SGCS : Stereo Gaze Contingent Steering for Immersive Telepresence

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SOMBRERO

1. Context

1.1 Research framework : Embodied Learning

Our goal is to "teach" a robot to interact autonomously in a face-to-face task with a human. Due to the complexity of the task, standard learning approach like learning by observation and kinesthetic demonstration are not efficient enough notably for social signals (such as gaze or head movements). Our approach,based on the ***embodied learning*** paradigm, will teach the robot with his own moves by embodied him [10]. Like a puppeteer, a pilot controls the robot remotely using an immersive teleoperation platform. In order to record an interaction with minimal bias, the platform should become "transparent" and the remote world represented in a "natural" way. **Our actual research aims at rendering a coherent representation of the remote space and depth perception.**

1.2 State of the Art

What we know about humans :

- Depth perception is based on several factors : Binocular disparity (stereovision), occlusion, parallax, convergence, known semantics of the objects, ... [16, 5].
- Stereoscopic vision is useful before 15m (cannot differentiate from monovision after)[1]
- Vergence is useful in the peri-personal space (<2.0m) [14]

Current use of immersive teleoperation

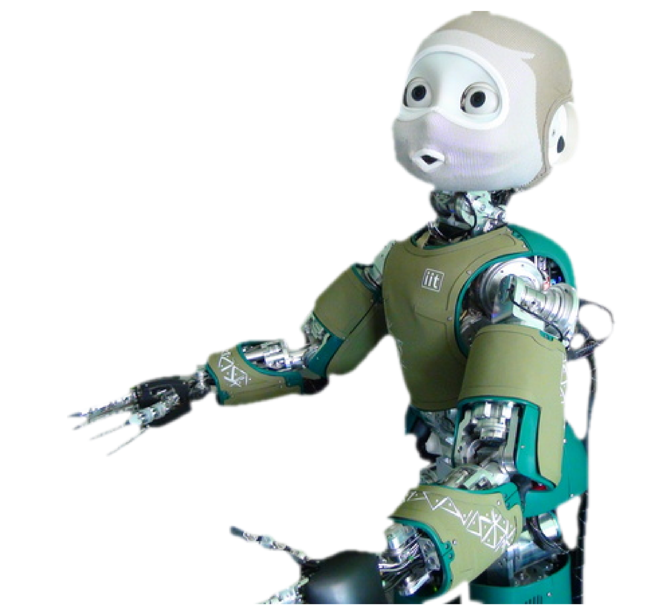
- Search and rescue robot [8]
- Drone navigation [4]
- Immersive telepresence [6, 7, 3]

Gaze controlled methods

- Virtual gaze joystick : "Moving to the center" [17] [12]
- EyeSeeCam [11, 13]

Limitations of current immersive teleoperation devices

- Underestimation of depth in peripersonal space (<2m), overestimation after 2m [2].
- Sensory motor conflict: Accommodation-convergence conflict [15]



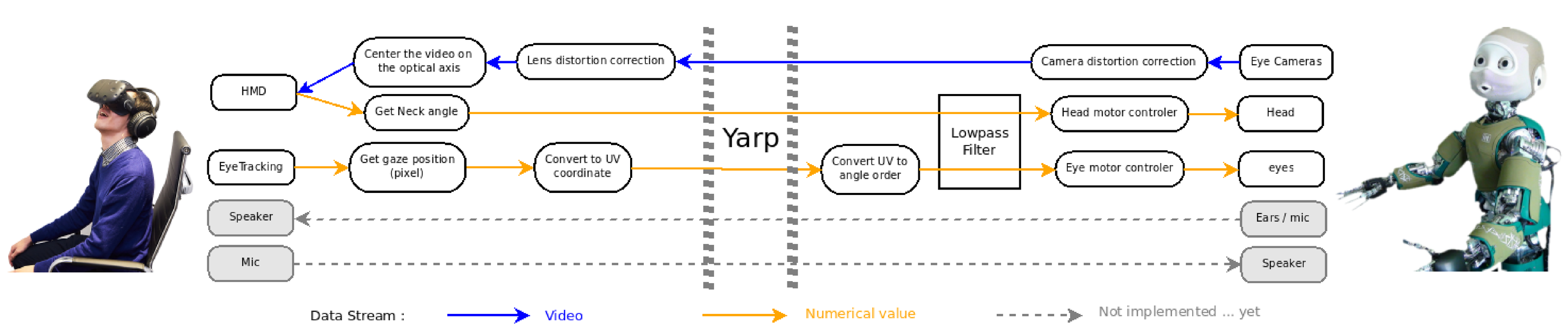
Our robotic platform "NINA" [9, 10]

Drawback : In those setups, the stereo rig is fixed. The pilot loses the vergence information/control, has reduced depth perception and experiences the accomodation-vergence conflict. For a human facing the robot, the robot gaze is less interpretable.

