ONTOLOGICAL MODELLING TO SUPPORT THE PLANNING OF IS DEVELOPMENT PROCESSES
A Position Paper

Robert T. Hughes, Graham Winstanley and Karl Cox

School of Computing, Mathematical and Information Sciences, University of Brighton
Watts Building, Lewes Road, Moulsecoomb, Brighton, BN2 4GJ, U.K.

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Abstract: IT projects are known for the high rate at which they fail. Past work by the authors has investigated the building of cognitive causal maps to find and represent what the participants in a project feel are factors that lead to project success or failure. It was found that while agreement can often be reached on the broad causes of failure, there tended to be differences about the precise nature of the identified factors (for example the exact meaning of 'inadequate resources'). The position paper proposes the use of ontological models to enrich and clarify causal maps with information about the classes of object in the real world to which they refer. This would facilitate more effective planning of new projects. An aspiration of the authors is to use the information generated by ontology-enriched causal maps to provide guidance on the tailoring of methodologies, particularly Agile ones, for specific projects.

1 INTRODUCTION

1.1 Context and Motivation

This position paper presents a proposed programme of work that seeks to enrich the understanding of participants in IT projects of the factors that affect project success and failure and the likely effectiveness of actions aimed at promoting success. It proposes to extend work which captures the perceptions of stakeholders by means of cognitive causal maps by adding ontological models to provide details of 'real world' entities and their attributes implied by the factors that have been identified. This will support project planners by clarifying the implications of decisions, particularly their alignment with the outcomes sought for the project.

There is justified dissatisfaction with the failings of IT development projects. For example, a report on the UK health service's national programme for information technology (NPfIT) noted a 30% failure rate for IT projects. One such IT project failure in the Wessex Regional Health Authority led to a loss of £43millions of public money (Hendy et al., 2005). Reducing the proportion of such failures would clearly generate financial savings and increase the benefits of successfully implemented projects.

One response to project failures from the project management community has been an emphasis on risk management – see, for example, Boehm (1991). Risks may be the result of uncertainty or of ignorance. In some cases, it is difficult, if not impossible, to predict what occurs – for example that a fire at a supplier will prevent specialist IT equipment being delivered. However, in many cases the risk is caused by a lack of knowledge. An enterprise with little IT experience might misguidedly acquire an order processing system unsuitable for their business. The knowledge that might have avoided this existed in the world, but had not been disseminated to those who needed it. It is this type of risk that is our focus.

It is acknowledged by most writers on the management of IT projects that it requires attention to both technical and social issues. For example, Winter *et al.* (2006) recognised the inevitably instrumental nature of much of project management – the execution of planned activities to achieve physical outcomes – but emphasised the need to develop a richer understanding of the '*concepts and images which focus on social interaction between people, illuminating the flux of events and human action…*'. Major projects have a range of

stakeholders with distinct interests and developers with differing expertise, each of whom is aware of different types of risk. Sharing of viewpoints and agreement on joint action to reduce risks is needed.

The identification of risks is futile unless projects are flexible enough to adapt to risks. Agile approaches address shortcomings in IT development by measures to promote flexibility, for example, delivering projects in smaller units with more interaction between developers and users. However, we believe that while Agile approaches hold great promise as an effective way of organising development projects, they demand a greater common understanding of the nature and context of the project by project participants. Our proposed research attempts to support this understanding.

1.2 Cognitive Causal Maps (CCMs)

This new research direction has grown out of previous work by the authors and their colleagues which investigated ways of improving the management of risk in IT developments – see Al-Shehab (2007), Al-Shehab *et al* (2005, 2006), Hughes *et al.* (2006). This work used cognitive causal maps (CCMs) to diagnose the causes of IT project failure. CCMs are diagrams consisting of nodes representing the outcomes of a particular course of action and connectors between the nodes which indicate where some factors influence others – see Figure 1. The technique is supported by a research tradition starting with Axelrod's seminal work (Axelrod 1976). In the UK CCMs are particularly associated with Eden and his colleagues – see, for example, Eden (2004).

When applying CCMs to the causes of project success and failure, some nodes represent the *desired outcomes* of the project. Other nodes represent *policies*, the means by which the desired outcomes are to be achieved. Further factors are *environmental* relating to conditions assisting or hindering the achievement of the desired outcomes. The factors are presented as 'concept variables' which for a context take a value within a range bounded by two opposing poles, for example, a range varying from an abundance of required skills on the one hand to a severe skills shortage on the other. Connectors are drawn between these nodes indicating the influence – positive or negative – of the factors on one other.

