way in which other projects can benefit from the DREAM is for them to use its infrastructure as a testbed for their ideas. This will also benefit the DREAM project as it will provide further feedback on openness and effectiveness.

It is anticipated that further avenues for co-operation will be discovered throughout the lifetime of the projects.

11. Other Contractual Conditions

Travel and subsistence funding has been set aside for dissemination activities. This funding is ring-fenced and should not be used for other purposes. The amount over the three-year period is €6,667 for Napier University, €3,333 for South Bank University, €1,036 for Leiden University, €3,064 for Free University Amsterdam and €5,000 for each other partner.

12. Supplementary Reports and Concertation Activity: Other action-specific activity

None

Appendix A – Consortium Description

The participants in this proposal are: Napier University, Scotland (Napier) the co-ordinator; University of Dortmund, Germany (UNIDO), Ecole Polytechnique, France (EEAAX); Leiden University, The Netherlands (UL); University of Granada, Spain (ATC-UGR); South Bank University, England (SB) and Free University Amsterdam, The Netherlands (FUA). Each of the participants has a long history of research in the area on evolutionary computing and plays a major role in the Network of Excellence in Evolutionary Computing (EvoNet).

In addition to this, each participant has some special expertise to offer the consortium, which is of particular benefit to the DREAM project:

- Napier University - Human resource scheduling, behaviour modelling, parallel systems.
- Dortmund University - Self-adaptive evolution systems, simulation.
- Ecole Polytechnique - Interfaces to evolving systems, machine learning, simulation of economic behaviour.
- Leiden University - Artificial life, data mining, evolutionary economics.
- University of Granada - EC software libraries, artificial life, Internet applications.
- South Bank University - Evolving systems, behaviour modelling.
- Free University Amsterdam - Artificial life, data mining, evolutionary economics.

Each participant is a major representative of evolutionary computing research in their own country and so the consortium is well placed to develop open and universal systems that will have a wide take-up across Europe.

EvoNet, the Network of Excellence in Evolutionary Computing, was set up in February 1996. The current contract expires in March 2000 and a proposal for extension will be made under FPV. The EvoNet network includes the key players actively using evolutionary computation techniques in Europe, collectively encompassing a wide body of knowledge and expertise. Managed by a 24-member Management Board, many activities are delegated to five Committees: Executive, Training, Research, Industrial Liaison, Electronic Communications. In addition, there are 11 specialist Working Groups providing a specific focus for collaborative research and development in particular fields. These are composed of researchers and practitioners with specialist expertise and industrial experience from a variety of application domains, including Evolutionary Computation in Telecommunications, Aerospace, Financial Applications, Scheduling and Time-tabling, Image Analysis and Signal Processing, Engineering Design, Systems, Control and Drives Industry, Dynamic Optimisation, Evolutionary Electronics, Evolutionary Robotics, Genetic Programming. Membership of EvoNet has trebled in three years, growing to 150 nodes (450 individuals) in June 1999. Napier University is the co-ordinating node of EvoNet and handles all of the network administration, and manages the EvoNet website (http://www.dcs.napier.ac.uk/evonet/) and quarterly newsletter, EvoNews. There are two full-time staff (Administrator and Technical Manager) based at the co-ordinating node in addition to three part-time committee assistants based at the University of Granada, Leiden University, and the University of Dortmund.

Project Personnel

All of the participants are using the additional cost model. The person months specified in the workplan therefore refer to additional personnel who will be employed by the project. For each institution there is a *principal investigator* who will give approximately 20% of his or her time to the project in a supervisory role. This time is given freely by the participants and no charge is made to the project for it.

Other personnel mentioned is the participant descriptions will be available to lend their expertise to the project when required, but will not formally allocate time to the project.

In addition to the personnel employed by the participating institutions, Thomas Baeck from the Informatik Centrum Dortmund will work closely with the University of Dortmund team and contribute to its supervisory effort. He will give supervisory and consultative time freely to the project. In order to allow his involvement in project management meetings, his travel and subsistence expenses will be paid by the University of Dortmund, and from its travel and subsistence budget.

Dr. Thomas Baeck received a Ph.D. degree in Computer Science in 1994, both from the University of Dortmund, Germany. In 1995, he received Best Dissertation award of the German Association for Computer Science (GI) for his Ph.D. thesis on evolutionary algorithms. Dr. Baeck is Director at the Centre for Applied Systems Analysis within the Informatik Centrum Dortmund (Germany), an independent Research and Software Development Company, since 1996. He also serves as an Associate Professor in the Computer Science Department of Leiden University, The Netherlands. He is author of the book Evolutionary Algorithms in Theory and Practice co-editor-in-chief of the Handbook of Evolutionary Computation, and associate editor of the journals Evolutionary Computation and IEEE Transactions on Evolutionary Computation.

