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Complexity, Agents, Volatility, Evidence and Scale

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1 Introduction

The CAVES project is in very good heart. We have produced the right number of deliverables on time and to the anticipated specification. All milestones have been accomplished. The path to this position has not always been smooth, but the unevennesses have themselves been useful to us in developing our understanding of how to use complexity science in social policy formation. Moreover, and perhaps more importantly, there is enormous good will amongst the partners in the project team, we communicate regularly and we are learning from and influencing each other.

The benefits of cooperation include the use of ontologies in model design (introduced to the project by the Macaulay team and used by the MMU and Kassel modelling teams as well), the integration of declarative and procedural modelling implementations in Java which will provide guidance or perhaps be used directly by the Kassel and Macaulay modelling teams and the implementation of multiple layers of social networks by the Kassel team and used in the MMU's prototype South Africa model.

A perhaps inevitable issue in the integration of genuinely multi-disciplinary teams is to identify deep misunderstandings and differences in objectives among the partners. The CAVES project team has made enormous progress in identifying these differences (perhaps to the point of complete identification) and substantial progress in using those differences for the benefit of the project.

The most important difference has been in the initial expectations and objectives of the case study teams on the one hand and the modelling teams on the other in the two cases where these are distinct: the South African and the Odra studies. The problem we have faced in developing the modelling and evidence for the South African study has turned on the need to develop a model of social complexity on the basis of relatively limited interview data and the anticipated reactions of participating stakeholders to models based on that limited data. Both the CPM modelling team and the SEI case study team have had to recognise the need to accommodate the needs of the project as a project in complexity science with the maintenance of the long term relationship of the case study team with their stakeholders. The resolution turns on a clearer understanding that the purpose of the models is not to “tell the truth” in some sense but rather to make precise and to elucidate the assumptions underlying stakeholders' and policy analysts' expectations and concerns both in order to identify the consequences of those assumptions and to support validation of policy scenarios. Whether some of the stakeholders in the Vhembe region of South Africa can (or indeed have to) understand this role of the modelling is a matter for ongoing discussion and investigation. Whilst a similar concern was expressed by the Odra River Valley case study team, a more important issue for them was the “respectability” of the hydrological model to be incorporated into the social model. All participants in that discussion came to agree that the project is concerned mainly with social complexity and that our target audience is not the community of hydrologists but rather social scientists and specifically stakeholders’ social policy formation.

Five papers based on CAVES project development have now been submitted to international conferences in complexity science and social science. Several of these papers a jointly authored by colleagues from more than one of the partner institutions – a further mark of the productiveness and integration of the project.

As the reports of the work of the project partners shows, good progress is being made on all fronts. For reasons explained in section 4 of this report, the dates for two deliverables have been exchanged so that the prototype model for the South African study has been delivered at month 12 rather than month 18 of the project while the Grampian model will be delivered in month 18 rather than month 12. This exchange has several benefits. One is that the faster progress of the South African modelling exercise will support the faster development of practical means of utilising the models in policy analysis. The other is that, by allowing more time for the development of the Grampian model, the technical developments of incorporating ontologies and GIS into the model implementations can be driven more clearly and directly by the substantive needs of the case studies. Indeed, this has been the reason for changing the deliverable date for the Grampian model prototype.

2 Modelling Issues

The following sections report on the work undertaken by the different modelling teams during the second six months of the CAVES project.

2.1 Centre for Policy Modelling

2.1.1 Prototype Model for the South African Case Study

Work has concentrated on the development of a prototype model for the South African case study. As suggested by the case study team (SEI) we focused on the social impacts of HIV/AIDS in villages in the Vhembe district, Limpopo Province, South Africa. Since field work for knowledge elicitation had to be done in parallel (see section 3.1), this prototype model is largely based on existing data from previous projects undertaken in the same region; namely the UNRAVEL project (Understanding resilient and vulnerable livelihoods in Malawi, South Africa and Zambia; Ziervogel et al. 2005) and FIVIMS-ZA (du Toit and Ziervogel 2004), a project assessing the feasibility of developing a Food Insecurity and Vulnerability Information and Mapping System (FIVIMS[1]) for South Africa. Within the framework of the latter, a pilot study was undertaken in the Sekhukhune district, whose data obtained from a detailed questionnaire was made available to our team. Unfortunately, it turned out that the data pertaining to social networks of individuals and/or households was either missing completely or aggregated in such a way that it was impossible for us to infer the necessary information. For the prototype model we thus had to make a number of assumptions, which we checked with our domain experts from the case study team.

In the case study area, HIV/AIDS is one of the major stressors for people's livelihoods, together with climate variability and food insecurity, leading to a high vulnerability. Most people in the area rely on state grants such as pensions or child/orphan grants and remittances from migrant workers for their subsistence, since agriculture alone is not sufficient. Death of the family member receiving the grant or sending money home can therefore have a devastating effect on a household, to the point of dissolution. Orphan children are usually accommodated by a household in the extended family. Other strategies for coping with stressors such as resource sharing or pooling of finances also rely on social networks in the community.

The model adopts the multi-layer network approach proposed by the Kassel team at the last project meeting in Wroclaw. So far, two network layers are considered, one on the level of individuals and one on the level of households. Individuals are represented as agents with a network of friends. Each individual is member of a household, with one of the household members acting as the household head. Households have a network of social neighbours with whom they interact. Since actual empirical data on the structure of these networks is yet missing, we assumed a small-world network. This assumption is supported by several other studies conducted in the region (e.g. Quinlan et al. 2005, Salomon et al. 2000).

These social neighbours are the basis for informal savings clubs, known as *stokvels*. Members of

[1] http://www.fivims.net/

a stokvel pay a mutually agreed sum into the club every month. The cumulative savings of the group are then rotated to each member of the group on a regular basis. After everyone has had their turn in receiving the contributions, the group may disband or start another cycle. Female household heads with higher literacy are usually the coordinators of these savings clubs (Verhoef 2001). We model this by introducing the role of 'innovators' for a certain proportion of agents. Innovators are able to initiate a savings club by inviting other agents and run the club after its formation.

To cover all agricultural aspects we obtained an agent-based cropping model from SEI (Bharwani et al. 2005), which models crop choices dependent on climate experiences and weather forecasts, the growth of the chosen crop, harvest and subsequent market transactions. We adapted this model to a package to be used as a component in other agent-based models. This included debugging the code and solving some of the implementation problems already identified by the SEI team. The imperatively implemented decision process was extracted and transformed into rules, so that the agents' decisions about which crop to plant when is now modelled declaratively.

The prototype model is implemented in Java/Repast, using the Repast scheduler, graphical user interface and network library. The declarative component integrates JESS (see below). Figure 1 shows a snapshot of a simulation run with the social networks of the households in the top right corner. The chart on the bottom left plots the number of savings clubs currently in existence.

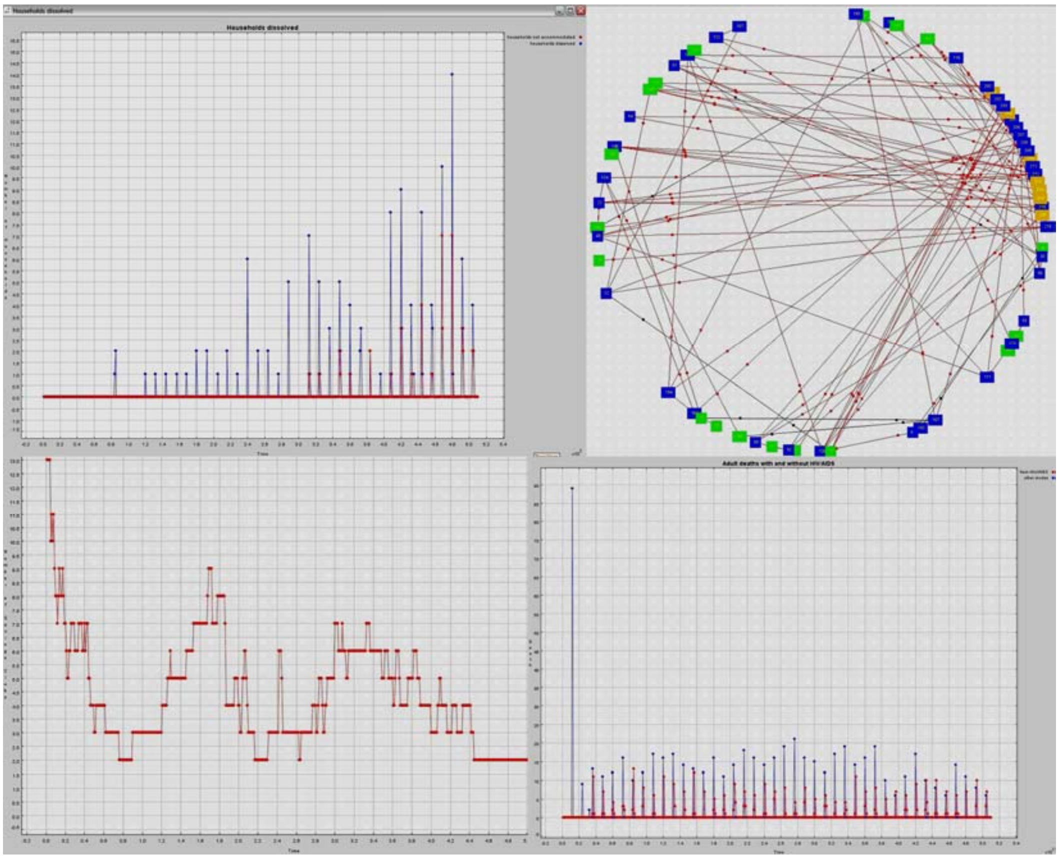

Fig. 1: Snapshot of a simulation run

2.1.2 Modelling Tools

JESS/Java integration

Another focus of work has been JESS[2] and its integration with Java/Repast. This combination was identified during the project initiation phase as the most promising candidate to integrate declarative features with agent-based social simulation software.

