

## Research Environments for Human-Machine Teaming

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Humans and machines are increasingly working together as teammates in various domains, for example firefighting. The ultimate goal of these teams is to harness the combination of strengths of both humans and machines, to accomplish what neither can do alone. Unfortunately, there is still a long way to go before machines will be effective teammates for humans. To further identify and optimize the critical success factors of human-machine teams, we need realistic and reusable research environments.

Since studying human-machine teams in practice can be both time and cost expensive, it is common to conduct experiments in simulated and/or controlled environments. Unfortunately, it has proven challenging to design realistic and reusable human-machine collaboration studies in these environments. Therefore, this workshop aimed to bring together people from various disciplines who face the same challenges, to discuss and identify reusable solutions and methods that can help overcome them. We believe the workshop managed to do so. All participants recognized the challenges of and need for realistic and reusable research environments for human-machine teaming. We had fruitful discussions on these topics, also facilitated by various backgrounds such as neuroscience, robotics, human factors, and computer science.

We also wanted to build a close network and stimulate knowledge gathering and sharing on the further development of appropriate tools for human-machine teaming research. Again, we believe the workshop managed to do so. We have already created a Discord channel with most of the participants, both for practical matters such as writing the paper and informal things such as potential meetups at conferences. Moreover, on the last day of the workshop we all contributed to a list of 1) conferences to attend/submit to, 2) workshops to continue what we did, 3) other organizations and people interested in the topic, 4) research environments to describe in the paper, and 5) people interested in joining the taskforce for creating a Wiki.

The workshop should also lead to reusable and realistic scenarios, collaborations, and measures for human-machine teaming research, as well as guidelines and templates for describing them. We believe the workshop mainly contributed to a taxonomy of tasks for human-machine teaming. The work sessions on Wednesday and Thursday especially contributed to this taxonomy. For example, categories such as interdependence relationships between humans and machines, degree of risk or failure, (communication) modality, and machine control.

We also wanted to combine these outcomes into a paper. This is still the goal. More specifically, we will write a paper on a taxonomy for human-machine teaming tasks, centered around three research environments presented during the workshop. We will use a bottom-up approach for writing this paper, based on the work session outputs. This paper will mainly be pulled by the organizing team, and we already had and have planned meetings on writing the paper. The goal is to have a first complete draft by the end of the year.

Finally, we wanted to work towards a Wiki that allows and stimulates the reuse of realistic research environments for human-machine teaming. Participants really liked the idea of such a Wiki, and they all

acknowledged its importance. We already created templates of what such a Wiki could look like, and the ideas were great. For example, users can search for human-machine teaming experiments based on queries such as the experiment modality (e.g., 2D grid world), measures (e.g., trust), and number of humans and machines (e.g., a dyad). The Wiki could then return all research environments on human-machine teaming that match with the query. We have planned a follow-up meeting for all participants to further discuss the development of this Wiki. When we have the basics of the Wiki in place, we also want to write a position paper that describes it and its contribution to the field.

All in all, we believe the Lorentz Center workshop allowed us to achieve our goals. The combination of hands-on work sessions, inspiring talks, and informal activities provided the perfect circumstances to do so.

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