# Executive Summary

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## 1 Executive Summary

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The vision of autonomous agents on the Web is almost as old as the Web itself: in his keynote at WWW'94[1], Sir Tim Berners-Lee was noting that documents on the Web describe real objects and relationships among them, and if the semantics of these objects are represented explicitly then machines can *browse through* and *manipulate* reality.[2] These ideas were published under the Semantic Web vision in 2001 [1]. Yet in 2007, after having spent the better half of a decade advancing this vision, James Hendler was looking back to conclude that most ideas in the original article were already seeing widespread deployment on the Web except for agent-based systems – and raised the question: "where are all the intelligent agents?" [2].

This question is yet to be addressed. On today's Web, we as *human agents* are often assisted by invisible software agents, such as crawlers used by search engines to navigate and index Web pages, agents that curate online content produced by people (e.g., Wikipedia's content agents), and recommender systems used all over the Web to generate more links and navigation paths (e.g., suggestions of related Web pages). In our everyday lives, we are assisted by more visible agents, such as Amazon's Alexa, Google Duplex, or Apple's Siri. Some of these agents may already use various AI methods (learning, reasoning, etc.), but they are specialized for narrow tasks and constrained to silos dictated by company ecosystems. We have yet to see more autonomous, cooperative, and long-lived agents on the Web [3] – the intelligent agents in James Hendler's question. We believe this decade-old question is now more relevant than ever before in the context of recent developments in three areas of research: (i) *Web Architecture and the Web of Things*, (ii) *Semantic Web and Linked Data*, and (iii) *Autonomous Agents and Multi-Agent Systems.*

The primary objective of this 5-day seminar was to create a network of senior and young researchers who can revisit and align the relevant research threads across the three targeted areas. The seminar was a blend of invited talks, live demonstrators, and group work. Some of the overarching research questions discussed during the seminar included (not an exhaustive list): How to design software agents able to achieve their tasks through flexible autonomous use of hypermedia? How to design hypermedia-based environments that support autonomous behavior? How to design, represent, and reason about interactions among autonomous agents, people, and any other resources on the Web? How to design and govern communities of autonomous agents and people on the Web?

A number of follow-up steps were already taken to continue the discussions and to further consolidate the community. Most recently, several participants submitted a challenge proposal that was accepted at the *20th International Semantic Web Conference (ISWC 2021)*: the *All The Agents Challenge (ATAC)* will take place in October 2021.[3] In addition, a one-day

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[1] The First International Conference on the World-Wide Web, CERN, 25-27 May 1994.
[2] Sir Tim Berners-Lee, *The Future of the Web*, WWW'94: `https://videos.cern.ch/record/2671957`, accessed: 07.05.2021.
[3] `https://purl.org/atac/2021`

■ **Figure 1** The traditional end-of-seminar photo on the stairs of Virtual Schloss Dagstuhl.

follow-up event was scheduled for July 9, 2021, and several participants offered to contribute to a shared "live" demonstrator space that would allow to integrate technologies and to try out new ideas across the targeted research areas (see also the working group report in Section 6.1).

## The Virtual Seminar Format

The seminar was organized in a fully virtual format due to the COVID-19 pandemic and brought together 45 participants across 4 different time zones. The seminar's schedule was designed for focused online interaction and to preserve to some extent the social dimension specific to regular Dagstuhl Seminars. The schedule was also designed to accommodate the participant's time zones as much as possible. To this end, the schedule was structured around three types of sessions:

- *plenary sessions*: time-zone friendly sessions that constructed the backbone of the seminar (4h per day);
- *Demos & Tech sessions*: sessions reserved for presenting demonstrators and technologies relevant to the seminar (3 sessions of 2h); the objective of these sessions was to ground the discussions and to paint a picture of what can already be achieved with existing technologies;
- *social events*: sessions reserved for online social interactions in a virtual representation of Schloss Dagstuhl via Gather.town[4] (see Figure 1).