To investigate this further we adopted a model of land use and migration developed at the CPM before CAVES, which also integrates the modified crop model. Our first approach has been to let each agent have its own rule interpreter (engine). This allows the rules describing the agent's behaviour to be specified in the respective agent class. Global facts like the state of the agents' environment, however, have to be copied for each engine. Because of the high memory requirements of this approach we have been researching the possibilities of sharing one rule engine amongst all agents.

Several options exist, with different advantages and disadvantages:

- Structuring the joint rule base into modules for each agent. This allows agents to share facts while using rules specific to a particular agent. The focus of the rule engine has to be set to the appropriate module before running the engine; this can easily be done in an agent's `step()` method. So far, the module approach has proven successful for a simplified land use model with 3 rules per agent (module).

  The advantage of this approach is its conceptual clarity: agents "own" their rules and are solely responsible for their execution. On the other hand, a large part of the rule base is made up of more or less identical rules.

- Defining rules per agent type and collecting them in the model class. This ensures there is only one copy of each rule in the rulebase. Agents are best declared as shadow facts so that rules can refer to individual agents easily. In every run of the engine, each rule will fire once per matching agent fact. Thus the engine has to be run only once per time-step to update all agents.

  This approach keeps the rulebase as small as possible. Its main disadvantage is the gap between conceptual model (rules describe an agent's behaviour and therefore belong to an agent) and implementation (rules belong to the model and are shared between agents). This could probably be overcome by developing a framework that allows a modeller to specify agent-specific rules and then transforms them to the model-specific approach.

- Differentiating rules by adding an identifier (agent ID) to their name, e.g. `plant-maize-rule-1`, `plant-maize-rule-2`, etc. This results in each agent having its own set of rules in a joint rule base. The engine is still run only once per time step.

  This approach is a mix between the first two: It allows agents to "own" their rules again but the execution of rules is initiated from the model. Depending on the number of agents and rules per agents, the rulebase can become very large. This approach is the least elegant of the options.

As a control and to provide a parallel development path in case the single-engine approach proves unsatisfactory, we have also been developing a trading model with one engine for each agent. The number of agents that can be implemented with suitable values for heap size is (so far) acceptable for a fine grain model – on the order of 500 – 700 agents.

[2] http://herzberg.ca.sandia.gov/jess/

GIS interface

We have also started to investigate GIS interfaces to models. Although Repast claims to have integrated GIS support with version 3[3], this is so far insufficient. The library for vector data (`anl.repast.gis`) has two major drawbacks: it focuses on vendor-specific software (Esri's ArcView/ArcInfo) and it represents geographic shapes as agents instead of incorporating them into a space object.

Due to a lack of relevant GIS data for the South African case study, the development of a package to incorporate GIS data as a spatial component into a model has been suspended.

2.1.3 Directions for Future Work

- Adapt and expand the prototype South Africa model. This includes work on the cropping package to incorporate adaptive strategies for the agents.
- Resume work on the GIS interface for use with Repast/Java
- Continue work on using Jess, especially sharing one rule engine amongst all agents
- Add logging functionality to Jess/Repast so that the trace of a simulation run is stored in a data base
- Continue work on social networks and statistical signatures

2.1.4 References

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[3] See http://repast.sourceforge.net/index.html

2.2 Universität Kassel

2.2.1 The Context of Our Model

In numerous real-world situations, people are confronted with tasks that they are unable to fulfil alone. Often, such tasks are characterised by the necessity to include a number of different expertises to their accomplishment. Consequently, people organise themselves into networks aimed at the completion of some specific task. Examples of such situations are to be found in virtually any domain, such as science, economy, or in the context of managing and maintaining natural resources.

The CAVES (Complexity, Agents, Volatility, Evidence, and Scale; see http://cfpm.org/caves/) project aims at describing the emergence, the characteristics and long-term behaviour of social networks of people using natural resources such as land or water. It is funded by the European Union and includes case studies in Great Britain, Poland, and South Africa to acquire data about real world evidence of social networks.

The Polish case study (with input provided by the Wroclaw Institute of Technology and Wroclaw University) focuses on those parts of the Odra river region that are at risk of regular flooding due to neglected or damaged dikes and the lack of maintenance of an old land reclamation system and also more generally on land use in the Odra river region. Social mobilisation or collective action by the individual farmers is required to maintain or re-establish the system of channels, ditches and dikes of the land reclamation system. Between the farmers, acquaintance or friendship links exist. When looking for collaborators to accomplish a maintenance related task however, the friendship network may serve as a starting point to build up a collaborator network, but the friendship network may not suffice to get all needed expertises together. By word of mouth, additional persons in the collaborator network (i.e. collaborators of collaborators) with the necessary expertise are sought, until the task can be solved. Such existing networks tend to be used again and again, thus leading to cliques of collaborators with complementary expertises.

In a more abstract way, situations like those just described can be characterised by the following features: They include multiple social networks representing multiple social contexts that interact, like friends vs. collaborators. People show goal or task-directed behaviour and use the networks at their disposition to fulfil their tasks. The conditions of the emergence of such multiple networks, their long term evolution, characteristics, interaction and their dynamics over time is of theoretical as well as practical interest to social science as well to complexity science. We will report on this dynamics by contrasting different social networks resulting from an agent-based model of task-oriented behaviour in a collective action situation. Specific measures have been designed to analyse the behavioural and structural efficiency of the networks and knowledge that is accumulated by the agents over time when solving tasks of varying difficulty.

2.2.2 Basic Modelling Concepts

In order to model the above mentioned situation characteristics, core features of the case study are abstracted. We follow a rather strict distinction between physical environment and social environment of the agents. This distinction focuses on a separation between physical and social spaces both in terms of semantics and techniques used for their representation. For various reasons, the simulation of the agents' physical environment uses a traditional grid based approach. The social "location" of an agent is given by his position within a social network context, where an agent is viewed as a node and social relations are represented by edges. Since agents are considered here in more than one social context an agent's social environment generally consists of more than one network layer. The modelled agents' perceptions vary related to their physical or social environment. Both perceptions are locally bounded in terms of a perceivable section of the surrounding physical space and in terms of network edges and neighbouring nodes. In the same way, the agents' repertoire of actions differs relating to their respective environment. In the model version presented in this paper, the focus is on the development of the social networks and the actions related to the natural or physical environment have been reduced to abstract tasks.

The agents' social environment is modelled as networks. An agent may be seen as a node in different social network contexts. Technically, an agent has slots that are nodes representing potential or actual social roles in different networks, so the networks actually reside in the agents' memory. Unlike in other network modelling approaches, agents do actively perceive their social environment and are enabled to act in their social network. In the model considered here, an agent has two semantically different nodes: One in a friendship or acquaintances network and one in an advisor or collaborator network.

The friendship network can be initialised with empirical data or in a more abstract way with an assumed small-world topology. A collaborator network does not exist initially. Once a task is assigned to an agent, it polls its social friendship network for expertise needed to accomplish the specific task additionally to its own. The search is started in the direct social neighbourhood of the agent. If the collected expertise provided by the network neighbour has been successfully applied, the agent builds up an edge to the respective node in the collaborator network. Next time the agent would first poll the collaborator context when looking for a new strategy. If the agent cannot find all the necessary expertise in the directly neighbouring links of the collaborator network it will pursue the search in the neighbourhood of collaborators, i.e. collaborators of collaborators to find additional expertises.

In the following section, a description of the agent architecture that uses the described basic concepts will be given.

2.2.3 The SONATA Model

The SONATA model (Social Networks of Abstract Task oriented Agents) has been realised in the RePast agent programming framework (http://repast.sourceforge.net). In order to describe the proposed agent architecture we follow the separation of the agent's functional components: perception, action repertoire and cognitive unit.

The perception unit generates information about the agent's physical and social environment. The perception of the physical environment provides local information about environmental attributes like resource availability, types of land cover, the locations of other agents, or in the more abstract version presented here, information about tasks and their accomplishment. The perceived social network environment is represented by lists of network neighbour nodes. Generally, these lists of nodes originate from multiple network layers. The agent "knows" about the semantics of each of those lists (as in the example above, it is known whether a network perception relates to the acquaintances network or the collaborator network). Perception is locally bounded, so no agent within the network has a global, bird's eye view of the whole network.

The action an agent may execute in its physical environment is to solve a task that has been assigned to it. To do so, it has to complement its own expertise by other expertises needed by looking for collaborators accordingly. Additional actions in the agent's social environment are network-related modifications like strengthening or weakening of outgoing and/or incoming edges, the establishment of new edges in already established networks.

The simulated social environment consists of two network layers. The friendship network the model starts with a pre-generated and stable small-world network with a given average node degree resulting from rewiring of a regular net according to the algorithm by Watts and Strogatz (1998). This network layer remains fixed over the whole simulation run. The second network layer is the collaborator network that builds up during the agent's search for supporters with specific expertises after being assigned a task. Thus, it is actively constructed by connecting to other agents that have already provided the leading agent with useful information, following the algorithm described below. In this layer, unused edges slowly decay in strength and disappear once their weight becomes zero.

