**Autonomous Robots manuscript No.**
(will be inserted by the editor)

# Working title

## Humans helping robots helping humans

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Received: date / Accepted: date

**Abstract** Assistive human cyber-physical systems have the potential to transform the lives of millions of people afflicted with severe motor impairments as a result of spinal cord or brain injuries. The effectiveness and usefulness of assistive systems, however, is closely related to their ability to infer the user's needs and intentions and is often a limiting factor for providing appropriate assistance *quickly, confidently and accurately.* The contributions of this paper are two-fold: firstly, we leverage the notion of *inverse legibility* and propose a goal disambiguation algorithm which enhances the intent inference and assistive capabilities of a shared-control assistive robotic arm. Secondly, we introduce a novel intent inference algorithm that works in conjunction with the disambiguation scheme, inspired by dynamic field theory in which the time evolution of the probability distribution over goals is specified as a dynamical system. We also present a experimental study to evaluate the efficacy of the disambiguation system. This study was performed with ten subjects. Results show that upon operating the robot in the control mode picked by the disambiguation algorithm, the progress towards the goal significantly became faster as a result of accurate and confident robot assistance and the number and rate of mode switches performed by the user decreased as well.

**Keywords** Shared Autonomy · Intent Inference · Intent Disambiguation · Assistive Robotics

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## 1 Introduction

Assistive and rehabilitation machines—such as assitive robotic arms, exoskeletons and powered wheelchairs—have the potential to transform the lives of millions of people with severe motor impairments. These devices can promote independence, boost self-esteem and help to extend the mobility and manipulation capabilities of such individuals, thereby revolutionizing the way motor-impaired people interact with society. With the rapid technological strides in the domain of assistive robotics, the devices have become more capable and complex—to the extent that control of these devices becomes a greater challenge.

The control of an assistive device is typically facilitated via a control interface. The greater the motor impairment of the user, the more limited are the interfaces available for them to use. These interfaces (for example, Sip-N-Puff and switch-based head arrays) are low dimensional, discrete interfaces that can operate only in subsets of the entire control space. The dimensionality mismatch between the control interfaces and the controllable degrees-of-freedom of the assistive robot necessitates the partitioning of the entire control space into smaller subsets called *control modes.* In order to achieve full control of the robot, the user switches between the control modes and this is referred to as *mode switching* or *modal control.* More importantly, as the control interface becomes more limited and low-dimensional, the greater number of control modes there are.

Complexity of device and dimensionality mismatch. Control modes etc. Switching between modes is hard, gets in way of task execution. Therefore shared autonomy.

What is shared autonomy. Different types of Shared autonomy. Common factor in all is that for successful assistance nad robot behavior intent infernece is important

Understanding intent is critical. Why? Shared intention in human-human teams. Human-robot teams. Different types of paradigms exist for the same.

Intent inference is harder in assistive domain, due to sparsity of signals. Could supplement it using other tyoes of sensor data, but makes it less practical and possibly affect user acceptance due to the cumbersome nature.

But we have human-in-th-loop. If the robot can elicit more intent expressive actions from the user, the inference problem becomes easier for the robot. Therefore the intent disambiguation system.

## 2 Related Work

Text with citations [McGeer(1990)]

## 3 Mathematical Algorithm and Implementation

### 3.1 Intent Disambiguation

### 3.2 Intent Inference and Shared Control

## 4 Experimental Design - Study Methods

## 5 Results

## 6 Discussion

## 7 Conclusion

**Acknowledgements** If you'd like to thank anyone, place your comments here and remove the percent signs.

## References

[McGeer(1990)] McGeer T (1990) Passive Dynamic Walking. The International Journal of Robotics Research 9(2):62–82