

Workflow- and agent-based cognitive flow management for distributed team Cooperation

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Abstract

Human cognition and work processes are two inseparable parts of human problem solving, however, the cognitive process is neglected in most research on knowledge-intensive team Cooperation. This paper presents an approach for modelling these two parts of the process for use by a distributed co-operative team. We define a new notion of cognitive flow to reflect the dynamic cognition processes of a team. The mechanism is built to model, control and manage the cognitive flow process. A solution for applying this approach to a distributed team during software development is presented. The experiment showed that the approach can improve the problem solving ability of a team.

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1. Introduction

People usually solve large-scale problems as a team where all the members make a co-operative effort to achieve a common goal. The process, however, may need the team members to be decentralised in order to make use of site-specific resources. Team members then must Cooperate in either a loosely coupled way, like a research or a robot football team [30], or a tightly coupled way, like a production line, depending on the application requirements.

Knowledge management plays an important role in promoting the team's work effectiveness. It concerns the management aspect (e.g. the organisational learning, organisational behaviour and organisational culture) and technical support [3,4]. The scope of this

paper is on tightly coupled Cooperation teams and their technical support.

Workflow, the automation of a business process in whole or part, is a useful tool for modelling and managing a business process. It can enforce tightly coupled co-operation between team members according to a pre-defined logical process between activities (tasks). A workflow management system (WfMS) is a system that defines, manages and executes workflow specification through the execution of software whose order of execution is driven by a formal representation of the workflow logic [15,16,31,32]. The workflow establishes the logical execution ordering between team members' activities, and therefore, it helps define the intra-enterprise or inter-enterprise business process [27]. Time modelling, reusability, exception handling, distribution, adaptability and formal modelling of workflow have been discussed in several articles (e.g. [5,20,21,24,35]) and these features,

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together with resource-sharing, should be incorporated into the current WfMS to provide better support to the distributed team.

The implementation of every task in a workflow is an interaction between team members and the support environment. In knowledge-intensive teamwork, the members' cognitive abilities and their Cooperation determine the efficiency and quality of their performing the team task. Thus, the team members actually cooperate at three levels, from low to high: work Cooperation, resource (information, knowledge and services) sharing, and cognitive Cooperation. At the *work Cooperation level*, team members implement their tasks according to the team's workflow definition. At the *information sharing level*, team members communicate to share information based on a pre-defined sharing paradigm. At the *cognitive Cooperation level*, team members learn from each other, make abstractions, make across-problem analogies, and use past experience and skills to solve new problems [6,7,33]. The current workflow model and WfMS do not include such a cooperation level.

Internet techniques can help a globally distributed team cooperate, but team members are likely to be changed more frequently. Those members who leave take away information, knowledge and experience that they acquired, and the replacement team members have to spend time learning the co-operative rules and problem solving methods and accumulating the information resources and experience from scratch. This addition will usually slow down the work of the team [2].

Another challenge is the contradiction between globalisation and co-ordination. A globally distributed team has the advantage of making use of global resources, but the complexity of the co-ordination as well as the costs of communication and transporting products will also increase. The co-ordination involves, task planning including such considerations as time difference and establishing a mutual-understanding. These require a distributed team development environment to support cognitive Cooperation as well as work Cooperation.

Similar problems apply in multi-agent Cooperation for distributed artificial intelligence [1,8,9,14,17,29] and decision-making in group decision support systems [10], as well as a collaborative knowledge base [12] and collaborative design [23]. They focus on the

computational principles, the operational models, and the support systems for interaction and co-ordination between team members, and the application of these principles and models. The dynamic decision, Cooperation, and creative user interfaces were investigated in [28,34]. However, previous research has neglected the evolution of the team's cognitive ability during Cooperation and the management of this evolution to enhance the problem solving ability of the team.

This paper proposes an approach that aids the cognitive Cooperation in a workflow-based team so that its work efficiency and problem solving ability can be enhanced. Consequently, two issues need to be investigated: (1) the process modelling and the evolution process of the team's cognitive information and (2) the management mechanism to help in Cooperation.

2. Agent-based workflow: modelling active human Cooperation

Conventional workflow models are activity-based. All the activities (tasks) and their order of execution are pre-defined at build-time. Any performer has to follow these activities into the order defined by the work-list of the related WfMS. However, this model is not in line with real people-centred team works [18,39] and performers' active characteristics are not considered. To overcome such shortcomings, we incorporate agents into the traditional model to form an *agent-based workflow model*. This consists of a set of agents, a set of *inter-agent workflows*, and a set of *intra-agent workflows* for every agent. The process semantics of both the inter-agent workflow and the intra-agent workflow are defined by the traditional workflow semantics. Every agent represents one or more team member, and it can perform the activities in the inter-agent workflow according to the agent's internal work process definition.

An actively co-operative team can be modelled by a set of agents, a team manager, and a set of pre-defined inter-agent workflows (denoted as *InterAgentWFS*) corresponding to different team tasks, represented as $AgentTeam = \langle \{Agent_1, \dots, Agent_n\}, TeamManager, InterAgentWFS \rangle$. The team manager is also an agent who is responsible for the membership management at the build-time of the team. When receiving a new task, the team manager is responsible for planning the new

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