A task object is represented by number of different kinds of expertise (know-how, expert knowledge) that is required to perform the task. Tasks are randomly assigned to agents and have a fixed difficulty which results from the expertise necessary to solve them. Expertises are evenly distributed among the agents. Each time step, one agent is assigned with a task for which he needs the expertise of other agents. It will utilise its social environment to compile the required expertise to accomplish the assigned task. An agent first polls its collaborator network to get help from agents that have previously been helpful. If it cannot find enough collaborators among its direct ties, it is able to contact direct collaborators of its collaborators. It will build up edges in the collaborator network to these agents if they supply it with the necessary expertise. Only in the event that polling the collaborator network does not yield the necessary expertise, the agent will use its friendship network. If an expertise looked for can be got from a network neighbour, the agent will build a new network edge in the collaborator context to the supplier of the expertise.

2.2.4 Discussion

We will compare scenarios where only the initiator of the task builds up arcs to his collaborators (scenario without pairwise linking) with scenarios where all the agents that took part in the task build up arcs to every one of the participating agents (i.e. with pairwise linking). In both scenarios the agent have a maximum in- and out-degree, i.e., they are able to build or receive a limited number of arcs. Special attention will be given to the behavioural efficiency in solving tasks and the structural efficiency (i.e. number of links that are built up). All analyses of the networks generated by the RePast model have been done with the Pajek network analysis tool (de Nooy, Mrvar, & Batagelj, 2004) and R, a free software environment for statistical computing and graphics (http://www.r-project.org/), with methods also discussed by Newman (2003) and Wasserman and Faust (1994).

All the networks discussed here have been produced with the following model parameters: There are 100 agents. Their degree in the (static) friendship network is set to 20. There are 10 expertises needed to solve a task. Accordingly, the maximum degree for the collaborators is set to 9, relating to the number of additional expertises (beside the one the agent possesses). Every time step, 1% of the agents are randomly assigned a task. All agents are cooperative in the sense that they do not turn down a request for joining a task solving group (except they have reached the maximum of in- or outlinks). Links decay over time and disappear after 150 time steps, unless noted otherwise. The simulation stops after 100,000 time steps.

The results of the SONATA model show how a forgetting rate higher than the rate of new tasks coming in causes established links to disappear, so that the collaboration network has to be built repeatedly. The structure of the network thus never stabilises, and efficient cliques never emerge. Stability of network links also depend crucially on the way of linking: If, after having completed a task successfully, all participating agents link to each other in both directions (pairwise linking), stable structures arise that can be used again as soon as the next task is assigned to one of the cluster's members. This can be interpreted as groups remembering the good work they did together and whom they did it with. These pairwise linked networks thus accumulate with each task completed a maximum degree of knowledge relating to possible future collaborators. The knowledge is distributed evenly among collaborators and does not reside only in the agent the task was originally assigned to (no pairwise linking).

The higher efficiency of pairwise linked networks is reflected in a higher degree of tasks successfully completed and a higher degree of connectivity, but it has one drawback. Long-term evolution of such networks shows a segregation of successful cliques over time. While this may be well adapted to the task structure used here (with a constant amount of 10 expertises needed), this system may break down if there are substantial fluctuations in the quality of those tasks. Since the tasks assigned are the abstraction of the problems posed by a natural environment, this may be an important consideration. It will be investigated how shocks on the system, e.g. by changing the task structure, affect the networks with regard to their structure and performance. What does the system need to adapt to new situations? How long does it take to stabilise again, if ever?

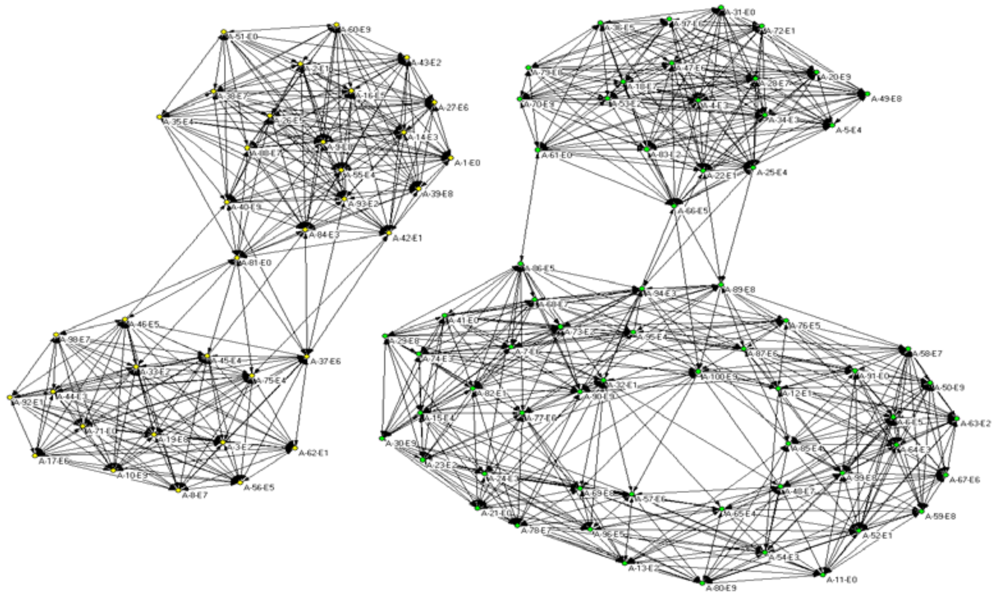

Fig. 2: Collaborator network with 100 agents ('A-1'-'A-100') with 10 different expertises ('E-1'-'E-10') and a maximum in- and out-degree of 9, after 10,000 time steps. At this point of the simulation agents with different expertises start to gather into (task oriented) cliques. This network has a clustering coefficient of 0,68.

2.2.5 Outlook: Further steps

- Incorporating data and further concepts from the Polish case study into the coarse grained model architecture as described above.
- Integrating rule based decision making mechanisms into the architecture to allow for incorporating more complex yet modular knowledge structures.
- How to make the model more realistic? The random assignment of tasks to agents will have to be replaced once there are more realistic assumptions about the processes included in the maintenance of the land reclamation system. Physical space, movement, economic effects of actions in the physical environment.
- The task to maintain land-reclamation systems is directly related to the physical environment. In future scenarios, agents will therefore look for collaborators not only in accordance to the friendship network but also in dependency of the physical environment.
- To simulate a commons dilemma there will be a payoff if the task has been successfully completed, i.e., if enough agents with the necessary expertise participated. Each participating agent will have to pay an amount of resources (money, time). The resulting payoff will not be received by the agents but will increase the value of the arable land where the agents executed the assigned task. Agents who live in the vicinity of the part where the

task was successfully executed will also profit from the maintenance of the land-reclamation system, even if they did not participate in the task. Agents have therefore an incentive not to participate in a time- and money consuming task but to profit from the work of other agents.

- If the necessary number of expertises was not reached no payoff will take place. The participating agents have then invested money and time without profiting from the work.
- This friendship network layer remains fixed over the whole simulation run. In future, this static view has to be replaced by a dynamic representation that takes into account aspects of (possibly fluctuating) physical neighbour-hood and aspects of growth and shrinking due to fluctuations in the absolute number of nodes.
- Expertise is not distributed evenly in real world situations. In future scenarios the effect of unevenly distributed expertises will have to be evaluated.

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2.3 Macaulay Institute

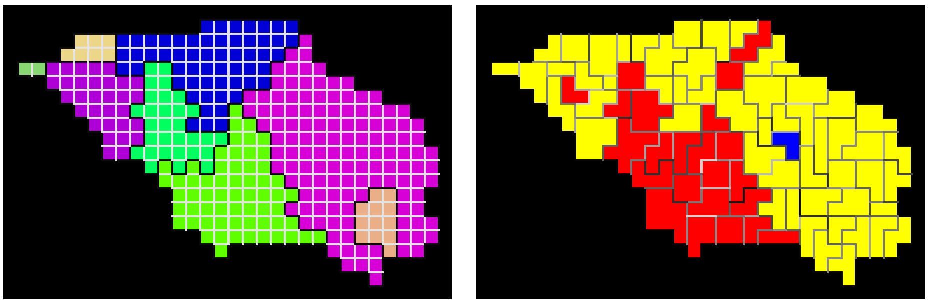
2.3.1 Overview

Work by the Macaulay team can be divided into enhancements of FEARLUS-0-8 to prepare it for use with the prototype fine-grained model based on the Grampian case study, work on the possible uses of ontologies in relation to FEARLUS and more generally within CAVES, and design and coding work for the ontology-based version of FEARLUS (FEARLUS-1-0) to be used in the final Grampian case study models.

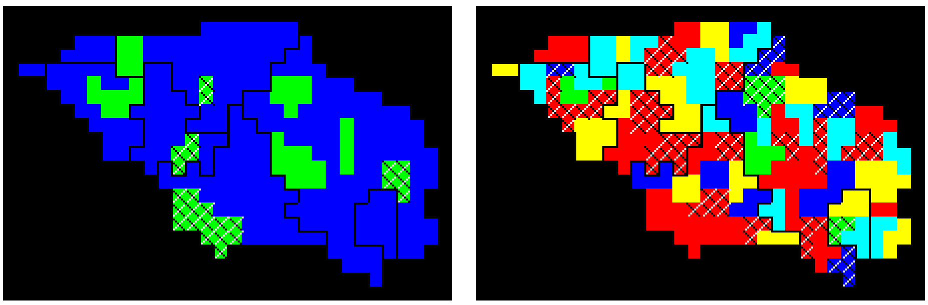
2.3.2 Enhancement of FEARLUS-0.8

Implementation has commenced of the designs for generalising the biophysical component of FEARLUS using look-up tables. As mentioned in the previous report, these look-up tables will enable FEARLUS to integrate with existing biophysical models where the latter are able to provide yield information for all combinations of situations in which crops might be grown.