The seminar started with five invited talks given by James Hendler, Mike Amundsen, Matthias Kovatsch and Simon Mayer (joint talk), Olivier Boissier, and Dave Raggett (in order of presentation). The invited talks were meant to help bootstrap the discussions and presented developments across the three research areas targeted by the seminar. The reduced virtual format did not allow for additional talks from participants, but we organized several rounds of personal introductions during the first two seminar days.

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[4] `https://gather.town/`, accessed: 14.05.2021.
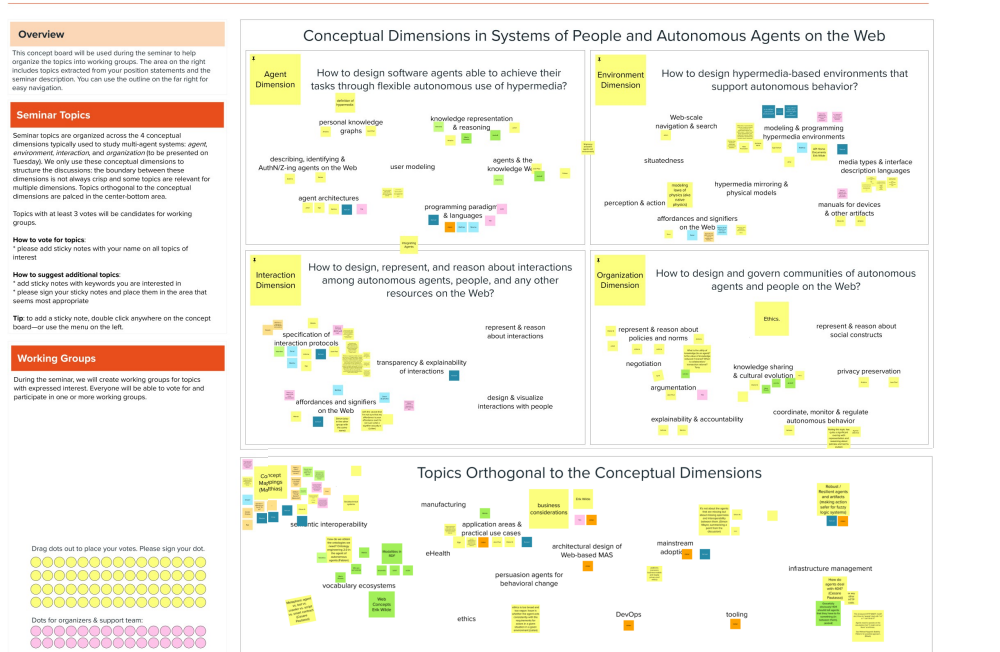
**Figure 2** Virtual concept board used to organize the seminar topics into working groups.

In the third seminar day, participants used a virtual concept board (see Figure 2) to organize the seminar topics and to assign them into working groups for the rest of the week. The concept board was created from the seminar topics proposed by the co-organizers, the position statements submitted by participants prior to the seminar, and topics that emerged during the first two seminar days. In total, five working groups were created and four working groups submitted consolidated discussion summaries for this report (see Section 6).

The Demos & Tech sessions attracted more submissions than initially foreseen: we initially scheduled two sessions in the second and third seminar days and eventually scheduled a third session in the fourth seminar day to accommodate all submissions. Submissions were in the form of short abstracts (see Section 5) and each participant was given 10 minutes to present a live demonstrator and 5 minutes for questions.

## Overview of the Report

This report is organized into four main parts. Section 3 includes the list of abstracts of the invited talks. Section 4 includes position statements submitted by participants before and after the seminar. Section 5 includes the list of abstracts for the demonstrators presented at the seminar. Section 6 includes the reports submitted by the working groups created during the seminar.

## Acknowledgements

### References

**1**    T. Berners-Lee, J. Hendler, and O. Lassila. The Semantic Web. *Scientific American*, 284(5):34–43, 2001.

**2**    J. Hendler. Where are all the intelligent agents? *IEEE Intelligent Systems*, 22(3):2–3, May 2007.

**3**    J. Hendler and A. Mulvehill. *Social Machines: The Coming Collision of Artificial Intelligence, Social Networking, and Humanity.* Apress, Berkely, CA, USA, 1st edition, 2016.