

Cognitive Architectures for Optimal Remote Image Representation for Driving a Telepresence Robot

Natalia Efremova

Plekhanov Russian University
Stremyanny per. 36, 107113 Moscow, Russia
natalia.efremova@gmail.com

Andrey Kiselev

Örebro University
Fakultetsgatan 1, 70182 Örebro, Sweden
andrey.kiselev@oru.se

ABSTRACT

In this paper, we examine teleoperation as a critical aspect of using mobile robotic telepresence systems. Particularly, we propose and advocate using cognitive architectures as means to ease teleoperation for novice users and to enhance social interactions.

Keywords

Human-Robot Interaction, Cognitive Architectures, Mobile Robotic Telepresence, Teleoperation, User Interfaces

1. INTRODUCTION

Robotic telepresence allows to enhance remote human-human interactions offering mobility to users who connect from remote locations. While being developed primarily for communication, mobile robotic telepresence (MRP) system require that pilot users can efficiently drive robots using teleoperation interfaces. This task may be difficult for inexperienced users and may require much effort from them. In this paper, we focus on teleoperation as a critical aspect of using MRP systems.

In teleoperation, users are de-coupled from the environment where the robot is installed and it may take time for them to adapt to actual parameters of de-coupling in the teleoperation system. Extensive training is usual in case of industrial or military robots teleoperation to overcome this issue. But it is unacceptable for consumer MRP systems. Attempts to minimize or eliminate training include introducing robots' autonomy [3] or semi-autonomy [14] and improving teleoperation interfaces.

The main focus of this paper concerns a visual feedback, which users receive from the robot in MRP system. [15] and [13] show that the quality of visual feedback significantly affects performance of operators in teleoperation tasks. In our opinion, cognitive architectures can be utilized to enhance the pilots' performance in several ways. Cognitive architectures for image recognition and mental rotation [6] might ease the recognition of the objects in the visual field of the

robot and also help to avoid obstacles when driving. Complex scene recognition models [12] can help to analyse the visual field in order to detect new or unusual objects in the environment. Visual saliency models [5] can help the robot to detect a person or human face.

To sum up, we want to discuss the ways to enhance telepresence of robot performance in two aspects: (1) in communication with the end users, (2) in operator interface. We will regard the possibility of application of cognitive architectures to robotic platform only in respect to vision. However, more complex approach to building cognitive architectures for telepresence robots is also regarded in [4].

2. IMPLEMENTATION OF VISUAL FEEDBACK

The importance of providing operators with high quality video feedback from a robot is undoubted. But exact metrics of quality can be unclear. There is a number of parameters the video feedback can have, such as: resolution and frame rate; color depth; time lag (latency); aspect ratio and field of view (FOV); geometric distortions; height and orientation of a camera. Influences of some particular parameters on a quality of teleoperation are very clear. These are characteristics of optical and digital quality of a video stream such as resolutions, color depth and others. Also, time lag must be as low as possible.

At the same time, often some parameters are not well understood, or their importance is underestimated. Particularly, it is absolutely true that "wider FOV is often used to broaden the scope of the visual scene" [2], but [2] also points out that it tends to negatively affect other factors. For example, increased scene distortion often increases operators cognitive workload and motion sickness and degrades depth perception. Wide FOV allows operators not to care about formations in conversations, but this degrades the overall experience of the interaction for local users [8]. The aspect ratio is also often not taken into account. However, as it is shown in [7] these parameters can have great effect on the quality of social interaction.

3. COGNITIVE ARCHITECTURE APPROACH

Cognitive architectures have only relatively recently been considered for application to robotics [1]. However, in the domain in human-robot interaction they have already proved to be very important, since human-like social behaviour is

important for setting natural communication with children [9] and elderly people [10].

Using cognitive architectures for the teleoperation robots can enhance the performance of human operator by providing substantiation help with visual processing. We propose that usage of cortex-like object recognition system might be helpful in complex visual scene recognition, like the environment in the end user's house. Typically, cognitive architectures for visual processing incorporate one of three main mechanisms of primate vision: the ability to recognise complex visual scenes, saliency attentional models or mental rotation mechanisms for recognition of objects from various viewpoints.

One of the biggest problems of visual perceptual processing is information overload. In natural cognitive systems (e.g. in animals) peripheral sensors generate afferent signals continuously, and processing of all this incoming information is computationally costly. Therefore, nervous system select which information is important and should be processed further and which should be discarded. The mechanism for sequential treatment of different parts of the visual scene is called selective attention [5]. In artificial cognitive systems, principles or functional processes is inherited from biological systems, especially from primates, since they offer the best examples of the desired functionality. Artificial system, which utilises attentional mechanisms, could be used for visual pre-processing in telepresence robots to help robot's pilot to analyse the environment in terms of selecting important parts of the visual input for analysis.