In the first step, a new version of FEARLUS (0-8-2) has been created. This version features enhancements that enable more realistic representation of the environment, facilitating import of data from a GIS. The environment is divided into two layers: the cell layer, which stores data from the GIS; and the land parcel layer, which represents the division of the land into decision-making units. A land parcel consists of one or more cells, meaning that land parcels of different areas can now be simulated. (In the real world, land parcels are distinguished from their neighbours by physical boundaries (road, fence, hedge, stream, ditch), or by a history of different land use/management: fertiliser and pesticide use, previous tree-cover, laying of drains etc.) It is also possible to create blank cells that do not belong to any land parcel, enabling arbitrarily-shaped environments to be specified, as opposed to the restriction to rectangles in earlier versions. Figure 1 illustrates.



(a) (b)



(c) (d)

Fig. 1. Example output from model 0-8-2. (a) Land cells coloured by the farmer who owns them. (b) Land parcels coloured by land use. (c) and (d) show farms with cells coloured by the most profitable and the most suitable land use respectively, with hashing used to indicate where there is more than one.

2.3.3 Ontology Literature Survey

The Macaulay modelling team have continued their work on identifying ways of using ontologies within agent-based modelling. A major part of this has been a survey of the most relevant parts of the extensive literature on ontologies. This has informed decisions about how ontologies will be used in future work using FEARLUS, and also proposals for their use within CAVES as a whole. Here, the main findings of the survey are briefly summarised, under headings reflecting the main relevant areas of the ontologies literature. In order to motivate the later subsections, we begin with a brief account of the main applications of ontologies thus far.

Application areas

The majority of work on applying ontologies has been outside the scientific arena, in areas such as knowledge management for businesses and e-commerce; or in developments which have both scientific and extra-scientific uses, such as e-learning and recommender systems. Within knowledge management (Abecker and van Elst 2004) ontologies are used to support knowledge visualization, search and retrieval; and as a basis for information gathering and integration. In e-commerce, the heterogeneity of product and requirement information used by sellers and buyers is a serious obstacle, which ontologies can help to surmount (Ying, Fensel et al 2004). E-learning applications can use ontologies to organize and classify resources such as scientific publications and software (Brase and Nejdl 2004); similarly, recommender systems can direct users to specific online papers (Middleton, De Roure and Shadbolt 2004).

Scientific disciplines for which domain ontologies have been built include biomedical science, ecology and bioinformatics, particularly as applied to molecular biology. McCray (2003) describes how a biomedical ontology has been built as part of a US National Library of Medicine project to provide integrated access to biomedical resources. Keet (2005) describes creating an ontology mapped to the STELLA ecological modelling tool, finding that the formalization of knowledge can itself suggest directions for further research in ecology. Stevens, Wroe et al (2004) review a range of bioinformatics applications.

Within multi-agent systems (MAS), ontologies have been applied to underpin agent problem-solving and inter-agent communication in financial applications (Sycara and Paolucci 2004). However, despite the fact that CAVES is using agent-based modelling, this line of work is not directly relevant to what we propose below, which does not involve the model agents themselves using ontologies. So far as we can ascertain, our proposed uses for ontologies in relation to agent-based modelling are novel.

Two "super-domains" of particular interest to CAVES are that of geospatial entities and relationships (Agarwal 2005), and that of processes (Grüninger 2004). The main geospatial applications are in relation to GIS. Issues include the relationship between purely spatial and spatio-temporal approaches, problems of scale and granularity, boundaries, and spatial vagueness. The representation of processes within ontologies has been explored in relation to domains including workflow management, Web services and manufacturing systems. More general process ontologies have also been attempted. Issues include sequence and repetition, causality, agency and the distinction between continuous processes and discrete events.

2.3.4 Ontology-Related Languages and Formalisms

There is a huge literature on ontology-related languages and formalisms. The most relevant to CAVES concerns the language OWL (Antoniou and van Harmelen 2004) and related formalisms. OWL is supported by the semantic web community (http://www.w3.org/), appears to be the most widely used formalism, is compatible with some of the most useful ontology-related software available – notably Protégé (http://protege.stanford.edu/) and has a sound logical basis in the description logic SHIQ.

2.3.5 Ontology Learning, Particularly From Free Text

In a previous report, the Macaulay modelling team outlined a 7-stage procedure for deriving ontologies from textual evidence. The first three stages were:

1. Assembling evidence.
2. Preliminary examination of evidence for key concepts and central themes, which will suggest (respectively) classes and properties in the ontology.
3. Detailed analysis. All occurrences of key concepts are highlighted in the source evidence, and surrounding text used to suggest subclasses, properties, and supporting classes.

At that time, we were not aware of software systems developed to partially automate step 3. Ding and Foo (2002) and Gómez-Pérez and Manzano-Macho (2005) survey "ontology generation" or "ontology learning" systems, some of which take free text as initial input (perhaps along with an initial ontology, or a set of key terms), while others require structured or semi-structured sources. From free text, natural language processing software is used to extract candidate terms for the ontology's concepts, along with information about their taxonomic and other relationships. We plan to examine the KAON Text-To-Onto system (Maedche and Staab 2002), the language processing architecture GATE (Cunningham, Maynard et al 2005), and possibly other systems.

2.3.6 Upper-Level Ontologies, and Ontology Design Principles

Upper-level ontologies are designed to specify the key concepts and relations within some very broad domain. They cover such high-level distinctions as abstract/physical and object/state/process; and relations such as part/whole (mereology), connected or separate (topology), and spatial, temporal and causal relations.

Their intended function is as "a foundation for more specific domain ontologies" (Niles and Pease 2001). These authors describe the "Suggested Merged Upper Ontology" (http://suo.ieee.org). Other upper ontologies are described by Degen, Heller et al (2001) and Masolo, Borgo et al (2003). These last do not aim to provide a single monolithic top-level ontology, but to help people and computers understand one another by isolating the "fundamental ontological options", and providing a range of "foundational ontologies" as possible starting points for domain ontologies, each explicitly based on specific "ontological commitments". A closely related line of work is exemplified by Guarino and Welty (2004), who outline the "OntoClean" methodology for "validating the ontological adequacy of taxonomic relationships". This is based on highly general notions drawn from philosophical ontology, which are used to characterise "metaproperties" of terms in an ontology. Awareness of these helps ensure that a domain ontology avoids inconsistency.

2.3.7 CAVES Upper Ontology

Work is underway on a CAVES upper ontology, constructed using the DOLCE upper ontology of Masolo, Borgo et al (2003), and the OntoClean methodology of Guarino and Welty (2004), along with the existing ontologies of the Grampian and South African case studies.

2.3.8 Design of FEARLUS successor

A successor to the current model 0 family of FEARLUS models has been designed. Dubbed fearlus1-0, the design is founded on the use of ontologies to act as a bridge between evidence and case study data. Four ontologies are used, as described below.

First, the *domain ontology* consists of a description, using an ontology, of the real-world concepts that fearlus1-0 implements. The purpose of this ontology is to describe the conceptual context in which fearlus1-0 sits. It will therefore contain the description of concepts that do not appear in fearlus1-0 necessarily, but are related to it in some way.

Secondly, the *framework ontology* is intended to represent the concepts that are implemented by fearlus1-0. The framework ontology contains a description encompassing all the particular models it might be used to implement, including descriptions of implementation variants on particular concepts. The framework ontology imports the domain ontology, adding subclasses and subproperties to it that correspond to each of the implementation variants of those concepts in the domain ontology that fearlus1-0 provides implementations for.

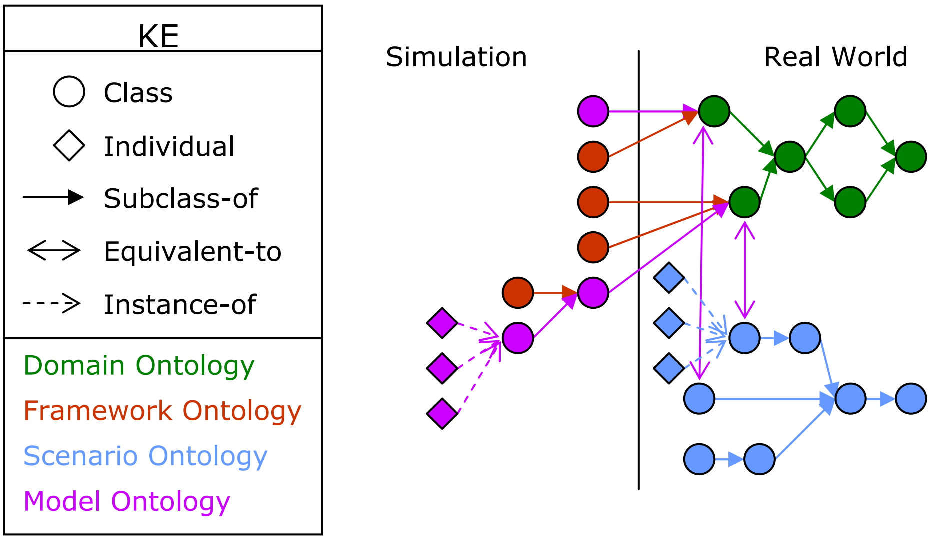


Fig 2. The relationship between the various ontologies. Assertions are colour-coded according to the ontology they appear in, with the domain ontology in green, the framework ontology in red, the scenario ontology in blue, and the model ontology in purple. The model ontology subclass-of and class assertions are also part of the framework ontology.