Napier University (Napier)

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 research and development strengths of the school centre around three broad areas; Evolutionary Computing, Human-Computer Interaction, and Database and Object Systems. With an annual research grant income of over £400,000 and a staff complement of some 10 active researchers, the research side of the School's activities is innovative and vibrant. The School is involved with three projects funded by the UK research councils and with four EC projects.

The **Evolutionary Computing Research Group** undertakes research in evolutionary computing and its applications. Its main focus on the theoretical side is on the development and use of statistical metrics to characterise and transform fitness landscapes. Self-adaptive and tracking techniques are being developed to improve evolutionary search. Combining evolutionary search with machine learning is being investigated as well as algorithms based on symbiogenesis (which allow co-evolving and co-dependent species to merge into a single species). The main application areas for the group are: timetabling and scheduling, evolvable hardware and evolutionary electronics, traffic control in both electronic and road networks, computer software optimisation and game playing strategies. The group co-ordinates the main European research network in the field, EvoNet, and participates in the European network on genetic algorithms in design engineering, INGENET.

The group is involved with research into modelling and simulation of many kinds, including evolving of producers and consumers, pedestrian behaviour, commuter mode-of-travel choice using agents and road traffic flow.

Key staff members for this project are:

Principal Investigator: Ben Paechter is a lecturer in the School of Computing. He leads the work on the application of evolutionary computing to human resource scheduling. Together with colleagues he has built an evolutionary timetabling system for Napier University which is used to optimise the timetabling of its 2000 weekly events. He has extensive experience in this area and has published a number of papers at international level. He Chairs the EvoNet Working Group in Scheduling and Timetabling, and is a Member of the Steering Committee of PATAT (Practice and Theory of Automated Timetabling). He has served on the programme committees of several international conferences and has reviewed papers for a number of international journals.

Jon Kerridge has been Professor of Computing at Napier University since 1996. His main research area is parallel systems applied to a variety of application areas. During the 1990's he was primarily researching the implementation of high performance parallel database machines. More recently, his interests have moved on to the modelling of pedestrian movement in urban spaces. He has implemented new parallel synchronisation primitives that permit efficient event driven modelling and access to shared data structures. He is currently investigating the use of a set of parallel primitives that have been incorporated into Java which permit secure, reliable and efficient parallel process implementation.

Universitaet Dortmund (UNIDO)

The Chair of Systems Analysis (LS 11) at the University of Dortmund, Department of Computer Science, is headed by Prof. Dr-Ing. H.-P.Schwefel, one of the two inventors of evolution strategies, a branch of evolutionary computation.

The main technical fields of expertise of the research group are: Evolution strategies and other evolutionary algorithms: theory, algorithmic foundations, applications; classical optimisation algorithms; coarse-grained and fine-grained parallel computing; modelling and simulation; data analysis and time series prediction; non-linear dynamics; genetic programming and artificial life.

Founded in 1985 by Prof. Schwefel, the research group has steadily grown and is now, with one associate professor and more than 14 people (3 post-docs, 11 doctoral students, plus administrative staff), one of the largest centres of expertise for evolutionary computation in the world. Since 1990, members of the group have contributed to all the major world-wide scientific events in evolutionary computation, either as members of the program committee or by organising or co-organising the meetings. Under the initiative of Prof. Schwefel, the biannual conference series “Parallel Problem Solving from Nature (PPSN)” started in 1990 with an event in Dortmund and since then has been organised in Europe every second year.

Research projects of the LS 11 group are funded from various sources, including the DFG (Deutsche Forschungsgemeinschaft), the VW foundation, the German Ministry for Research, Science, and Technology (BMBF), and the European Union. These projects cover both theoretical and practical aspects of evolutionary computation, but also of the other focus points mentioned above. At the European level, the group is a member of the EvoNet Network of Excellence.

Concerning industrial applications, the chair of systems analysis co-operates closely with the Informatik Centrum Dortmund (ICD), where Prof. Dr. Thomas Baeck is head of the department “Center for Applied Systems Analysis'”. Industrial applications in the above mentioned technical fields of expertise are conducted within this group, with business partners such as Siemens AG, Lufthansa AG, and the Dutch Ministry of Transport, Public Works and Water Management. In addition to these activities, the ICD is also a member of the European thematic network INGENET. By their co-operation, both groups achieve synergies by pushing recent results from research into practical applications and by challenging the researchers with applications of practical relevance.

