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Shared control is the sharp end of cooperation: Towards a common framework of joint action, shared control and human machine cooperation

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Abstract: As an introduction to the session of shared and cooperative control, this article will briefly look into the history, start with definitions and sketch a common framework of shared and cooperative control that sees the two phrases not as different concepts, but as different perspectives or foci on a common design space of shared intentionality, control and cooperation between humans and machines.

One working hypothesis which the session will explore is that shared control can be understood as cooperation at the control level, while human machine cooperation can include shared control, but can also extend towards cooperation at higher levels, e.g. of guidance and navigation, of maneuvers and goals.

We propose to view the relationship between shared control and human-machine cooperation as being similar to the relationship between the sharp, pointy tip and the (blunt) shaft of a spear. Shared control is where cooperation comes sharply into effect at the control level, but to be truly effective it should be supported by cooperation on all levels of interaction beyond the control level, e.g. on the guidance and navigation level.

Keywords: human machine systems, human machine cooperation, joint action, shared control

INTRODUCTION: FROM SHARED AND COOPERATIVE CONTROL OF SITUATIONS TO SHARED AND COOPERATIVE CONTROL BETWEEN HUMANS AND MACHINES

Shared and cooperative control of situations affects homo sapiens already much longer than human-machine systems exist. Tomasello (2014) describes how human cognition evolved and stresses that an essential element of the rapid evolution of homo sapiens toward the most dominant species on this planet was the ability to develop a shared intentionality and to cooperate towards common goals. Although other species have this ability to some extent (Harcourt & de Waal 1992), homo sapiens excels in the complex cooperation with other members of its species but also with different species.

The cooperation between humans is increasingly studied as “joint action”), which can be regarded as “any form of social interaction whereby two or more individuals coordinate their actions in space and time to bring about a change in the environment” (Sebanz, Bekkering & Knoblich 2006). Interestingly, even as human human cooperation exist already since hundreds of thousands of years, and has been under investigation in philosophy since milleniums, in psychology and sociology since hundreds of years, essential aspects e.g. on the neurological level like mirror neurons have been unrevealed just recently (Rizzolatti & Sinigaglia 2008). It could have a high potential to use this knowledge also for the joint action and cooperation of human and machines.

Another essential element in our evolution was the development of more - and more complex - tools. Even the earliest tools like the first wooden spears about 270.000 years ago, found 1995 in Schoeningen, were already an extension of our physical power and mobility, that increased even more with machines e.g. during the industrial revolution. Since World War Second, the advance of cheap and powerful computing and sensing power in the last decades, enabled us to extend not only our physical, but also our cognitive ability to develop tools with cognitive capabilities, capable to act automatically – albeit within boundaries. Norbert Wiener was the first to realize that human and machine would need to

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communicate in order for them to interact well (Wiener 1948). By having developed tools that can think and act, the intimate connection and interplay between humans and technology has come back full circle to shared and cooperative control. Our society is increasingly confronted with automation, not only in airplanes and behind fences in factories, but also in highly- or fully automated vehicles (Tsugawa et al. 2000; Dickmanns et al. 1987; Parent & Daviet 1993; Thrun et al. 2006), and many foresee the advance of robot technology directly in our living environment.

Traditionally, there is a clear distinction between assistance systems, where the machine only support the human, and automation, where the machine is taking over the main task, replacing the human. Sheridan already recognized that the distinction should not be so black and white, and proposed the influential concept of levels of automation (Sheridan & Verplank 1978). It illustrates that many design options for human-automation interaction exist. There are many situations where both the human and the machine should act together at the same time, and where authority and tasks need be shifted or adapted (Sheridan 2011; Millner & Parasuraman 2003). These insights have led to much related theoretical concepts and design approaches known by a plethora of names, such as shared control, cooperative control, human-machine cooperation, cooperative automation, collaborative control, co-active design, robots, physical human-robot interaction, adaptive automation, and adaptable automation, etc. There is much overlap between these concepts and approaches, and the field suffers from a lack of consensus and definition.

The authors of this paper have been particularly involved in "shared control" and "human-machine cooperation" (sometimes also termed "human-machine collaboration"). Shared control stresses the fact that human and machine share control over a system together, (e.g. Griffiths & Gillespie 2004; Abbink 2006; Flemisch et al. 2010) whereas human-machine cooperation, stresses the fact that humans and machines share the same tasks and control a situation cooperatively (e.g. Hoc & Lemoine 1998; Hoc 2000; Flemisch et al. 2003; Biester 2008; Pacaux-Lemoine 2014; Flemisch et al. 2015; Johnson et al. 2015).
The authors firmly believe that shared control and human-machine cooperation have so many aspects in common that they should be analyzed and developed together. The goal of this paper is therefore to

- provide a clear overview of commonalities and differences in shared control and human-machine cooperation, and the links to other related concepts
- propose working definitions that show the connection between shared control and human-machine cooperation.

2. A BRIEF OVERVIEW OF CONCEPTS AND DEFINITIONS: FROM INFLUENCE AND CONTROL TO SHARED CONTROL

What is the most crucial point of our discussion about shared control and cooperation? We think that "influence" and "control" is a good starting point. The essence of control is a strong enough influence of some parts of the world on other parts of the world:

In general and in an abstract perspective, the world including natural systems and human-machine systems embedded in their environment is not static, but changes over time from one state or situation to another. A substantial part of this change is not incidental, but due to actions of acting subsystems or actors (sometimes called agents), which can be natural (e.g. humans, animals) and/or artificial (e.g. machines), and their interplay with the environment. Based on (explicit or implicit) understanding of good or bad situations (e.g. with the help of goals and/or motivations), actors perceive the world and influence the situation by using their abilities to act, thereby forming (open or closed) control loops. Control means having "the power to influence […] the course of events" (Oxford Dictionary 2016). Applied to human machine systems, the common understanding might be even more crisp: Having control means to influence the situation so that it develops or stays in a way preferred by the controlling agent.

Applied to a concrete task, imagine somebody carrying a small table, along a way without dropping it. We could certainly say that this person controls the movement of the table. Now imagine a second person joining the first in carrying the table (see Figure 1). It is very natural that as soon as the second person joins, he or she also influences some part of the movement in a way that the situation develops or keeps in a certain way, e.g. not dropping the table to the ground or not bouncing with the table into an obstacle. Both persons share the physical load, share the control of the table, share the guidance or maneuvering, and share the task of safely navigating the table to another place.

Now let's apply this to a human machine situation by replacing the second person with a machine. Let's use a simple machine at first, e.g. a small wagon that carries the load. We would certainly not say that the wagon is controlling the movement, but we might call it assisting with the physical load. Now imagine that the wagon is a robot also sensing the environment, and trying not to bump the table into obstacles. In this case we would talk about sharing of control between human and machine.

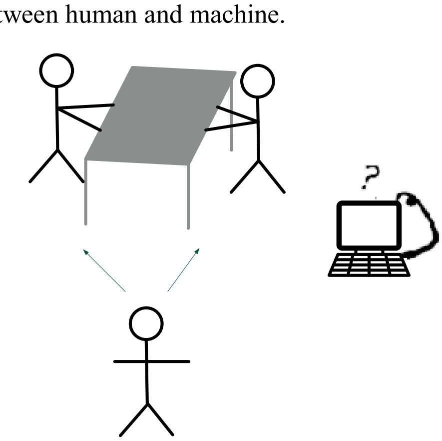

Figure 1. Everyday situation with joint action, shared control and human human cooperation