Thirdly, a *scenario ontology* describes the concepts applying to a particular scenario or case study. The idea is that this ontology could be developed independently of the domain ontology, fearlus1-0 or from any particular model one might have in mind. This would be desirable for methodological reasons if, for example, one wished to show strictly that the model was derived from evidence rather than the other way round. Where there are no such constraints, the scenario ontology could of course be influenced by the domain ontology and/or design for a model.

Finally, the *model ontology* brings fearlus1-0 and the scenario together, linking the evidence to the model through importing both the framework ontology and the scenario ontology. To reflect the fact that the model ontology is a specific instantiation of the modelling framework, the model ontology contains a subset of those concepts in the framework ontology that do not appear in the domain ontology, i.e. a particular choice of implementation variant concepts. The model is presumably intended to reflect some specific aspect of the scenario, so the model ontology needs also to specify how the relevant concepts in the scenario ontology are related to concepts in the domain ontology. The model ontology should explicitly state which classes in the scenario ontology are deemed equivalent to concepts in the domain ontology. Thus, an explicit, transparent link is created from entities in the scenario to their particular implementation in the model: all classes in the model are subclasses of concepts in the domain ontology that have been declared to be equivalent to concepts in the scenario ontology. The relationships between the various ontologies is shown in figure 2.

Figure 3 shows a UML class diagram outlining this aspect of the design of fearlus1-0. The OWLObject class is used to read in the model ontology and configure those classes and instance variables in subclasses of DataObject that will be used. Many classes act simply as data repositories (LandParcel, Environment and SubPopulation), not responsible for any change to the state of the system during a simulation, but containing information that will be used as a basis for change.

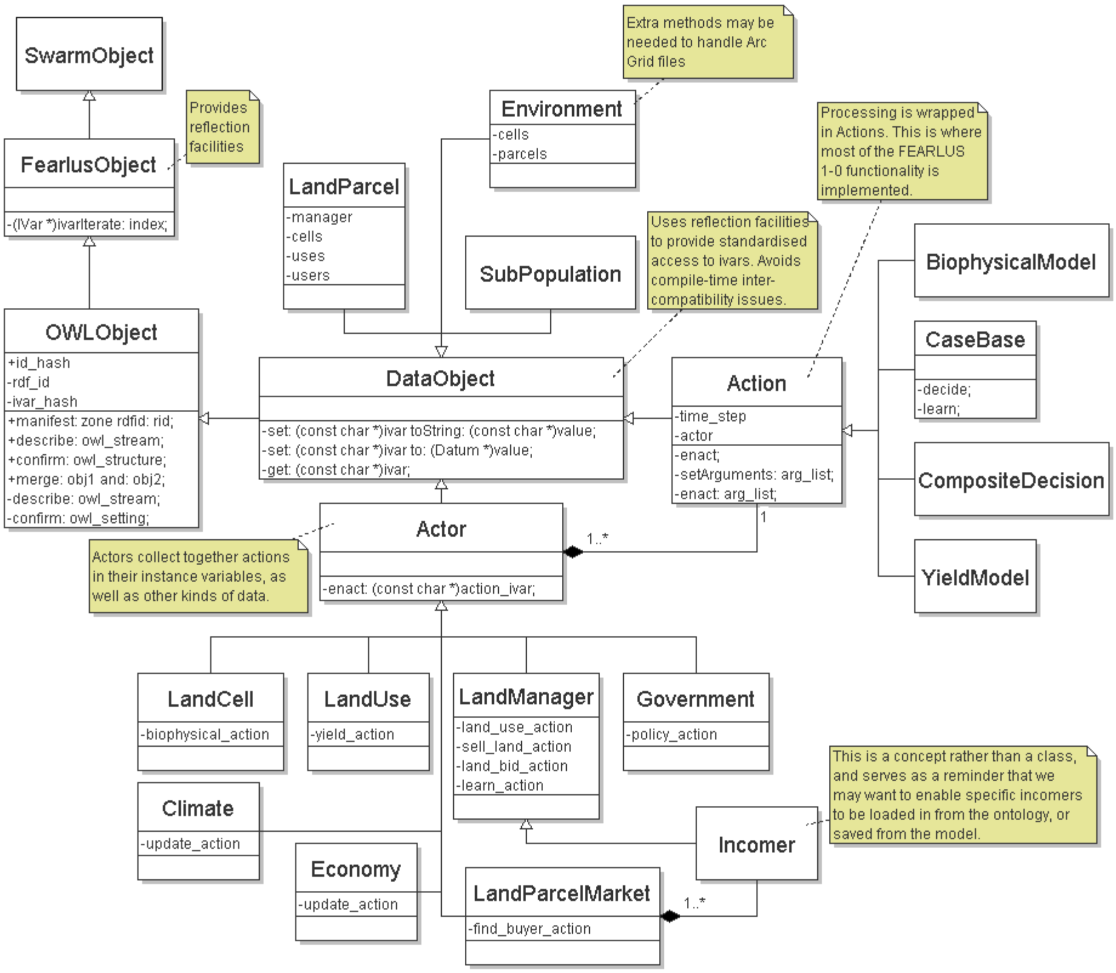


Fig. 3. UML class diagram for FEARLUS-1-0. Note that a more Obj-C-like syntax is used for the instance variables and methods than in standard UML.

Actors are entities that are responsible for changing the state of the system. They are distinguished from the data repositories by merit of containing instance variables that store Actions rather than other kinds of information. A method is provided to cause the Action to run. Finally, subclasses of Action store the algorithms that will be used to create the changes that occur in the model.

This design has been submitted as a paper entitled "A new approach to modelling frameworks" to WCSS 2006. This is the first submitted CAVES publication from the Macaulay modelling group.

2.3.9 Future Work

The next step for FEARLUS-0-8, currently under implementation, is to integrate look-up table code with version 0-8-2 to create a new version, FEARLUS-0-8-3, that uses look-up tables. The planned approach is to use the bitstrings that currently form the basis of the biophysical model in FEARLUS to represent the presence or absence of a certain symbol in the look-up tables. The current bitstring-matching algorithm to calculate yield will be replaced with an algorithm that looks up the yield for the particular combination of symbols that the bitstrings represent.

Experiments have been conducted, and are currently being run with an earlier version of FEARLUS that uses an endogenised land market model. Early results indicate that the land market model does have an effect on the overall behaviour of the model in a simulation involving innovating and imitating subpopulations of land managers. It is intended to integrate the endogenous land market model with FEARLUS-0-8-3 to produce 0-8-4, considerably increasing the realism and flexibility of the model. This should be completed by the end of April.

At that point, work on FEARLUS-1-0 will recommence, alongside work on the prototype model of the Grampian case study, which will be informed by the first batch of interviews carried out by Dr. Small.

The work reported in the sections on ontologies will be described in greater detail in the document "Ontologies in Relation to the CAVES project", to be completed in time for the forthcoming project meeting. This will be accompanied by a draft of the CAVES upper Ontology. It will also include proposals for using ontologies as one approach to maintaining coherence between the multiple case studies and models within CAVES, which do not require teams other than the Macaulay modelling team to take an ontology-based approach.

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2.4 Politechnika Wroclawska

2.4.1 Biophysical Model for the Odra Case Study

The model for the Odra Case Study, developed by the Kassel team, requires a biophysical model that would be responsible for hydrology simulation, weather generation and crop prediction. This model is being developed by the WUT-IP team. At this point the model is capable of simulating such processes as soil water movement, channel routing and crop growth. It also contains a weather generator. As we expected, the hydrological part of the model was the most problematic one. At this point, soil water movement is based on Darcy's equation, while channel routing algorithms use Manning's equations for calculating the volumetric flow rate. The weather generator and the crop sub-model are based on SWAT (Soil and Water Assessment Tool). The weather generator produces daily values of rainfall, maximum, minimum and average temperatures, solar radiation and potential evapotranspiration. Rainfall is generated using a Markov chain and an exponential distribution. The temperature and solar radiation values are generated from a standard distribution, while the potential evapotranspiration is calculated using the Hargeaves method. The crop sub-model implements the heat unit theory. Plants' growth is stimulated by temperature and can be reduced by a shortage of water. The crop sub-model also takes into account the destructive effect of flooding on crops. For simplicity's sake, we decided to ignore the influence of nutrients and fertilizers on plant growth. However it is technically possible to include these two factors in the crop sub-model.

The biophysical model is fully spatially explicit i.e. for every time step it produces 2D grid spaces with such data as ground water level and biomass. The model requires a digital elevation model, currently in ASCII grid format, and a channel network specified in an ESRI shapefile. We are planning to add support for GeoTIFF files in near future.

Because of the complexity of this type of models and their intrinsic composite structure, we decided to build the biophysical model around the design pattern called “delegation”. The object which represents the whole model doesn't actually do any modeling on its own. It delegates tasks to specialized objects, called delegates, which perform required operations and return the results. At this point there are seven delegates. Each of them is responsible for one of the following tasks: weather generation. soil water movement, channel routing, rainwater distribution, evapotranspiration, crop growth, crop management. Each of these tasks can be performed in various ways, using various algorithms. The strong point of the “delegation” design pattern is that it makes it possible to easily replace one delegate without making any changes to other delegates. This in turn means that we can easily experiment with, for example, different channel routing algorithms, or various weather generators.

