Lifelong Learning and Personalization in Long-Term Human-Robot Interaction (LEAP-HRI)

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ABSTRACT

While most of the research in Human-Robot Interaction (HRI) focuses on short-term interactions, long-term interactions require *bolder* developments and a substantial amount of resources, especially if the robots are deployed *in the wild*. Robots need to incrementally learn new concepts or abilities in a *lifelong* fashion to adapt their behaviors within new situations and personalize their interactions with users to maintain their interest and engagement. The "Lifelong Learning and Personalization in Long-Term Human-Robot Interaction (LEAP-HRI)[1]" Workshop aims to take a *leap* from the traditional HRI approaches towards addressing the developments and challenges in these areas and create a medium for researchers to share their work in progress, present preliminary results, learn from the experience of invited researchers and discuss relevant topics. The workshop extends the topics covered in the "Personalization in Long-Term Human-Robot Interaction (PLOT-HRI)[2]" Workshop [12] at the 2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI) and "Lifelong Learning for Long-term Human-Robot Interaction (LL4LHRI)[3]" Workshop at the 29th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), and focuses on studies on lifelong learning and adaptivity to users, context, environment, and tasks in long-term interactions in a variety of fields (e.g., education, rehabilitation, elderly care, collaborative tasks, customer-oriented service and companion robots).

CCS CONCEPTS

• **Computer systems organization → Robotics**; • **Information systems → Personalization**; • **Computing methodologies → Lifelong machine learning**.

KEYWORDS

Lifelong Learning; Continual Learning; Personalization; Long-Term Interaction; Human-Robot Interaction; Adaptation; Long-Term Memory; User Modeling; User Recognition

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1 INTRODUCTION

Social robots should be able to operate in highly challenging environments populated with complex objects and in social settings involving humans, animals, and other robots. Despite these challenges, we expect these robots to be mindful towards us while executing their tasks, demonstrating adaptive behaviors. Consider a robot that is vacuuming while a person is reading a newspaper. When given negative feedback in this situation, the robot should be able to identify this as a new context, and thereon adapt its behaviors accordingly in similar spatial or social contexts - e.g., when people are watching TV, the robot should be able to link this situation to the previously experienced one and avoid vacuuming.

Conventional learning approaches do not scale well with the dynamic nature of such real-world interactions as they require samples from stationary data and situations. The real-world is not stationary, it changes continuously. In such contexts, sensor data and learning objectives may also change rapidly. Lifelong learning and personalization aims to address this challenging problem in human-robot interaction by learning incrementally and facilitating the learning of new concepts, situations, and abilities over time [4].

In light of this, "Lifelong Learning and Personalization in Long-Term Human-Robot Interaction (LEAP-HRI)" Workshop aims to bring together a multidisciplinary group of researchers to identify and address key challenges for studying lifelong learning and personalization and its relevant aspects for social robotics in both lab and field. More specifically, the workshop aims (i) to bring forth existing efforts and major accomplishments in long-term and lifelong learning that can potentially be used for HRI and social robotics, (ii) while encouraging the design of novel models, datasets, tools

[1]The website of LEAP-HRI Workshop: https://leap-hri.github.io/
[2]The website of PLOT-HRI Workshop: https://longtermpersonalizationhri.github.io/
[3]The website of LL4LHRI Workshop: https://sites.google.com/view/ll4lhri2020/

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and applications in the context of long-term human-robot interaction and adaptation, and (iii) to focus on current trends and future directions in this area.

2 BACKGROUND

Humans excel at continuously learning new skills and knowledge across a lifespan. The ability to incrementally acquire, refine, and transfer knowledge over sustained periods of time drives the experience-driven specialization of perceptual and motor skills. Artificial agents and robots in the real world are required to continually learn from novel experience to trigger behaviourally relevant decisions in a changing environment [18, 22, 28]. Lifelong learning models aim to reflect a number of properties of biological systems and their ability to adapt over time with dedicated mechanisms that facilitate learning from novel input while protecting consolidated memories (e.g., [17, 19, 20]). Despite significant advances, current models of lifelong learning are still far from providing the flexibility, robustness, and scalability exhibited by biological systems. Importantly, in HRI, it is unclear how agents and robots can effectively and efficiently learn from extended interactions with the environment. For instance, the creation of closed-loop dynamics and social interactions with humans require robots to continually adapt towards their users' behaviours, their affective states and moods while keeping people engaged in the task they are performing [4].

