tions. Another type of user models, "UM agents" will learn about their individual user, negotiate with the UM-brokers concerning desirable application-adaptations, teaching and possible partners for help or collaboration. UM-agents will collaborate among themselves and compete for getting services for their users from the UM-broker, while UM brokers will compete among themselves for better services.

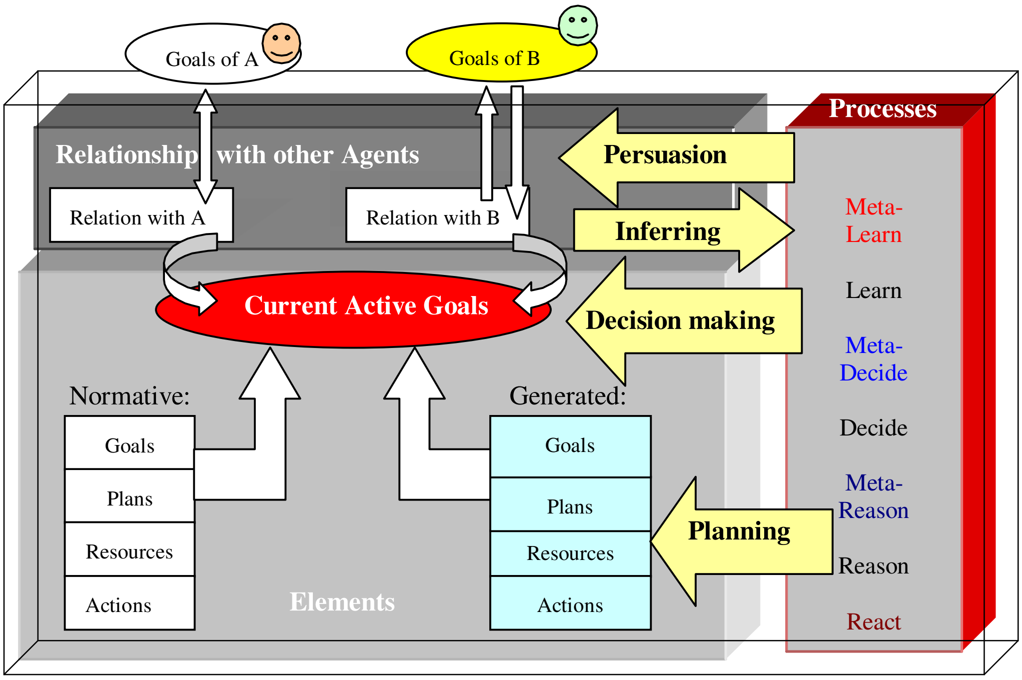

Figure 1. An Architecture of Intelligent Communicative Agent in IHCE.

- Taking into Account User Motivation, Emotions, and Moods. According to the principle of importance, the motivation can be easily taken into account when reasoning about the relative importance of goals.
- Unified Model of Collaborative, Cooperative, Competitive, and Adverse Behavior. A truly adaptive system should be able to modify its type of relationship with the user. The explicit representation of the sign of the relationships will allow the agents to reason and dynamically modify their behavior with respect to other agents.

The EPR view helps to integrate a lot of different research. However, to bring this architecture to a computational framework, one has to find appropriate ways of reasoning and decision-making, especially with respect to inter-agent relationships.

References

Slade, S. (1994) *Goal-Based Decision Making: An Interpersonal Model*. Lawrence Erlbaum Associates Inc. Hillsdale, NJ.

resources, actions, goals, plans. The basic processes (reaction, reasoning, deciding, learning) operate with elements (goals, plans, resources and actions), while the meta-processes operate on basic processes. Meta-reasoning is the ability of the agent to reason about and plan its reasoning process. Meta-decision making is the ability to decide whether to react, reason, or learn. Finally, meta-learning is the ability of the agent to learn how to plan, to decide and to learn (perhaps also meta-reason, meta-decide and meta-learn).