Key staff members for this project are:

Principal Investigator: Prof. Dr.-Ing Hans-Paul Schwefel holds the chair of Systems Analysis as a Full Professor at the Department of Computer Science of the University of Dortmund since 1985. He is one of the inventors of evolution strategies. He is President of the Informatik Centrum Dortmund since 1989, and Speaker of the Sonderforschungsbereich (``Collaborative Research Center") "Design and management of complex technical processes and systems by computational intelligence methods" since 1996. Dr.-Ing. Schwefel is author of the book Evolution and Optimum Seeking , member of the editorial boards of “Evolutionary Computation” and “BioSystems”, and associate editor of the “IEEE Transactions on Evolutionary Computation".

Ecole Polytechnique - Centre de Mathématiques Appliquées (EEAAX)

The node denoted as "EEAAX" is the Artificial Evolution and Machine Learning Team at Ecole Polytechnique. It is the largest French group working in the field of Evolutionary Computation. Today EAAX's staff includes 3 permanent researchers, 5 PhD students and one post-doc, while four PhDs have been defended in the last 3 years.

Including researchers from both the Applied Maths and the Solid Mechanics departments of the most prestigious French "Engineering Schools", EEAAX team is mostly working on evolutionary optimisation of numerical problems, including constraint handling and multi-objective optimisation, with applications ranging from inverse problems in Structural Mechanics and Chemical Engineering, design problems in Optics and Electromagnetism, and combinatorial problems in Air Traffic Control. Some of these applications were done with industrial cooperation involving companies such as Thomson RCM, IFP, Eurocontrol, CEA or the French Ministry of Industry (Eureka project).

Of particular interest with respect to the DREAM project, EEAAX Evolutionary Software (written in C++) is publicly available on the Web, and is being used by many French researchers in EC. EEAAX is also involved in the recently funded project "EvoLab" together with the "Fractales" group at INRIA. EvoLab's aim is to build a user-friendly interface in the domain of Evolutionary Computation. One basic component of this project is the EO library whose development started at the University of Granada (another partner of the DREAM proposal). Finally, EEAAX is involved in a collaboration with the "Ecole de Paris" (Management research center, Ecole des Mines de Paris). In that context, M. Sebag has supervised some MSc theses evolving drivers' behaviours and studying their consequences on the global traffic.

Key staff members for this project are:

Principal Investigator: Marc Schoenauer has a PhD in Numerical Analysis (1980) and the "Habilitation" in ComputerSciences - Evolutionary Computation 1997. Charge de Recherche 1st class of CNRS (French National Research Centre) since 1980 at CMAP (the Applied Maths Laboratory) at Ecole Polytechnique, he has been working in the field of Evolutionary Computation since the early 1990s. He is the founding president of Evolution Artificielle Society, responsible for the Evolution Artificielle conference series since 1994. He is a member of numerous program committees of international conferences (co-program chair of PPSN'98, technical chair of CEC99 and general chair of PPSN2000 in Paris). He is associate editor of the IEEE Transactions on Evolutionary Computation and of the Genetic Programming and Evolvable Hardware Journal. H serves on the IEEE Technical Committee on Evolutionary Computation, on the PPSN Steering Committee, on the ISGA Council, and on the Executive Committee of the European Network of Excellence on evolutionary computation (EvoNet) since its origination in 1996.

Michele Sebag passed two DEAs (French post-grade), in Numerical Analysis (1980, UniversityPierre et Marie Curie) and in Economy (1985, University of Paris Dauphine), a PhD in Computer Science - Machine Learning at University Paris-Dauphine (1990), and the "Habilitation" in Computer Sciences - Machine Learning and Evolutionary Computation in 1997. She is Charge de Recherche at CNRS (French National Research Centre) since 1991, working at LMS (the Solid Mechanics Lab) at Ecole Polytechnique, involved in Machine Learning through the I&A team of University Orsay and participating to the seminars of the "Ecole de Paris" (organised by Michel Berry - Technology and Innovation Management, Ecole des Mines, Paris). She is member of numerous program committees of international conferences, and was general chair of the AFIA (French AI Society) set of conferences in 1999. She is associate editor of the IEEE Transactions on Evolutionary Computation and of the Genetic Programming and Evolvable Hardware Journal.

