Human-Computer Symbiosis by Mutual Understanding

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Abstract
This paper provides the authors' perspective on human-computer symbiosis. It describes how human and computer will form one symbiotic team to increase their capacity and deal with disturbances. Complementing and mutual understanding are identified as the key issues to successfully accomplish new challenging performance objectives. The human as well as the computer build this understanding out of a variety of sources, integrated in so-called information models. The challenge to build understanding at the side of the computer component lies in the collection of data and the combination and interpretation of the models' results. For the human we see the elusiveness of complex and distributed systems as critical issue. We argue that making such an elusive system tangible again requires a new approach. Via networked electronic Partners, policies for symbiotic information exchange can be implemented. We propose the humanized interface 'Ashley' as solution. The paper ends with some discussion items to feed the discussion.

Keywords
Human-computer interaction, symbiosis, adaptive automation, virtual assistant.

ACM Classification Keywords
H1.2. Information Systems, Models and Principles, User/Machine Systems, Human Factors.

Introduction

The introduction of computing systems and the personal computer opened up the possibility to allocate cognitive tasks to 'a system'. In 2006, Nature predicted that the achievements of computing power, networks and humans will grow beyond human creativity within the next 15 years [8]. This prediction illustrates the skills that computing systems are developing, inevitably leading to a paradigm shift from an HCI perspective. Computer and human will not remain separate entities but will confluent into a symbiotic cooperation [1]. As the definition of the word "symbiosis" states, two equal entities will work together and fulfill their goals with mutual advantages. Fusing both entities will result in an improved ability to handle disturbances and unexpected events, and therefore increase performance and resilience.

Figure 1 gives a schematic overview of our human-computer symbiosis in action. At the bottom, tasks and related goals come in which should be optimally handled by the symbiotic entity, leading to maximum task performance at the top of the figure.

Complementing each others' tasks requires mutual understanding of beliefs and goals, at the level of perception and cognition. On the right disturbances interfere with this process, which could lead to a suboptimal performance. To be resilient for such disturbances, the symbiotic system should be adaptive, again accommodated by the mutual understanding of both entities.

Cooperation in our symbiotic entity is model based. It is no longer just automation of routines and re-allocating tasks to the user or the system, but a knowledge based relation to for instance optimize interaction. Moreover, both user and system are pro-active, based on new knowledge that is constantly updated by active learning processes in case of uncertainty.

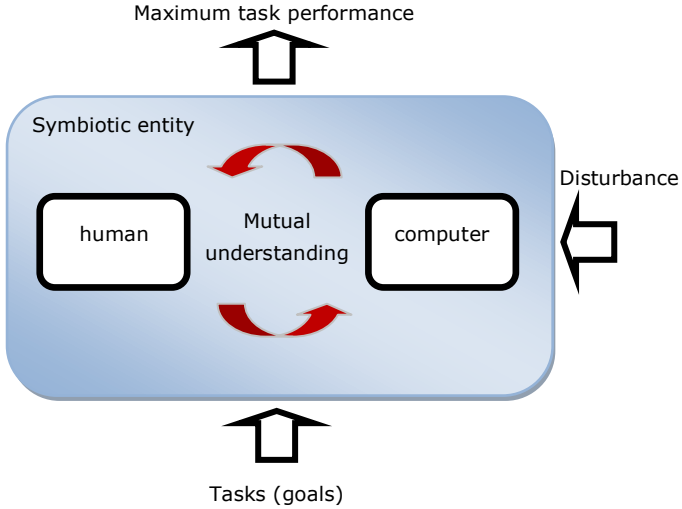

Figure 1. Schematic overview of our human-computer symbiosis in action with mutual understanding as key issue.

As can be seen in figure 1, mutual insight and understanding is a key issue in a symbiotic relation. We therefore stand for a challenge: If the human and the system should have mutual insight and understanding, which knowledge is then needed? What is relevant information for the human to know about the system? And the other way around? Furthermore, human and system are equal partners, but not similar, so both will have their own constraints and requirements. How can needed data be gathered and transformed in valuable information? How does this information need to be presented to the human?

This paper will briefly describe our vision on how to gain mutual understanding in the creation of the human-computer symbiosis.

Information models for mutual understanding

In the past, computer based adaptation (e.g. adaptation of the level of automation) was often based on the user's workload. Literature however also shows that "*workload is a multidimensional, multifaceted concept that is difficult to define".* Furthermore, " *(…) attempts to measure workload relying on a single representative measure are unlikely to be of use*" [5]. Therefore, to achieve symbioses we need to combine information from multiple models. In a straightforward manner we at least need a human and computer model in our symbiosis. However, to give meaning to this information, we state that we need a task and context model as well.

- Human model. This model can contain a large variety of static information of the individual, such as general performance, preferences and capacities (and in the future possibly data on affective processes: emotions, engagement, frustration, surprise, intention, and boredom). The human model also contains dynamic information about the state of the human and the current active task from the task model.
- Computer model. The computer model contains technical information about the different system components (e.g. layout, dialogues, software applications and dependencies).
- Task model. The task model is a static representation of the possible tasks, containing information on the task demands that affect human operator performance and effort. The task model is not a definition of the operator's cognitive state: The effects these tasks have on the operator depends on the interaction between the tasks and the human model [6].
- Context model. The (dynamic) context model contains high level information of the environment, such as information about the importance of tasks, the hierarchy of events and organisational context.

Mutual understanding should be at least based on the models mentioned above. If more models are added, the accuracy increases, but complexity will also increase. The challenge for the automated component in our symbiosis lies in the combination and interpretation of this information. Possible starting points could be the Cognitive Task Load method of [6], combined with the Emotional State model [7]. For the "symbiotic" information exchange, we first need an ontology that the human and machine share [2]. Policies have to be formulated for this exchange, possibly tailored to different forms (or organizations) of symbioses (e.g., master-slave, manager-assistant, peer-peer or coach-trainee; [3]). Via networked electronic Partners (ePartners), such policies can be implemented. The actual form of information exchange for mutual understanding can be divers, such as Brain-Computer Interfacing or Human-Virtual Character Dialogues (like Ashley, see next section).

Symbiotic Interfaces

Computers are being experienced as social actors by their users [4]. We are aiming at a next step: a symbiosis in which human and computer cooperate intuitively, based on shared beliefs and goals. Joint (symbiotic) task performance concerns the cognitive, affective and social information processes. The human-machine interfaces that support such performances will be substantially different than the classical WIMP paradigm. For clarification, we describe a short example of our symbiotic entity: "… *the computer knew where the human was paying attention to (e.g. based*

on brain-based indices), and handled the information that was outside the focus of attention (e.g. based on task and context model). After that, the human is informed that the situation is under control according to the computer's view (e.g. via background sound and/or vibration) and if possible the joint performance is discussed via an Ashley interface (figure 2)".

Figure 2. Ashley and human discussing joint performance.

Discussion

This paper describes an inevitable paradigm shift in HCI and the creation of a symbiosis consisting of human and computer. Complementing and mutual understanding were identified as key issues to success. We stand for two main challenges:

1. Building understanding at the side of the computer component lies in the collection of data and the combination and interpretation of the models'.
2. For the human we see the elusiveness of complex and distributed systems as critical issue.

We proposed 4 information models and gave an example of an symbiotic interface. Important discussion items which we did not discuss can be:

- How should the information models deal with uncertainty?
- If computer and human should cooperate intuitively, is emotion then an important factor?
- Does our symbiosis needs change in case of more entities (multiple humans and computers)?

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