Supporting Knowledge-based Processes Using Flexible Intelligent Agents

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Introduction

We are concerned to develop knowledge-based approaches to facilitating teams of people who must co-operate in the operation of business processes. We are particularly interested in processes characterised by high degrees of situation specificity (e.g. project-based processes such as product design) and by contexts in which the individual team members have comparable levels of authority/power and autonomy in respect of their roles in a business process. To the extent that we are interested in process design, we attempt to identify key information that needs to be made available at early stages of a project to avoid revision costs at later stages.

The successful deployment of knowledge-based systems in such circumstances is relatively limited. Among the reasons offered to explain this are: the knowledge models with which people are supposed to work do not naturally align with the cognition of the individuals concerned (Landauer 1995); the computational (AI) techniques used reflect what machines can do and not on how people actually reason (Smithers 1996), and the adjustability of the autonomy of the support software is inadequate (usually absent) (Barker and Meehan 1999). The significance of the problem is reflected in the 'Cognitive Engineering Research Programme' and the 'People at the Centre of Communication and Information Technologies (PACCIT) Programme' launched jointly by the UK's Economic and Social Research Council and Engineering and Physical Sciences Council (ESRC 1999). Research within these programmes seeks to develop a better understanding of how we should design interactive, knowledge-based systems through studying people, organisations and processes. This paper describes work which attempts to address some of the issues above.

We have chosen two domains: in studying mechanical product design we have sought to develop knowledge models which reflect the cognition of the designers, identify (some of) the communication dynamics of the design process, and examine ways in which these might be captured in computational approaches to support design activity. We have also considered annual timetable design in a large, university (25,000 students). The scale and complexity of the task, the absence of a well defined objective function, the political environment and the distributed authority and autonomy of those participating make this very different from routine scheduling problems.

The remainder of this short paper outlines the processes we have explored; it then abstracts away from the domain specific aspects of these processes to describe how we have attempted to develop more general principles for designing interactive, flexible, IT-mediated systems to support processes (as characterised above) so that relatively powerful and autonomous individuals within 'co-operative' environments make more and better use of knowledge resources.

The design problem

Design can be considered as consisting of two distinct tasks: the *analysis* task generates a formal design specification from an informal problem description; the *synthesis* task entails the generation of a design solution from the formal specification (Bernares and Van de Velde 1995). Concurrent product design is a specialisation of this model and is distinctive in the degree to which it seeks to incorporate a large number of different product life-cycle perspectives at the earliest stages of product design. Commonly, these perspectives include design for market, cost, manufacture, assembly, maintenance, component reusability and recylclability, energy efficiency, etc. (Shiva Kumar et al. 1994). Concurrent design is characterised by an iterative process of 'propose-critique-negotiate' both at the stage where a (revised) conceptual design is arrived at during analysis and in the detailing of that conceptual design during synthesis (Barker, Tranter and Meehan 1998).

In early work with product designers we have developed a knowledge model to guide the development of design support systems. The methodology used in mapping user cognition and modelling the knowledge they work with is described elsewhere (Barker, Meehan and Tranter 1999). It involved using a technique (similar to concept graphs) to re-represent a linguistic representation of the designers knowledge, their behaviour and their organisational context in a semi-formalism based upon CommonKADS models (de Hoog et al. 1992).

Those studies revealed the need to examine computational techniques which allowed ways of implementing support systems which capture some of the dynamics which characterise concurrent design. To achieve this we proposed an agent-based approach which features human/agent interaction, and specifically, human control of adjustable agent autonomy as an essential property of a system which seeks to support concurrent design (Barker and Meehan 1999; Barker, Meehan and Tranter 1999).

The timetabling problem

Timetabling/scheduling is a familiar problem but the scale and complexity of the task determines the extent to which it is amenable to current computational solution techniques (increasingly AI-based). Current computational approaches can achieve valuable results when the scale is relatively limited, the information upon which the timetable is constructed is stable and there is a clearly formulated and agreed objective function.