Universiteit Leiden (UL)

The Leiden Institute of Advanced Computer Science (LIACS) of the Leiden University is responsible for education and research. The Leiden Centre for Natural Computing (LCNC) encompasses two of the four chairs within LIACS. The LCNC staff have considerable experience and expertise in the areas of novel computing methods, such as evolutionary computing, neurocomputing, molecular computing, and artificial life. The three professors and staff members have an extensive publication list in these areas and have considerable project experience (ESPRIT and industry oriented as well). In particular, approximately ten members of the group are active in evolutionary research.

The main areas of activity related to the DREAM project are the following:

- Investigation of evolutionary operators, such as different mutation and recombination mechanisms.
- Studying self-adjusting evolutionary algorithms, that is, mechanisms to adjust the features driving an evolutionary process on-line, while running the same evolutionary process.
- Experimental studies and applications in constrained problems and data mining. Comparing evolutionary and other techniques for analysing data.
- Investigating dynamic population behaviour and the effect of communication in an artificial life context. Studying the influence of various environmental characteristics on population equilibrium and coexistence of species.
- Studies in the area of artificial societies. Based on a course on evolutionary economics, a team is working on simulating the effects of different tax regimes.

The key staff member for this project is:

Principal Investigator: Prof.dr. A. E. Eiben is the director of the evolutionary research programme within LIACS, together with prof.dr. Th. Baeck (who is partly affiliated with Dortmund and partly with Leiden). A. E. Eiben has been active in evolutionary computing (EC) from 1989 and has published dozens of research papers. He is a member of the editorial board of three international journals related to EC and (co-)editor of three books and two journal special issues on EC He has been organising committee member of six major international EC conferences (PPSN-V, EP'98, GECCO'99, FOGA 5, CEC2000 and PPSN VI) and programme committee member of several conferences. He is a member of the executive board of the European Network of Excellence in Evolutionary Computation (EvoNet). He has conducted projects in data mining for major Dutch banks, a multinational computer manufacturer, and an investment found. He is teaching courses on evolutionary computing and evolutionary economics, and is supervising three PhD students in the field of EC.

Universidad de Granada (ATC-UGR)

The Departamento de Arquitectura y Tecnologia de Computadores de la Universidad de Granada (ATC-UGR) was founded 2 years ago as a spin off of the Electronics and Computer Technology Department. The department has 1 full professor, and several associate and assistant professors. The main lines of research of the department are based on soft computing and its hardware implementations. Within it, the GeNeura team has been working since 1991 in artificial life, evolutionary algorithms, neural networks and hybrid techniques. It is composed of 1 Associate Professor, 1 Assistant Professor (from University of Jaen), and 4 PhD students with grants. The GeNeura team concentrates all research efforts on evolutionary computation. Its main activities in the research and development area (also available from the web page at http://geneura.ugr.es) are:

1. Applications of evolutionary algorithms: to optimisation of web newspaper layout, to solving board games like mastermind, to optimise neural nets. In this area, it has published several papers in relevant EC conferences such as PPSN, CEC and GECCO.
2. Web and internet development: this is mainly done through external contracts; right now it is in the process of developing a search engine that looks for business news in the internet daily news. It has received regional development funding to carry out intelligent filtering of news.
3. Software development: it has published, and maintained, on the public domain several software libraries for soft computing, such as GAGS (http://kal-el.ugr.es/GAGS) and EO (http://geneura.ugr.es/~jmerelo/EO.html).

Currently, the main sources of funding of GeNeura team are external contracts (around 1%); regional development European funds (around 90%), to develop an intelligent news filtering system; and INTAS funds, in a joint research effort with institutes in Russia and Germany (around 9%). In all these projects, JJ Merelo is the principal investigator. GeNeura team has also received researchers for short visits from several countries in the EC (including Spain), Poland and Russia.

Key staff members for this project are:

Principal Investigator: JJ Merelo: Degree in Theoretical Physics in 1989, PhD in Physics in 1994, both from University of Granada. He has been Associate Professor at the University of Granada since 1997. He has been Visiting Professor at several American centres (Santa Fe Institute, NM, USA, 4 months, and University of Southern California, LA, CA, USA, 3 months); and European centres (RISC-LINZ, Université Paris V, Politecnico Torino). He has seven papers in refereed international journals and more than 20 in refereed international congresses. He is currently active in evolutionary computation software development and soft computing applications, especially Internet applications.

Victor Rivas has been Assistant Professor at the University of Jaen and a PhD student at the University of Granada since 1997. He has worked on artificial life applications, especially agent-based models applied to publicity. He has been visiting researcher at the Centre de Mathematiques Apliqués at the Polytechnique in Palaiseau, France. His main line of research now is fuzzy controller optimisation.