Figure 1 below describes a situation where a shortage of staff with the skills needed for a task means that resources available to a project do not have the expertise envisaged when the project was planned. (The minus sign indicates that the skill shortage influences the second pole of

adequate...inadequate resources, i.e. makes resources inadequate). This leads to the planned project duration being exceeded. A policy of additional training can, to a certain extent, offset the problems caused by the skills shortage.
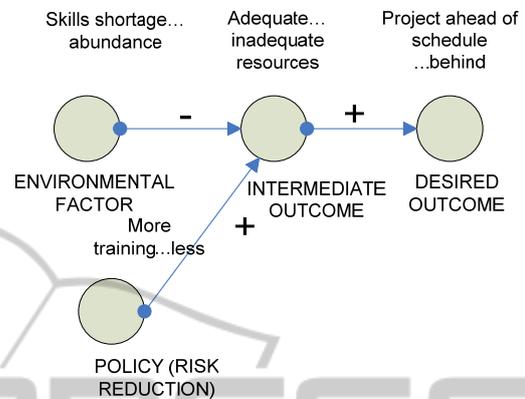

Figure 1: Notations used in a primitive Cognitive Causal Map, following Eden 2004.

As part of our previous work, collaborative sessions with stakeholders involved in problematic projects were used to generate relevant CCMs. Two problems emerged from this:

1) There might be agreement on the importance of a factor such as '*inexperienced staff*' or '*poor project management*', but with differences of opinion about what the participants meant by these;

2) Little guidance was generated on the practical steps needed for success on new projects.

1.3 Adding Ontological Support to CCMs

CCMs need details of their context to be more effective. Recent work by Chauvin and colleagues (2007) shows the scope for ontological models that describe the context of CCMs. We intend to assess this approach to ontological modelling as a basis for enriching the data gathered from the collaborative creation of CCMs by project stakeholders. In Figure 1, the classes of interest in a project environment might include:

- Developers who carry out the work
- The technologies with which they are familiar
- The activities to be carried out
- The technologies that the activities will use.

A collection of such descriptions can form the basis

of a project management ontology. If the participants in a project agree on this ontology, then the potential for agreement on the meaning of higher-level terms such as '*adequate resources*' is increased. This facilitates the selection of actions to reduce or mitigate obstacles to project success.
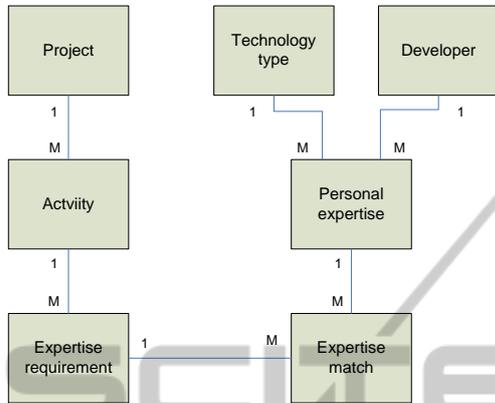

Figure 2: A fragment of an ERD to support the concept variable *adequate...inadequate resources*.

A fragment of an entity relationship diagram (ERD) which might support the concept variable *adequate...inadequate resources* is illustrated in Figure 2. A developer could be skilled in a number of technologies which could include particular programming languages such as Java. A project consists of a number of activities, each of which requires the application of one or more technologies. The relevant expertise of a developer will depend not just on their innate qualities but the demands of the new project. Someone who has been highly regarded as knowledgeable may have their expertise reduced by the introduction of new technologies.

The classes in the project ontology can be mapped to instances in the project plan. Thus a three level structure of concept, class and instance can be envisaged – see Figure 3. In this context 'concept' has a broader meaning than class and can be composed of a number of classes and relationships.

Previous work on ontological modelling has been mainly associated with artificial intelligence, seminal work in the field being that of Gruber (1995). The drive to create a 'semantic web' enabling more meaningful and trustworthy information retrieval has led to a wider interest in ontology creation.