Humans are individuals with different needs, preferences, and personalities. Thus, adaptable systems that recognize users, learn from them and personalize their behaviors are essential and integral for interactions over extended durations [6]. Moreover, personalization brings in a variety of crucial benefits for long-term interactions within real-world applications, such as eliciting and improving user engagement and experience, increasing perceived familiarity, trust and sociability, and improving task performance, in education (e.g., [1, 9, 13, 16, 21]), healthcare and therapy (e.g., [5, 10, 23, 25, 27]), retail and customer service (e.g., [8, 11, 14, 15]), and domestic applications (e.g., [7, 24, 26]).

Conventional machine learning approaches do not scale well to the dynamic nature of such real-world sensory data and interactions as they require samples from stationary data distributions. Furthermore, the complexity of the datasets used for the evaluation of lifelong learning tasks is very limited (e.g., [3]) and does not reflect the richness and level of uncertainty of the stimuli that artificial agents can be exposed to in the real world. Thus, novel datasets, benchmarks, and protocols are required to evaluate *long-term* learning and personalization in HRI scenarios (e.g., [17, 29]). In addition to designing and properly evaluating lifelong learning approaches, one must consider the philosophical, ethical, and legal implications of lifelong learning agents [2]. This workshop proposes a forum for inspirational and technical discussions to foster a *leap* of paradigm in long-term learning and personalization.

3 WORKSHOP OVERVIEW

LEAP-HRI Workshop is a half day workshop on the topics of lifelong learning and personalization in long-term HRI. The workshop will consist of:

- **Keynotes:** Invited researchers Michelle Zhou (Juji Inc., USA) and Oliver Lemon (Heriot-Watt University, UK) will present their experiences and perspectives on the topic.
- **Full talks:** The authors of the accepted research papers of full length (3-4 pages) will give 7-minute presentations followed by a 3-minute question session.
- **Video/demonstration session:** Accepted videos and demonstrations that are maximum 3 minutes in length, will be shown during this session.
- **Panel:** A panel will be organized with leading researchers in HRI and Human-Computer Interaction (HCI) on the topics of interest, namely, Iolanda Leite (KTH Royal Institute of Technology, Sweden), Alessandra Sciutti (Istituto Italiano di Tecnologia, Italy), Ognjen Rudovic (MIT Media Lab, USA) and Cristina Conati (University of British Columbia, Canada), to discuss the key challenges and advancements in these areas. The questions from the audience and organizers will be taken prior to the panel, as well as during the panel.
- **Break-out session:** The workshop attendees will be divided into groups of 4-5 after the panel to follow up on the discussions.

3.1 Target Audience and Approach for Recruiting Participants

We invite papers of 3-4 pages (plus additional pages for references and appendices), including work in progress containing preliminary results, technical reports, case studies, surveys and state-of-the-art research in lifelong learning and personalization in a variety of fields (e.g., education, rehabilitation, elderly care, collaborative tasks, customer-oriented service and companion robots) and long-term studies. Additionally, we invite video and demonstration submissions of 3 minutes maximum, that are related to the topics of this workshop, and may showcase work, describe conceptual designs and prototypes for innovative ideas for long-term interactions or contain videos from experiments. Papers will be reviewed for their relevance, novelty, and scientific and technical soundness. Similarly, video and demonstration submissions will be reviewed for relevance, novelty, impact and appeal of the presentation. The submissions will be asked to follow the guidelines established by HRI2021. Researchers from HRI, robotics, cognitive science, rehabilitation and educational backgrounds are invited to contribute. The workshop will be announced through a dedicated website, a call for papers on robotics mailing lists and on social network channels (Facebook, Twitter, LinkedIn).

3.2 Plan for Documenting the Workshop

The accepted papers will be published on the workshop website, as well as in arXiv. The proceedings may be made as a single submission, or as a set of individual papers with an index submission. The extended versions of selected papers will be invited for submission to the Frontiers in Robotics and AI research topic "Lifelong Learning and Long-Term Human-Robot Interaction[4]", which is edited by a subset of the organizing team (H. Gunes, S. Kalkan, G. I. Parisi) and I. Leite (granted approval).