Julio Ortega Lopera is Associate Professor at the ATC department and PhD in Physics. He has been Visiting Professor at the Open University, and has more than 60 publications in international congresses and journals. He has also been the principal investigator in national projects to optimise water distribution. Main lines of research are parallel algorithms and optimisation techniques.

Pedro Castillo has been EvoNet system administrator since 1997, then briefly assistant professor at the University of Jaen, and he now holds Ministry of Education scholarship at ATC-UGR. His main lines of research are optimisation of multilayer perceptrons using evolutionary computation.

South Bank University (SB)

South Bank University was founded in 1892 as the Borough Polytechnic Institute and in 1970 merged with four other colleges to become South Bank Polytechnic. In 1992 it was granted University status and has become one of the largest universities in London with over 19,500 students of which 19% are postgraduate. The School of Computing, Information Systems and Mathematics is one of five schools in the Faculty of Engineering, Science and Technology. The School offers a range of courses at both undergraduate and postgraduate levels, and undertakes research in a variety of areas including Computer Science, Information Systems, and Management and Technology. The School has over 56 academic staff (96 staff in total) and includes five full professors and one reader.

The Centre for Neural and Evolutionary Computation undertakes research in Evolutionary Computing, Neural Networks and Fuzzy Systems and their applications. Its main focus on the theoretical side is on the development and use of statistical metrics to characterise and transform fitness landscapes for evolutionary algorithms. Self adaptive and tracking techniques are being developed to improve evolutionary search. The aim is to build easily usable and robust evolutionary search tools. Using evolutionary search to optimise neural and fuzzy systems is being investigated as well as algorithms based on symbiogenesis. The main application areas for the centre are evolvable hardware and evolutionary electronics (in co-operation with the Centre for Concurrent Systems and VLSI), computer software optimisation (in co-operation with the the Centre for Software and Systems Engineering), traffic control in both electronic and road networks, fuzzy modelling of information systems, optimisation of visual inspection systems and intelligent tutoring.

It is hoped that he centre will be the new co-ordinating node for EvoNet: the Network of Excellence in Evolutionary Computing.

Key staff members for this project are:

Principal Investigator: Terence C. Fogarty: gained a PhD at the University of the West of England in 1990 on the use of the genetic algorithm to optimise a rule-based control system for British Steel. He went on, at the University of the West of England, to lead a number of research projects in the development of evolutionary computing techniques to solve problems in classification, communication and control and their application to credit control, industrial inspection and robot control. He has supervised six successful PhD studies and is currently supervising seven PhD students, three of whom are writing up this year. He has published many articles on the practice and application of evolutionary computing and has edited nine books in the area. From 1996 to 2000 he led the Evolutionary Computing Research group in the School of Computing at Napier University. He is the co-ordinator of EvoNet, on the editorial board of the main journals in the field and on the programme committees of the main international conferences.

Free University Amsterdam (FUA)

The FUA staff have considerable experience and expertise in the areas of novel computing methods, such as evolutionary computing, neurocomputing, and artificial life and artificial societies.

The main areas of activity related to the DREAM project are the following:

- Investigation of evolutionary operators, such as different mutation and recombination mechanisms.
- Studying self-adjusting evolutionary algorithms, that is, mechanisms to adjust the features driving an evolutionary process on-line, while running the same evolutionary process.
- Experimental studies and applications in constrained problems and data mining. Comparing evolutionary and other techniques for analysing data.
- Investigating dynamic population behaviour and the effect of communication in an artificial life context. Studying the influence of various environmental characteristics on population equilibrium and coexistence of species.
- Studies in the area of artificial societies. Based on a course on evolutionary economics, a team is working on simulating the effects of different tax regimes.

The key staff member for this project is:

Principal Investigator: Prof.dr. A. E. Eiben is the head of the Computational Intelligence group within FUA. A. E. Eiben has been active in evolutionary computing (EC) from 1989 and has published dozens of research papers. He is a member of the editorial board of three international journals related to EC and (co-)editor of three books and two journal special issues on EC He has been organising committee member of six major international EC conferences (PPSN-V, EP'98, GECCO'99, FOGA 5, CEC2000 and PPSN VI) and programme committee member of several conferences. He is a member of the executive board of the European Network of Excellence in Evolutionary Computation (EvoNet). He has conducted several industry funded projects in data mining in marketing, finance, retail, and chemistry. He is teaching courses on evolutionary computing and evolutionary economics, and is supervising six PhD students.

Appendix B – Contract Preparation Forms