Eden (2004) and Marshall (2009) have used CCMs to analyse existing organisational contexts. The proposed work will also use CCMs as an investigative tool, but will in addition follow some of the relatively few examples (most prominently Abdel-Hamid 1988) where CCMs have been used to
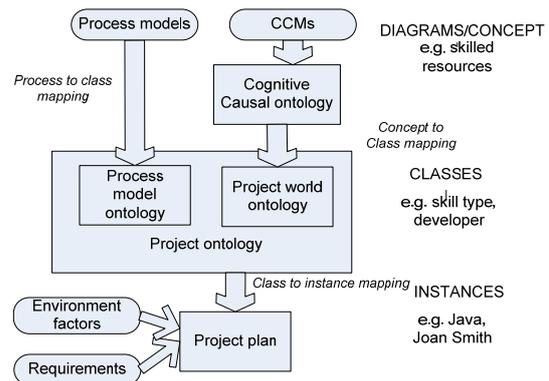

Figure 3: Relationships between a CCM, a Project world ontology and a project plan.

construct decision-making tools. Techniques have also been developed which trace linkages between business objectives and the IS/IT developments needed to support them (Bleistein *et al.* 2004, 2006a, 2006b, Babar *et al.* 2008). These use a CCM-like goal modelling notation, but generate guidance on *what* is to be developed whereas the current work is concerned with *how*.

Some ontological modelling techniques are similar to those of database specialists. Methods in use in the construction of object-oriented software are applicable to ontology construction (De Nicola *et al* 2009). Conventional data modelling may be adequate, but a pragmatic advantage of a specifically ontological approach is that it facilitates the incorporation of existing project-related ontologies, for example, PROMONT (Abels *et al.* 2006), PLANET (Gil and Blythe 2000) and KANAL (Kim and Gil 2001), into new ontologies either directly or in a modified form.

Some research has developed more rigorous forms of CCMs where the strengths of factors and the links between them are expressed numerically and the models executed to produce predictions (Abdel-Hamid 1988). One middle way uses a fuzzy quantitative approach (Stach and Kurgan 2004). Our own work has made extensive use of fuzzy quantitative mechanisms developed by Montibeller *et al.* (2007) to describe, through reasoning maps, expert decision-making processes. The emphasis on the new direction of our research is to make CCMs created in conjunction with stakeholders more useful by increasing their semantic richness, rather than simply attempting to quantify factors which may in any case lack clear definition.

Agile project management is a good fit with the aspirations of the new work as it emphasises the tailoring of project processes to fit the project's context. The focus will be on DSDM/Atern (DSDM

2007) because: it is applicable to a wider span of IS/IT development activities than approaches such as XP (Beck and Andres 2005) which focuses only on software code production; it has a relatively wide user base in the UK and, pragmatically, the project team have links with DSDM/Atern practitioners. DSDM/Atern is characterised by: (i) The initial formulation of requirements in terms of the business objectives to be met by a development; (ii) the division of the product delivery into increments, each of which should achieve the deployment of usable system components generating user benefits and (iii) the prioritisation and allocation of requirements to increments with fixed deadlines. The second Agile approach to be considered will be Scrum (Schwaber 2007), which, like DSDM/Atern, is not focussed exclusively on software code development. Scrum appears to emphasise the behavioural aspects of projects, compared to the DSDM/Atern concern with process. The examination of more than one approach encourages the development of more generic and robust research outcomes.

2 RESEARCH QUESTIONS

We propose that CCMs enriched by ontological modelling can support more effective decision-making by those planning and managing IT projects, particularly projects that use an Agile approach. To confirm this, we believe the following research questions will need to be addressed:

R1. *How can project processes be most effectively represented as ontologies?*

R2. *Can ontological models effectively capture cause-and-effect relationships?*

R3. *Can ontological models be created which clarify the perceptions of a project captured by a CCM?*

R4. *To what degree can ontological models usefully support tools and operations at the level of practical project planning and management?*

These four questions will be discussed in turn in the next four sections.

2.1 How can Project Processes be Most Effectively Represented as Ontologies?

A methodology contains a set of recommended (sometimes mandatory) steps for carrying out a procedure. It may be a codification of good practice or be mandated by an authority (as with the PRINCE2 project management standard in UK

government projects). Any method will inevitably have to be 'fine-tuned' for local use (Fitzgerald *et al.* 2003). We have already established the feasibility of representing project processes in an ontological model (Hughes 2010). We now need to find a way of not only modelling core work practices in an ontology, but also variations on that core.

We believe that Höfferer (2007) provides valuable guidance on deriving ontologies for processes. Processes can be modelled for an instance of a project (level M_0), e.g. a plan. At the next highest level (M_1), activities and other project characteristics can be generalised to cover a class of projects – e.g. as a software development lifecycle. A metamodel (M_2) can further generalise to superclasses – for example, '*design*', '*build*' and '*test*' can be generalised as instances of '*activity*'. This procedure will be applied to the two Agile process models DSDM/Atern and Scrum, with separate level M_1 models for the two approaches, and then an attempt at a level M_2 model of a general Agile project model. The resulting models will be validated by populating them with sample instance (level M_0) data from specific project scenarios. These procedures implement the *process to class mapping* transition from process model at the Diagram/Concept level in Figure 3 to the Process Model Ontology at the Classes level.