Relationships. This dimension refers to the way the agent interacts with other agents. Agents help each other to achieve their goals, i.e. they adopt each other's goals. An agent can be involved in many relationships with other agents. Each relationship can be classified with respect to several orthogonal sub-dimensions. The *type of agent* shows who is the partner in the relationship: a human user or a computer system. The *type of goal adoption* shows whether the goals that the agent wants to be adopted by the other agent are directly assigned by the agent, inferred by the other agent, or whether they are goals to be developed independently by the other agent (teaching goals). The *symmetry* of the relationship shows the predominant direction of goal-adoptions along this relationship. The *sign* of the relationship shows whether the agents will collaborate (share resources and plans for achieving the same sub-/goals), cooperate (work independently on different sub-goals for achieving the same main goal), compete (for resources in pursuing different goals) or behave adversely (try to block each other's goals).

An agent can apply its processes to influence the inter-agent goal adoption. For example, it can generate a *persuasion* plan for enforcing goal-adoption (teaching strategies in intelligent tutoring systems). It can also reason and infer the goal of the other agent (*diagnosis* of user goals, knowledge state, preferences etc. in adaptive systems).

2 Effects of the EPR View

From the EPR View of IHCE one can derive the following general architecture of an intelligent communicative agent (see Figure 1). This architecture has the following properties:

- Explicit representation of goals, plans, resources and actions available to the agent;
- Explicit representation of the agent's relationships with other agents and ensuring that all the parameters of the relationship can be manipulated by the agent;
- Internal processes which can be applied to the elements, but also on the parameters of the relationships of the agent and for enforcing inter-agent goal-adoption.

There are several problems of current adaptive IHCEs which could be addressed in a more systematic way in this architecture:

- Explicit reasoning about the purpose of adaptation. The system can reason about the importance of the goals adopted from the user directly, the goals, inferred from his behavior and the teaching goals which it wants the user to develop. By modifying the parameters "type of goal adoption" and "symmetry" of the relationship between two agents a system can decide whether to adapt, not to adapt, or to teach the user.
- Treating users and computer systems as unified agents in a multi-agent environment. Centralized agents called User Modeling (UM) brokers can be developed which collect information about normative goals of other agents (applications and users). An UM broker can support cooperation, collaboration, and competition among users and applica-

An New View on Interactive Human-Computer Environments

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Abstract: This paper proposes to view interactive human-computer environments along three orthogonal dimensions: Elements, Processes and Relationships. This view allows to see in a systematic way some problems of current adaptive systems and to find directions of future development.

1 EPR View on Interactive Human Computer Environments

Facing a recent explosion of adaptive Interactive Human-Computer Environments (IHCE) for example, information retrieval and filtering applications, hypermedia, text- and graphic editors, and teaching systems, I feel that there is a need to take a new viewpoint which allows to integrate most of this work and see it in the light of the new theories of learning and cognition and the emerging distributed and networking technologies. I propose to view IHCE along three orthogonal dimensions: Elements, Processes and Relationships (EPR view). Along each dimension there are categories, which are partially orthogonal. In this way a discrete space is defined in which any system can be classified. Following this view, I define an agent architecture representing a human or computer system in an IHCE. The main dimensions in the EPR-view are discussed briefly below.

Elements. This dimension refers to the elementary entities about which interaction among the agents happens. They are: *goals, plans, resources* and *actions*. All agents in an IHCE pursue goals. According to Slade's (1994) goal classification these can be goals for achievement, preservation, satisfaction, crisis-goals, but also duties, tastes and preferences. For achieving goals an agent employs resources, which can be tangible (time, money, credentials etc.) or cognitive (memory, attention, knowledge and skills). Plans decompose goals into sub-goals which can be achieved by actions and resources. According to Slade's principle of importance, an agent will be willing to expend resources for achieving a goal, proportional to the importance of this goal. We define motivation of an agent for achieving a goal as the idiosyncratic importance of this goal for the agent.

Processes. This dimension refers to the processes taking place inside of an agent. These are: *reaction, reasoning/planning, meta-reasoning/-planning, deciding, meta-deciding, learning* and *meta-learning*. Reaction is achieving a goal with ready (pre-designed or normative) resources or plans. Reasoning is the ability of the agent to generate new plans or to modify existing plans to adapt them for the current goal. Deciding is the ability to choose among conflicting goals. Learning is the ability of the agent to improve its behavior by acquiring new