The biophysical model does not contain any data visualization. However, we have developed a graphical front-end for the model, which enables viewing of spatial and non-spatial data. In order to visualize spatial data, we have developed a special GUI component, that is capable of displaying multiple layers of both raster and vector data. Values of non-spatial data can be plotted on a 2D graph or displayed in a text field.

2.4.2 Tools for Visual Model Assembling and Editing

We are developing a set of tools, that would allow both programmers and non-programmers to build, or more precisely, to assemble models. The process of model assembly would resemble the creation of a GUI using a visual editor and the so called “pick and plop” technique. The modeler would select components from a palette and place them on a diagram representing the structure of the model. The tools would enable connecting these components together with various links to create a model. Some of the components in the palette would be visual components that enable data visualization or simulation controls, while other would be non-visual components of the model's logic. We are expecting that the majority of non-visual components will simply represent various classes from the RePast library.

The development works on such a set of tools are well on their way. The first POC (Proof Of Concept) project has been recently completed. In its current form, the tool enables placing both visual and non-visual components on a boundless plane and connecting them together.

2.4.3 Discrete Choice (Opinion Dynamics) Models

We have investigated the properties of two classes of discrete choice (opinion) models. One of them, more often used by economists, is formulated using generalized utility function, where utility may include subjective components. The evolution of the second class is formulated using “supporting” and “persuading” influences on individuals states. We have found that these two approaches can be formulated in a uniform way and each of them can be expressed in terms of the other. We have formulated a generalized model, which covers models of Brock-Durlauf, linear variant of Nowak-Latane and Holyst-Kacperski. Multistability of this model was shown within mean-field approach, i.e. within some range of model parameters and strength of external influences two stable stationary states are possible, one of them being more favorable then the other. This phenomenon can be used as a representation of “social traps” – overall utility of the system is smaller than it could be, because the system is stuck in a “trap". In our simulations this phenomenon is manifested as existence of hysteresis, a phenomena similar to the occurrence of hysteresis in physical systems undergoing phase transitions. Work on formulation of general model covering the widest class of existing discrete-choice models is in progress.

Based on this generalized model, the analysis of influence of “self supportiveness” was performed. It occurs that in the presence of individuals’ tendency to persist in the state they are in, the phenomenon of “social traps” is more pronounced and stronger external influence is needed to convert the system to the more favorable state. In our simulations this effect was manifested as widening of the hysteresis.

We have analyzed the similarities and differences between this approach to the social systems and physical methods used in exploring physical systems, (particularly, thermodynamics of spin systems). In literature the parallel between social models and physical models was pointed out; in spite of this, many difficulties in this parallel may arise when analyzing the background of physical and social approaches. The status of so-called “social temperature” and “stationary states” in social systems is still questionable.

The preliminary investigation of spatial cluster formation in the model of binary choice was performed. The results known from literature were verified. Investigation on the role of non-uniformity of individuals, existence of a strong leader, interaction between individuals vanishing with mutual distance and topology of a network, is in progress.

We have formulated the differential equation for the “mean choice” within the mean-field approximation. Preliminary analysis of dynamics of such systems was performed. We have found, that these simulations confirm earlier results obtained within stationary state approach, but they allow much more detailed analysis, including obtaining a dynamical potential. We are still working on some simple models that would give intuitive insight in the meaning of inflows and outflows in the model.

We have investigated properties of the Brock-Durlauf model on small world networks. It occurs that increasing probability of “rewiring” (i.e. creation of long-distance connections among individuals) causes increase in the width of hysteresis. Similar effect is obtained by increasing the number of neighbours. This may lead to interesting considerations on definitions of “dimensionality” of networks regarding their topology. It also gives assumption to investigations of one more effect of the small world – only “a few” long distance connections modify structural properties of the system making it multistable.

2.4.4 Evolution of Social Networks

We have reviewed the literature about the structures of social networks and implemented algorithms for the calculation of their generic parameters. We have also reviewed the literature regarding evolving networks.

For some evolving networks the phenomenon of Self Organized Criticality can be observed (e.g. the power law in distribution of avalanches of changing links). Such networks, having also a sociological interpretation, may be a promising material for modelling social phenomena. We have created an initial model of an evolving social network, basing on recent research on social network evolution. Currently, we are investigating mechanisms leading to high clustering coefficient in social networks. We have also started working on the implementation of opinion dynamics models on evolving social networks.

3 Case Studies

In this chapter the different case study teams report on the work undertaken during the second six months of the CAVES project.

3.1 South African Case Study (SEI Oxford)

3.1.1 Introduction

Due to the evidence-based nature of this project, a fieldtrip was carried out in February 2006 to ascertain the key drivers and stresses in the chosen case study area of Sekhukhuneland. Much data and background work has been done in this area which has helped to inform the initial pilot model. Collaboration with the previous FIVIMS (Food insecurity and vulnerability information mapping systems) project was established and with the RADAR project to explore collaboration using their data that relates to HIV/AIDS and social networks.

The fieldtrip highlighted some key issues which now need to be integrated with the next round of modelling. There is also the need to focus the future fieldwork in order to provide more detailed information to feed into the model and in order to communicate with stakeholders as to their needs.

The proposed outline will be presented to stakeholders to establish whether this approach might be of interest and use to them in their planning.

3.1.2 Case Study Focus

There were a number of issues that emerged as important and relevant to development and livelihoods in the Sekhukhuneland area. Water is a key stress at the local village level, as it constrains daily activity and development such as field-based agriculture and other activities such as home gardens, projects that require water such as brickmaking and livestock. Water is also a key stress at the district level. There are separate schemes for agricultural and bulk water and both of these are strained. There is talk of decreasing agricultural water quotas to supply more water to the bulk schemes. Development is being undertaken to improve the supply of bulk water as the district and regional hospitals both had to have water tankered in last year. There are a number of agricultural schemes that are aimed at poorer farmers that require water. Mining is an important part of the Sekhukhuneland economy and it is rapidly growing. This has implications for water use. A large dam has been planned and construction is expected to start this year yet there are environmental concerns about it.

Another key stress in the area is employment. Over 90% of the population is rural and there are very few jobs in the villages. People therefore have to migrate to find employment. It is seldom that households migrate but rather it is the individuals who migrate. This migration appears to be based primarily on social networks as people migrate to areas where they have friends or family they can stay with while they are looking for work. When they do find a job they send remittances home and visit their village a minimum of twice a year. Although due to urban living cost their remittances are sometimes infrequent. The mines also form a part of the employment opportunity although have associated costs. Many people from the district move outside the district to find work as that is where their connections are based. Many of the people securing work on the mines are from outside the district as they have the necessary experience. There is a move to support training of local people so that they can become more qualified and their can be increased local employment. Associated with the influx of migrants from outside the district, is an increase in HIV/AIDS. This has implications for local social networks. The water stress also has an impact on health and so health becomes a key concern in this nexus. At the same time there is the suggestion from villagers that health has become worse because of the food people eat. They are unable to grow enough of a range of vegetables to remain healthy as their grandparents used to in the past.

The water and employment issue related closely to food security as it appears that this district is not able to feed itself. Households therefore need to secure income to secure their food. Water availability could help to supplement food supply.

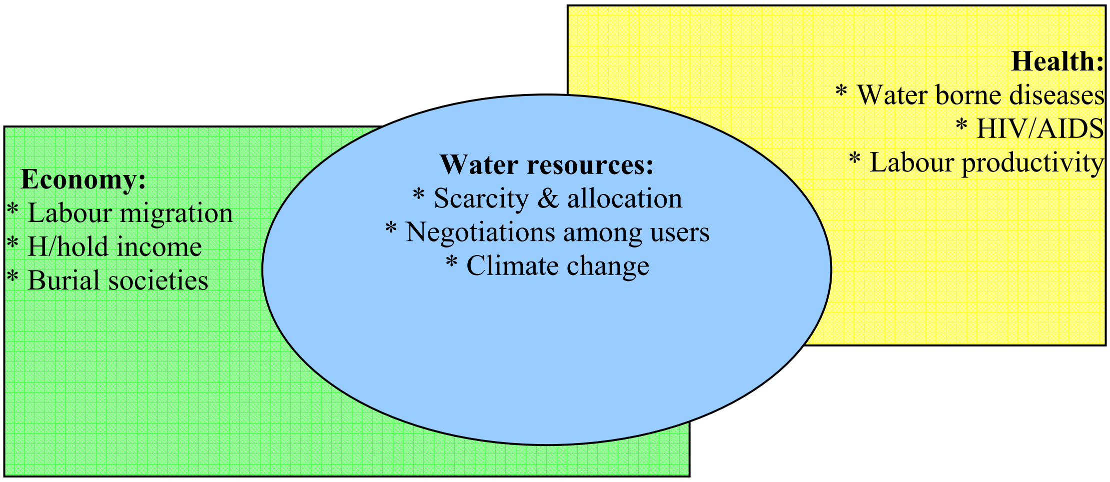

Fig 1: Schematic of areas of interest that emerged out of fieldwork and could be modelled.

3.1.3 Social networks

Social networks are of interest to the CAVES project. Certain areas of interest with regards to social networks emerged during the fieldwork and are presented below.