2.2 Can Ontological Models Effectively Capture Cause-and-effect Relationships?

Although we often generalise the idea of causality, different cause-and-effect relationships involve different processes. Some are physical processes, e.g. '*fire destroys data centre*', others matters of human motivation, e.g. '*better job opportunities cause staff departures*'. These differences are noticeable when trying to combine the different influences on a particular concept variable: in some cases *both* A and B are needed to cause an effect (e.g. a reliance on external resources *and* a shortage of those resources), in other cases *either* A or B (e.g. an increase in costs *or* a decrease in income).

Our experience with CCMs leads us to believe that the types of causality identified in CCMs need to be more carefully analysed. Some guidance on this may clearly come from the literature on causality – one obvious source is Pearl (2000). Our aspiration is to create a causal taxonomy to be incorporated into the process-oriented ontologies identified above. This is part of the *concept to class* transition from CCMs to Cognitive Causal ontology in Figure 3, but relates only to the categorisation of

linkages at CCM Concept level and equivalent properties at Class level.

2.3 Can Ontological Models be Created which Clarify the Perceptions of a Project Captured by a CCM?

The successful construction of the envisaged ontologies depends on effective modelling of stakeholder perceptions. Existing ontological modelling tools are usually not designed primarily for easy communication with subject specialists. We need a way of identifying and eliciting the information needed to obtain a clear understanding of the influences on a project. Ultimately some form of online collaborative development of ontologically enhanced CCMs would be desirable, but to achieve this we need ways of establishing ontological commitment, that is, agreement on the terminology to be used and the way that a project is to be viewed.

Established methods (see Al-Shehab *et al* 2005) will be used to create preliminary CCMs capturing overall project objectives, environmental factors and policies. A 'straw man' Project World ontology will be created from existing sources such as PROMONT (Abels *et al* 2006) which will describe the generic classes of object that would be expected in the context of a project. Classes in this ontology will be mapped to concepts in the CCM ontology. Chauvin *et al* (2007) describe a way of enriching CCMs with contextual information which provides a basis for this work. The initial prototype will be evaluated and modified through a series of test-analyse-modify iterations. Once again populating the resulting model with data from real world projects will form the basis of the validation. This would implement the *class to instance transition* in Figure 3.

2.4 To what Degree can Ontological Models usefully Support Tools and Operations at the Level of Practical Project Planning and Management?

The research questions above address the feasibility of representing processes and what are effectively ontologically-enhanced causal maps as ontological models. It remains to establish the actual usefulness of these. We need to know if it is possible to adapt existing tools and techniques, or develop new ones, that use knowledge captured in the ontologies to support typical project planning and control tasks. The extent to which guidance on decision-making – for example the selection of methods to execute the project – can be provided needs to be assessed.

The starting point for this is the identification of tasks and key decisions involved in planning a project, initially by examining existing practitioner and academic literature. Recognised guidelines supporting project method configuration need to be analysed to assess the extent to which the knowledge held in the project ontologies, in conjunction with heuristics, can offer useful advice the optimal configuration of an Agile method for a particular project. Karlsson's and Ågerfalk's (2009) work which uses goal-modelling as a basis for Agile method configuration provides a guidance on a possible way forward. We need however to be aware that each development project that claims to be guided by a particular process model, may interpret the model in a different way or may modify it to fit a particular context.

3 CONCLUSIONS

This proposal is *not* just an engineering project to create a prototype artefact that might then be 'commercialised'. Rather it is the development and integration of a set of interlocking techniques – many of which already exist although some are in a rudimentary or fragmentary form – and, where appropriate, supporting prototype tools.

It can be envisaged that a potential user might have difficulty simply plugging in such a tool and then trying to use it effectively. The use of the techniques and tools by a wider community would depend on the acquisition of means-end reasoning skills. It could be argued that the promotion of such skills would itself be beneficial in many fields including planning.

Some researchers will find that the ontological modelling of processes by itself can be usefully applied to a broad range of process scenarios beyond the Agile development methods that are the subject of the proposed work. The practical application of contextualised CCMs is of use to researchers in broad range of social science and other applications who wish to document their theories in a structured way which is sensitive to context. Software engineers may be particularly interested in the greater opportunities for informed method tailoring that this work promises.

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