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# cBDI-based Collaborative Control for a Robotic Wheelchair

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**Abstract**

In this paper we present a collaborative control architecture for a robotic wheelchair with the aim of providing "assistance as required". The architecture is based on cBDI - an extension to the Belief-Desire-Intention model to support human-machine collaboration. We present results of an evaluation of the architecture in a simulated environment and conclude that collaborative control could ensure "feeling in control" even under assistance.

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## 1. Introduction

Intelligent Wheelchair (IW) is presented as a solution to the lack of independence suffered by mobility impaired individuals. The term *robotic wheelchair* is used synonymously with IW. Several prototypes have been developed; control algorithms proposed[?]. However, more often than not, the user is relegated to being a *rider* rather than taking advantage of user's potential. Nevertheless, there are brain-computer-interface (BCI) driven systems taking user mental states to consideration for driving IWs[?]. For retention of residual skills, IWs need to provide "assistance as required"[?]. Most of the current approaches for control of IWs[?] ignore the basic evidence that human act independently (of the system) and are often satisfied with a good solution (which may not be optimal), a phenomenon that is called satisficing[?]. It is important that the system should not only automatically adapt the level of assistance but also perform in a way so as that the user is unable to realize that he is getting help! Could there be a way to create cognitively capable machines that given a human team-mate affect peer-to-peer interaction and collaboration? An *agent* can serve as the basis for such machines[?]. Within agent literature Belief-Desire-Intention (BDI) paradigm is widely used to achieve human-like intelligence. The BDI architecture needs to be extended to enable collaboration[?]. To that end we present cBDI - an extension to the BDI model to support human-machine collaboration. The cBDI agent is the core for a collaborative control architecture supporting "assistance as required". The control architecture: a. facilitate human-centric "decision capabilities" of the machine and b. facilitate "negotiation" in control.

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We are interested in understanding whether a collaborative control architecture could give the sense of “feeling in control”[? ?] even under assistance. We present results of an evaluation of the architecture in ROS-USARSim. The proposed collaborative controller could ensure “feeling in control”.

## 2. Collaborative Control Architecture

The proposed architecture is three layered (see Figure 1). User Interface facilitates communication with the human user. Superior Control Layer (SCL) built around a cBDI agent provides human-centric decision capabilities including a negotiator, making collaboration possible. Local Control Layer takes care of the low level control of the hardware.

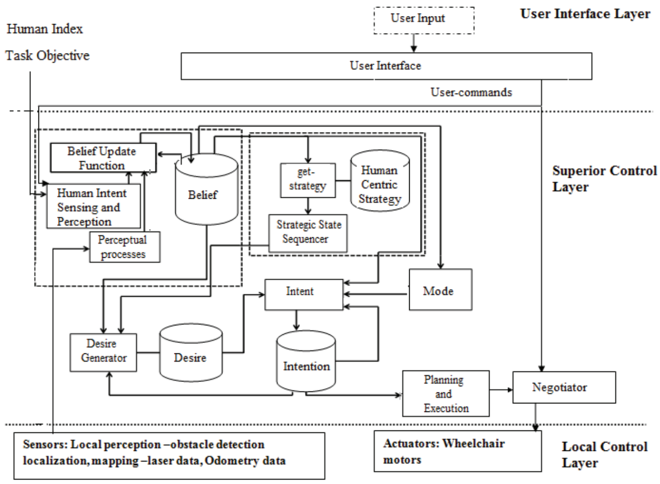


Fig. 1. Collaborative Control Architecture.

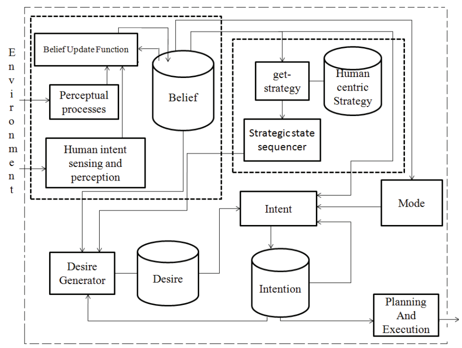


Fig. 2. cBDI Agent Architecture

### 2.1. cBDI: A Collaborative BDI Agent

cBDI architecture (shown in Figure 2) retains the *Belief*, *Desire* and *Intention* modules. Additional modules include *Human Intent Sensing and Perception* (HISP) and the *Strategic Planner* (SP) together with a *mode* function.

*Belief:*. Belief describes proprioception-localizing information about self; and the set of executable action of the agent. In cBDI, beliefs have been enhanced to include *human intent* and knowledge of human capacity.

*Desire:*. Desires $D$ describe the set of goal states that the agent tries to achieve. Desires are obtained through a desire generation function, on the basis of its current beliefs and current intentions.

*Intention:*. Intention $I$ is the commitment of an agent to a specific action(s) in order to actively follow a desire.

*Human Intent Sensing and Perception:*. For collaboration the agent should be aware of the intentions, capabilities and actions of the human team-member. The HISP module is a mechanism capable of obtaining the desired information from certain stimuli provided by the environment and translated into agent’s interaction beliefs.

*Strategic Planner:*. The SP is responsible for maintaining a human-centric strategy and facilitates derivation of a set of “adopted” goals; goals are based on agent’s a priori knowledge of human-centric strategies.

*Belief Revision Functions:*. There are three belief update functions: a. belief revision function through perception including proprioception ($self$-*aware*); b. *Interaction* and c. human-intent sensing and perception (*Human-intent*).

*Desire Generator Function:*. Desire generator function described here is similar to the one in classical BDI agent.

*Intent Function:*. The *Intent* function described here is similar with the one in classical BDI agent; however, here we have added agent’s behaviour state *value*. *value* reflects the agent’s mode.

*Mode:*. Mode function generates agent behaviour state based on the human capacity.

*Plan Function:*. The plan function generates a ordered sequence of actions to satisfy agent’s intention.