Traditional institutions

Marriage

People marry both from within and from outside the village. If they marry someone from another village, they decide together which village they will live in. Traditionally they would have lived in the husband's village. Marriage appears to be a significant investment as money or other goods known as *lebola*, have to be paid to the bride's family. It is also necessary to have a big celebration where the whole village is usually invited.

Burial societies

Most people in rural villages belong to burial societies. These societies have different forms, with some being more formal than others. The banks run funeral policies but most people were involved in village based schemes that often seem to cover a number of villages in the area and village members serve on the committees.

Burial societies also have an important social function. The society meets once a month usually and matters relating to the society are discussed. After this, a social gathering is held which strengthens networks. Enrolment in these societies also seems to be the one activity that people do as an investment. It is interesting that death is the one certainty and so this is perhaps seen as insurance so that the family can manage the future after the expenses of funerals and feasts.

Food

People tend to borrow food from neighbours if they do not have sufficient. People might go to their neighbours house and eat there or 'borrow' food. This food is usually not taken back but means that if the other household is in need of food they can expect reciprocity.

Activity/employment

Social networks seem to be key in accessing employment. People mentioned that they look for work outside the village in areas where they can stay with people they know. Even though there are mines opening up in Steelpoort, an hour and a half away, people from Mohlotsi are more likely to travel to Gauteng, which is further, as that is where they know people. When they are looking for work, the person they are staying with will host them and they do not have to pay for accommodation but will be expected to return the favour when they do find employment. Information about jobs reaches people where there are strong social networks. People said they do not spread the word widely about new jobs, but someone might send information about job prospects to their close friends and family back in the village.

Community projects

People are keen to get involved in community projects. The youth seem to be primarily interested in community projects if they can access an income through them. Older people would like to get an income but also seem to want to be involved if the project can provide produce. Communal gardens were therefore of interest to the youth only if they would be able to produce for market. In the villages we visited, water is a key constraint and so although they were interested in establishing gardens, they were battling to secure water. Many community-based projects seem to focus on supporting the youth or women. These projects seem to hinge on key individuals and at times, those individuals' links to higher levels. For example, if the headman supported a project and had connections to the municipal level, the project was more likely to get going.

Family networks

There are stong family networks. Families who are related might meet once monthly to discuss issues and socialise. Often children live with their parents even when they are married and have children. The grants received by individuals are seldom used only for individuals but tend to be used to purchase food for the whole household. Household members often seem to relocate in order to cope with stress. For example, in one household the children had been sent to live with the woman's sister who was able to care for them. In another case, the household members who were living together were split up when the daughter received an RDP (Reconstruction and development programme) house.

Linkages across scales

All villages have a traditional head. In most villages there is a headman, usually established through family networks and birth rights. These headmen are under a chief, who will oversee his own village as well as a number of surrounding villages that will have headmen, although one might have a foreman who has more status than the other headmen and helps to support the chief. These chiefs report to the ward counsellors. Ward counsellors are supported by the municipalities. The ward usually consists of a number of villages. This system enables the municipalities to get feedback from the villages without having to communicate with each village separately as the ward counsellor is responsible for that. The ward counsellors report to the municipality. There are a number of municipalities in a district and a handful of districts in the province and 9 provinces in South Africa.

3.1.4 Conclusion

In order to use the RADAR data it is necessary that the modellers meet with the RADAR project coordinator to ensure that there is a common understanding of the data and how it will be used. This will also enable to modellers to understand the context of their model and to engage with potential users of the model. This will be undertaken in a fieldtrip in June.

A masters student will be supervised by the SEI. Her dissertation in Sekhukhuneland will focus on water and the associated allocation rights and governance issues. She will use the WEAP model to frame her work and feed this information back to the modellers.

The fieldwork has enabled a more focused pathway to be identified. This needs to be developed further with the modellers and case study experts to ensure the modelling addresses the methodological challenges it set out to explore at the same time as representing the case study material in a way that integrates multiple stresses and social networks and can be validated by stakeholders.

3.2 Grampian Case Study (Macaulay Institute)

3.2.1 Progress on Literature Review

Research Questions

1. How has (agricultural) land use at a study site in North East Scotland changed over the past 20 years?
2. Why does agricultural land use change?
3. What is the role of land users' social and informational networks in this process?

Question One

Dr. Small has completed a preliminary review of background literature on data sources on land use change in Grampian, including data from interview-based surveys of farmers in the region. She utilised these findings primarily to identify a field research area, and as context for the development of an interview guide. Ongoing contextualisation of study findings, through synthesis with literature on land use in North East Scotland, will occur throughout the research.

Questions Two and Three

Dr Small has completed a preliminary literature review of social networks as studied in the social sciences. She began by reviewing the history of social network studies, before identifying four major approaches to the study of social networks: social network analysis, actor network theory, social capital, and social networks as studied in the rural sociology literature. She identified the primary assumptions of each of these approaches and compared them to the assumptions of the CAVES project, and the Grampian case study in particular. Recognising that there is no 'perfect fit' within the sociology literature for the CAVES project, she determined that the concept of 'social capital' would be most useful as a theoretical approach for structuring the research in the Grampian case study.

Social capital is an interdisciplinary concept widely accepted in the social sciences. Social capital has varying definitions, dependent on the major theorist utilised, but in general is considered to be "the features of social organization … that can improve the efficiency of society by facilitating coordinated actions" (Putnam, 1993, p. 167). Social capital may include trust, social norms, social credentials, information channels, family relationships, voluntarism, group membership and community engagement. While typically recognising that social capital is held by groups or within the context of relationships, rather than by individuals, studies of social capital do not usually address specific types of network structure. Studies of social capital vary widely, ranging from quantitative analysis of standardised survey data to qualitative description of social norms.

For the purposes of the Grampian case study, the flexibility in definition and use of the social capital concept is beneficial, allowing integration of the diverse ideas embedded in the project documentation. The concept fits well with the proposed qualitative field research, and theoretical linkages to economic decision-making. Use of the social capital concept allows the focus of field research to remain on the role of social networks within land use change processes, without the identification of whole or ego-centred networks. As such, social capital enables the development of a more feasible field research approach (under the conditions of the Grampian case study) than a more formal 'social network analysis' of nodes and ties. The literature on social capital is sufficiently wide ranging as to include all of the issues identified in the CAVES project documentation, but care will have to be taken to ensure theoretical consistency when bringing these ideas together to define social capital in the project. Some work will also need to be done in order to integrate social capital with complexity theory.

3.2.2 Research Plan

Dr. Small has developed a research plan to address the research questions. She will undertake qualitative interviews with 50 – 60 land managers, including 10 – 12 'successors' (individuals intending to become the primary land use decision maker in the future), plus approximately 20 key informants (agricultural business-people and agricultural stakeholders). This range of interview respondents will give depth to the study, through the identification of different perspectives on the process of land use change. The interviews of both primary land managers and their successors are expected to result in the identification of different networks and social influences on land use change, which will assist in identifying 'networks of networks', as well as identifying changing patterns of land use in both the past and anticipated future.

Upper Deeside has been chosen as the study site location. The area stretches from Kincardine O'Neil to Braemar, with half of the territory within the boundaries of the recently established Cairngorm National park. The area is fairly large, but this was considered necessary to include a broad range of land use holding types and patterns. In addition, holdings within the study area are often quite large, due to the large estates in the area and extensive agricultural production characteristic of hilly and semi-mountainous land. The large study site is also more conducive to the 'snowball' sampling technique, whereby initial respondents identified members of their network for further research. Pilot testing demonstrated that these connections are often somewhat distant. The initial sample is taken from two key informants – one with access to large scale farms and estates, and another with access to small-scale farms. The combination should ensure a wide range of study respondents.

The interviews will be structured utilising an 'interview guide' of issues relevant to the research questions, rather than a formal questionnaire. This will allow respondents to speak openly about what they view as the most important issues surrounding land use change, and the types of social networks in which they are involved. The interview guide, currently being pilot tested, addresses the following topics:

- Land holding characteristics (scale, commodities produced, management structure)
- History of land use change, and new land acquisition on the holding
- Largest change in land use during the current land manager's tenure
- External shock of greatest significance during the current land manager's tenure
- Process of land use decision-making

- Response to the Single Farm Payment (major policy shift significantly impacting farm incomes)
- Group membership and community participation
- Sharing behaviours – information, labour and equipment
- Anticipated future changes to land use
- Respondent demographic characteristics

The interview guide is expected to evolve over the course of the research, as other important areas become identified. Study results will be utilised to answer the study questions, and identify decision rules for land use change and transactions. These decision rules will in turn be utilised to guide model development.

3.2.3 Field Research

The initial stage of field research has begun, with interviews of seven farmers, three estate managers and two key informants completed to date. These interviews form the 'pilot study' – preliminary work to evaluate the utility of the interview guide and general research approach. Some minor changes have been made to the interview guide, but the general approach appears to have been successful. Interviews have ranged between 45 minutes and 2 hours in length. Analysis of these interviews is underway. Potential respondents have been identified for a second wave of interviews, to occur in March.

3.2.4 Stakeholder Validation Protocol

The 'triangulation' of research findings through identification of three different data sources (in this case: land managers, land manager successors and key informants) is a well-established means of academic validation of study findings. In addition, we are planning a workshop for winter 2006, in which study respondents will be invited to respond to the decision-rules identified by Dr. Small as arising from the field research. This workshop will occur before data analysis is complete, to ensure that the study is truly responsive to respondent feedback.