[4]https://www.frontiersin.org/research-topics/14495/lifelong-learning-and-long-term-human-robot-interaction

3.3 List of Topics

Topics of interest include but are not limited to:

- Lifelong personalization and/or adaptation
- Modelling user(s) and/or user behavior(s) in multi-session/long-term HRI
- Modelling robot behavior in multi-session/long-term HRI
- Modelling context in multi-session/long-term HRI
- Agent/robot architectures for personalization/adaptation
- Lifelong (long-term) human-agent or multi-user/multi-agent interactions
- Lifelong (long-term) multimodal interactions
- Continual/lifelong machine learning
- Long-term memory (episodic, semantic, associative)
- Long-term HRI studies
- Development concerns, including deployment, scalability and complexity
- Tools and testbeds for evaluation of multi-session/long-term HRI
- Methodological challenges for achieving successful long-term HRI
- Metrics for evaluating long-term/lifelong HRI
- Deployed and/or emerging applications for long-term HRI
- Alternative approaches (e.g. interactive program repair)
- Philosophical, legal and ethical considerations in long-term HRI

4 ORGANIZERS

Bahar Irfan, *University of Plymouth, UK*. Bahar Irfan is an Early-Stage Researcher and a PhD candidate at the Centre for Robotics and Neural Systems, University of Plymouth and SoftBank Robotics Europe, France, in the joint Marie Skłodowska-Curie ITN project APRIL. Her work focuses on multi-modal personalization in long-term human-robot interaction, which involves incremental and online learning of users, their behaviours and preferences in customer-oriented service and socially assistive robotics domains.

Aditi Ramachandran, *Vän Robotics, USA*. Aditi Ramachandran is the Chief Technology Officer at Van Robotics where she works on building educational robots and oversees all software development at the company. She received a PhD from the Social Robotics Lab at Yale University where her research focused on personalized social robot tutors for children.

Samuel Spaulding, *MIT Media Lab, USA*. Samuel Spaulding is a PhD student in the Personal Robots Group at the MIT Media Lab. His thesis research is focusing on building robots that can learn personalized cognitive and affective models of users over repeated interactions across different tasks.

Sinan Kalkan, *Middle East Technical University (METU), Turkey*. Dr. Kalkan received his Ph.D. degree from University of Göttingen, Germany and afterwards joined the Dept. of Computer Engineering, METU as a faculty member. Dr. Kalkan's research interests in robotics include context modeling and life-long learning. His 2016 paper on the subject has received the Outstanding Paper Award by the IEEE Transactions on Cognitive and Developmental Systems in 2019. Dr. Kalkan has served as the program chair for the 17th International Conference on Advanced Robotics (ICAR2015), co-organized the Lifelong Learning for Long-term HRI workshop at Ro-Man2020, and he is one of the founders and counsel board members of the Turkish Robotics Conferences.

German I. Parisi, *University of Hamburg, Germany*. German I. Parisi is postdoctoral research affiliate of the University of Hamburg, Germany, and the Director of Applied AI at McD Tech Labs in Mountain View, California, a Silicon Valley-based research centre established by McDonald's Corporation. He is also the co-founder of ContinualAI, the largest research organization on continual learning for AI. In 2017 he received his PhD in Computer Science from the University of Hamburg. In 2015 he was a visiting researcher at the Cognitive Neuro-Robotics Lab of the Korea Advanced Institute of Science and Technology (KAIST), South Korea, winners of the 2015 DARPA Robotics Challenge. His main research interests include human-robot interaction, continual/lifelong learning, and multisensory integration.

Hatice Gunes, *University of Cambridge, UK*. Dr. Gunes is a Reader in Affective Intelligence and Robotics (AFAR) and the Director of the AFAR Lab at the University of Cambridge. Her expertise is in the areas of affective computing and social signal processing cross-fertilizing research in multimodal interaction, computer vision, machine learning and social robotics. She has published over 100 papers in these areas (H-index=32, citations > 5,000) and her research highlights include Best Paper Candidate at IEEE RO-MAN'20, Outstanding Paper Award at IEEE FG'11 and Best Demo Award at IEEE ACII'09. Dr Gunes is the former President of the Association for the Advancement of Affective Computing, the General Co-Chair of ACII 2019, and the Program Co-Chair of ACM/IEEE HRI 2020 and IEEE FG 2017.

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