The ability of the the artificial system to recognize different objects in various positions in the visual scene and to recognize the position of familiar objects (i.e. object recognition at a particular location) might be useful in terms of analysis of current status of the end user (or user's house). Such task can be accomplished in a biologically plausible way by means of the cognitive architectures as well [12].

In terms of obstacle avoidance, the built-in mechanisms of mental rotation can be used. Mental rotation is a cognitive ability to transform mental images, in which one imagines how an object would appear if rotated around some axis in three-dimensional space [11] first conducted a systematic behavioural investigation into the process of mental rotation. Since the pioneering work of Shepard and Metzler, a large body of behavioural and neuroimaging research has provided evidence that supports the existence of such spatial analogue representations relevant to the process of mental rotation. Today, a variety of models, which utilises mental rotation mechanisms [6] exist. Mental rotation for the recognition of objects from various viewpoints can be simulated together with other important features for visual pre-processing in a cortex-like modular architecture.

In conclusion, we want to outline the main properties of the proposed solution. We propose building the cognitive architecture for visual pre-processing for telepresence robots. These should consist of series of modules, resembling the series of areas in ventral in dorsal streams. The proposed architecture should inherit such properties of primate visual processing as complex scene recognition, visual attentional awareness and mental rotation. In communication with the end users the enhanced architecture might provide better social interaction between the end user and the teleoperated robot (i.e. the robot would "look in the user's face" if it detects the face with the saliency model). Image pre-

processing might also improve operator's task by addition of obstacle avoidance and image analysis.

4. REFERENCES

- [1] P. Baxter, J. de Greeff, and T. Belpaeme. Cognitive Architecture for Human-Robot Interaction: Towards Behavioural Alignment. *Journal of Biologically Inspired Cognitive Architectures*, 2013.
- [2] J. Y. C. Chen, E. C. Haas, K. Pillalamarri, and C. N. Jacobson. Human-Robot Interface : Issues in Operator Performance , Interface Design , and Technologies. *Engineering*, 3834(July):ARL Technical Report ARL-TR-3834, 2006.
- [3] A. Cosgun, D. a. Florencio, and H. I. Christensen. Autonomous person following for telepresence robots. *2013 IEEE International Conference on Robotics and Automation*, pages 4335-4342, 2013.
- [4] V. Harutyunyan, V. Manohar, I. Gezehei, and J. W. Crandall. Cognitive Telepresence in Human-Robot Interactions. *Journal of HRI*, 2012.
- [5] G. Indiveri, R. Majrjer, and J. Kramer. Active Vision Using an Analog VLSI Model of Selective Attention. *IEEE Transactions on circuits and systems-II: analog and digital signal processing*, 2001.
- [6] T. Inui and M. Ashizawa. Temporo-parietal network model for 3d mental rotation. *2nd International Conference on Cognitive Neurodynamics*, 2009.
- [7] A. Kiselev and A. Loutfi. The Effect of Field of View on Social Interaction in Mobile Robotic Telepresence Systems. In *HRI2014*, 2014.
- [8] A. Kristoffersson, S. Coradeschi, A. Loutfi, and K. S. Eklundh. Assessment of Interaction Quality in Mobile Robotic Telepresence - An Elderly Perspective. *Interaction Studies*. in press.
- [9] F. Papadopoulos, K. Dautenhahn, and W. Ching Ho. Exploring the use of robots as social mediators in a remote human-human collaborative communication experiment. *Journal of Behavioral Robotics*, 2012.
- [10] J. Pineau, M. M. Montemerlo, M. Pollack, N. Roy, and S. Thrun. Towards robotic assistants in nursing homes: challenges and results. *Special Issue on Socially Interactive Robots, Robotics and Autonomous Systems*, 2003.
- [11] R. N. Shepard and J. Metzler. Mental rotation of three-dimensional objects. *Science*, 1971.
- [12] S. Tarasenko and N. Efremova. Neural Architecture for Complex Scene Recognition Based on Rank-order Features of IT Neurons. *IJCNN2013*, 2013.
- [13] J. Tittle, A. Roesler, and D. Woods. The Remote Perception Problem, 2002.
- [14] K. M. Tsui, A. Norton, D. J. Brooks, E. McCann, M. S. Medvedev, and H. a. Yanco. Design and development of two generations of semi-autonomous social telepresence robots. *2013 IEEE Conference on Technologies for Practical Robot Applications (TePRA)*, pages 1-6, Apr. 2013.
- [15] D. D. Woods, J. Tittle, M. Feil, and A. Roesler. Envisioning human-robot coordination in future operations. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, 34(2), 2004.