As part of the research process, several additional stakeholders have been identified. These include staff from the Cairngorm National Park Land Use Division, the Aberdeenshire Council Rural Development, and the National Farmer's Union. Dr. Small will interact with these individuals on a bi-monthly basis to discuss the research process and findings.

3.2.5 Directions for Future Work

- Field research: A second wave of field research will be completed at the end of March. A third wave of interviews will occur in June/July, reaching an anticipated total of 45 by August. A fourth wave of interviews will be undertaken in Oct-Dec 2006.
- Data analysis of interviews in consultation with other members of the CAVES research team. This will occur in April/May and August/September, reflecting the busy times of year for farmers.

3.2.6 Reference

Putnam, Robert D. with R. Leonardi and R. Nanetti (1993): Making Democracy Work – Civic Traditions in Modern Italy. Princeton University Press, Princeton, New Jersey.

3.3 Odra Valley Case Study (Uniwersytet Wroclawski)

3.3.1 Description of the Work Undertaken

Knowledge elicitation

Decision rules – field research

In order to collect sufficient data for modeling team, the research tool – semi-structured interview questionnaire (in two versions: for experts and landowners) was created. Included questions concern following issues: land use changes in the past, decision rules regarding land use, land reclamation system maintenance and collective action, social networks, future scenarios. The questionnaire was tested and discussed with experts.

Interviewees (landowners) in Rogow Legnicki village were identified (names and addresses, phone numbers) according to landownership maps, data form local authorities and other sources of information. Following decisions made at the Wroclaw meeting in September 2005, we have chosen landowners owing the land along Kwiatkowicki and Rogowski Canals.

The covering letter was prepared and distributed among interviewees in order to get permission for interviews. Technical aspects of field research were fixed (preparing required documents, printing questionnaires, buying dictaphones etc.).

Interviews were conducted in February. All listed addresses were visited. We managed to conduct 14 interviews. Five persons refused to give an interview. The rest was unavailable; from their neighbors we do know that most of them moved away to other localities and do not cultivate land anymore. Additionally two long (up to 4 hours) and very detailed expert interviews were conducted.

Formal rules – legal acts analysis

Legal acts concerning land reclamation were collected and analyzed in order to find formal rules of land reclamation system maintenance and related collective action. We regard these rules as important, since all landowners and relevant institutions must follow them. These rules indicate the hierarchy of responsibility and the scope of decision reference of our potential agents. The results of this analysis were described in a document „Legal Framework for Land Reclamation and Collective Action in Water Partnerships".

KnETs

The work on knowledge elicitation tool (KnETs) for the Odra case study has been started (according to a template sent by Sukaina Bharwani).

GIS

A 1:5000 map of the village Rogow Legnicki was scanned, geo-referenced and integrated into the Odra river case study GIS database as a backdrop map for digitization of following thematic vector maps, which will be the input for a development of the land reclamation model:

- land reclamation system (canals, ditches, water bodies, culverts),
- land ownership and land use along the Rogowski and Kwiatkowicki canals in Rogow Legnicki.

In order to facilitate understanding of land ownership and land use in the Odra case study area, consultations with local authorities and experts were held, as well as legislation and literature regarding GIS based ecological-economical modeling in the agricultural landscape were studied.

The methodology for field verification of LULC and land reclamation system maps, derived from cartographic and remote sensing sources, was developed.

In cooperation with Wroclaw University of Technology, the TOPMODEL hydrological model software was evaluated to asses the TOPMODEL usability as a basis for Odra river case study biophysical model.

Further sheets of the contemporary 1:10 000 topo maps where obtained, georeferenced and stored in the Odra river case study GIS database. The maps are being used as a backdrop for digitising elevation contour lines and points in the catchments encompassing Rogow Legnicki.

A preliminary digital terrain model (DTM) was interpolated using the above data, to be utilized in the biophysical model developed by Wroclaw University of Technology. Different interpolation algorithms were evaluated. Due to numerous spots of high curvature and prevailing low denivelations in the study area terrain, the natural neighbor interpolation has proved to yield best results.

Other issues

Meetings

- Organisation and coordination of CAVES project partners meeting held at the Wroclaw University, Wroclaw 2005 Sept. 27-30, including the presentation “Evidence collected so far”, as well as the field trip with accompanying field trip guide “Odra River Valley Case Study - Policy Relevant Issues for Modeling”. Accomplishment of formalities connected with the CAVES Meeting set off.
- The whole UWr team participated in the Wroclaw CAVES Project Meeting 26-29.09.2005.
- The whole UWr team is going to participate in Aberdeen CAVES Project Meeting 13-17.03.2006.

Data for Kassel modelling team

A document “Information Package for Modeling Team No. 1” was prepared and sent in order to answer the questions from Kassel modelling team concerning floods/droughts, crops, knowledge/skills. Initial GIS data package for Kassel University modelling team was included.

Project management

Large amount of organisational and office work connected with project management is being done continuously (preparing documents – invoices, reports, agreements, project description for www site etc., contact with University offices, purchase – tickets, stationery etc.).

Technical maintenance

Our team learned CAVES CVS server usage for data exchange with CAVES project partners. Besides, the Odra case study staff computer network and workstations where maintained due to moving to another work place. GIS software (Grass 6.1, GDAL, PROJ.4, Quantum GIS) was updated for stability and performance improvement.

3.3.2 Outline of How to Proceed

Knowledge elicitation

- The results of field research must be elaborated, including interviews transcription, coding and analysis in order to elicit decision rules.
- There are plans to work out knowledge elicitation tools (KnETs) for Odra case study.
- Other work depends on the needs of the Kassel modelling team.

GIS

- Further digitising of land use, land cover, land ownership an land reclamation system maps in the Rogow Legnicki village, from cartographic and remote sensing sources as well. Land ownership and land use database provided by Prochowice Commune will be integrated.
- Field verification of the above maps will be done in the late springtime.
- Once verification and data accuracy assessment performed, the final data package will be provided to Kassel University modeling team.
- A method for optimal drainage enforcement in the DTM will be developed, in order to improve hydrological soundness of the DTM for better biophysical model performance.

4 Publications

The CAVES project is dedicated to publish results in relevant scientific journals and conferences. During the second six months of the project, the following papers have been written:

- G. Polhill and G. Ziervogel: Using ontologies with case studies: an end-user perspective on OWL. Submitted to NCESS 2006, Second International Conference on e-Social Science, 28-30 June 2006, Manchester, UK
- A. Ernst, F. Krebs and C. Zehnpfund: Dynamics of task oriented agent behaviour in multiple layer social networks. Submitted to WCSS 2006, First World Congress on Social Simulation, 21-25 August 2006, Kyoto, Japan
- N. Gotts and G. Polhill: Simulating Socio-Techno-Ecoystems. Submitted to WCSS 2006, First World Congress on Social Simulation, 21-25 August 2006, Kyoto, Japan
- S. Alam, R. Meyer and G. Ziervogel: Modelling the Socio-Economic Impact of HIV/AIDS in South Africa. Submitted to WCSS 2006, First World Congress on Social Simulation, 21-25 August 2006, Kyoto, Japan
- B. Werth, S. Moss, G. Ziervogel and T. Downing: Modelling Migration in the Sahel: An alternative to cost-benefit analysis. Submitted to WCSS 2006, First World Congress on Social Simulation, 21-25 August 2006, Kyoto, Japan

5 Deliverables

5.1 Current Deliverables

There are five Deliverables due at the end of project month 12. These are the internet portal, a knowledge base, a report on resilience theories and measures, and two prototype models, one for the Odra River case study and the other for the Grampian case study. Since work on the Grampian prototype model was delayed due to the necessary enhancement of the underlying modelling software (FEARLUS), it was decided to swap the due dates of Deliverable No. 4 (Grampian prototype) and Deliverable No. 7 (Limpopo prototype model). Thus the prototype model for the Grampian case study is now due in project month 18 and the one for the Limpopo case study is due in project month 12.

The following Deliverables are available now:

- Deliverable No. 2: Internet Portal. The CAVES internet portal went on-line several months ago. It consists of a publicly accessible part and a part with restricted access for eligible users. The URL is `http://caves.cfpm.org/`.
- Deliverable No. 3: Knowledge Base. The knowledge base contains briefing notes on foundation topics for the CAVES project. These are publicly available as part of the internet portal at `http://caves.cfpm.org/knowledgebase/`. The current version 0.4 of the knowledge base will be replaced by a Wiki[4]-based component in the near future.
- Deliverable No. 5: Prototype of the initial model for the Odra River valley. The full source code of the Odra River prototype model is available on the CAVES CVS server, which provides access for all CAVES participants.
- Deliverable No. 6: Critical examination of resilience theories and measures. Since the dissemination level of this report is PP (restricted to other programme participants), it can be found in the restricted area of the CAVES internet portal.
- Deliverable No. 7: Prototype of the initial model for the Limpopo region. The full source code of the Limpopo prototype model is available on the CAVES CVS server, which provides access for all CAVES participants.

5.2 Future Deliverables

At the end of the next six month period (project month 18) another two Deliverables are due: the prototype model for the Grampian case study (Deliverable No. 4) and a working paper on case study structure, stakeholder/agents and validation data (Deliverable No. 8). Considering the current progress in the case studies and the respective model development, we anticipate a delay for the latter. This will enable us to base the working paper on experience instead of an ideal outline, which will enhance the value of the Deliverable significantly.

[4] See e.g. http://en.wikipedia.org/wiki/Wiki