In our case study, the timetable was constructed by a large team of staff distributed not just spatially but across different functional units of the organisation. The essential information was volatile throughout the process. There was no stable or shared understanding of what constituted an optimum timetable: not least because the construction of the timetable was sometimes made an indirect means of pursuing institutional change agenda by influential managers.

The outcomes of this study were a proposal for a re-engineered institutional process featuring a clear map of what knowledge was needed and when along with the specification of a suite of integrated software tools for facilitating the co-operative operation and management of the process in future. The design for this software is again agent-based and features human control of agent autonomy.

Negotiation in Business Processes

One hurdle in developing knowledge management systems is that it is sometimes difficult to distinguish whether an institution has 'systems of documentation' and 'documented systems'. It is useful to distinguish between organisations which have institutionalised self-censorship and those which manage conversations working with valid knowledge (Argyris 1993). Our studies have led us to the view that observation of negotiation behaviour allows access to important, valid, organisation knowledge which can be preserved, developed and shared.

Negotiation emerged as a significant social experience in both the product design and timetabling domains; it provides the principal context within which the social dynamics which characterise the operation of the process. We believe that effective support systems for processes featuring negotiating behaviour (especially those characterised by high degrees of situation specificity and co-operative but relatively autonomous functional individuals/agencies) need to allow the reproduction of the process dynamics that users are comfortable with.

Support for Negotiation

Negotiation is a distinguishing feature of advanced multiagent systems in which individual agents exhibit autonomous behaviour. Understanding and modelling ways in which human negotiation may be supported in a flexible fashion emerged as one of the central issues in both our studies. In earlier work we have proposed a knowledge-level model for use in the development of multiagent systems to support concurrent design (Barker, Tranter and Meehan 1998). In refining this work we have proposed an agent-based approach to supporting negotiation which features human/agent interaction, and, specifically, human control of agent autonomy in negotiation (Barker, Meehan and Tranter 1999).

It does not significantly misrepresent the current situation to assert that, from an HCI perspective, there is a largely bipolar distribution of computational approaches to support negotiation: at one pole are those systems which seek to facilitate efficient and effective human communication - leaving members of a (distributed) process team firmly in control of their associated communication agents (Wong 1994); at the other pole there are approaches which implement wholly autonomous agent-based negotiation (Kraus, Sycara and Evenchick 1998; Zlotkin and Rosenschein 1996a,b). There appear to be very few examples of computational techniques which facilitate the degree of variable agent autonomy necessary to capture the social dynamics identified in our case study although there is the occasional exception (Galitsky 1999).

Computational approaches to supporting/implementing negotiation are characterisable in a number of ways. For example, negotiating agents may be co-operative or competitive. In other negotiation systems computational agents are debarred from altering their beliefs/goals. Such systems leave human users to determine agent goals and change them in the event of unresolved conflict. We established that most computational models of agent-based negotiation fall short of capturing human negotiation.

In seeking to realise flexible, agent-based approaches to support negotiation we have been able to exclude many computational approaches which, whilst valuable in other contexts, do not capture negotiation dynamics as we have witnessed them e.g. because they depend upon central arbitrators or mediators. Negotiation techniques proposed for Task, State and Worth oriented domains (Zlotkin and Rosenschein 1996a,b) offer some scope for control of autonomy however, we feel some of the underlying assumptions behind these techniques are overly restrictive and they are of limited value in systems to facilitate human negotiation.

However, we have identified two approaches based upon preferences supported by argumentation (Wong 1994; Kraus, Sycara and Evenchick 1998) which we have combined to develop a prototype system which supports negotiation in the context of materials selection for product design. We have exploited the 'Belief, Desire, Goal, Intention' (BD(G)I) agent architecture (Kraus, Sycara and Evenchick 1998) in identifying means of controlling autonomy e.g. in managing mental state via introduction, modification or deletion of desires, desire and preference ordering, belief revision, goal determination and selection, intention generation and argument generation and evaluation. All of these 'control points' offer scope for human-agent interaction that will determine the dynamics and outcome of a process involving negotiation.

We are currently evaluating the prototype for its 'usability' in design teams and validating our design.

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