1.3 SGCS : *Stereo Gaze Contingent Steering*

Proposed approach : Here we propose a new natural control method for a pair of stereoscopic robotic eyes with vergence abilities, called SGCS (Stereo Gaze Contingent Steering), running alongside the control of a robotic head. An evaluation of the control method has also been performed.

2. Technological platform



Platform process

We use the Mical platform *NINA* from the CRISSP team at Gipsa. Specification :
* Icub 2.0 with enhanced face articulation [9].
* Cluster of 4 PC (3 Linux + 1 windows) running a yarp (client-server robotic middleware).
* HTC Vive + SMI integration for eye-tracking
* IPD cameras equivalent to human IPD => reduced hyperstereopsis
* Communication with UDP/TCP through the YARP middleware
* The camera's feeds are synchronised and displayed in the HMD (Head Mounted display) as video texture.

3. Control methods

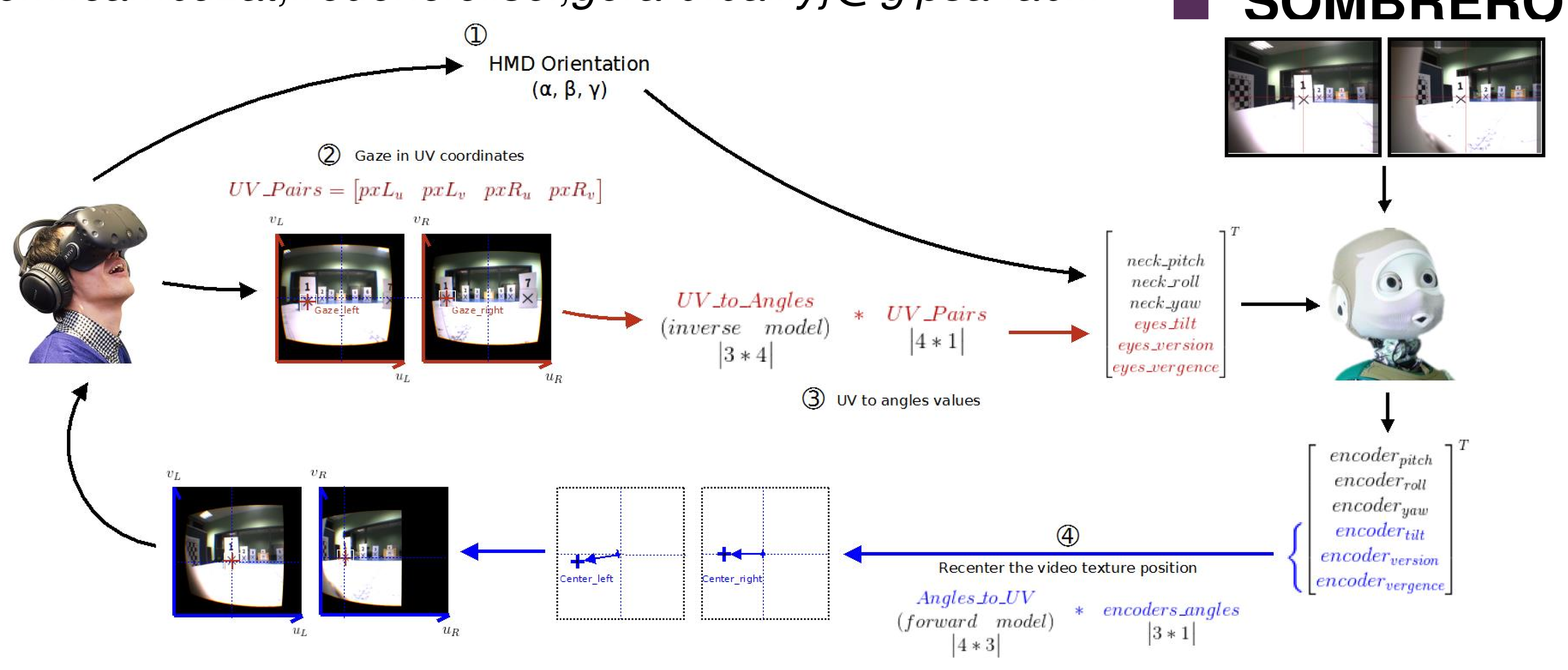
The control of the head and eye is done trough a angular command for the six head encoders:

$$[neck_{pitch}\ neck_{roll}\ neck_{yaw}\ eyes_{tilt}\ eyes_{version}\ eyes_{vergence}]$$

1. ***Head control:*** The head angles are driven by the HMD orientation value (standard approach).
2. ***Eye control:***
   (a) The gaze information returned (in pixel) is converted in UV coordinates, relative to the displayed video texture referential.
   (b) ***StereoClick:*** Using a transfer matrix UV_to_angle (*inverse model*), the module is able for a chosen target (defined by a UV pair) to return an absolute angular command value, to center the two stereo cameras images on it. This inverse linear model has (surprizingly) a precision of 0.5 on the three angles.

$$UV\_to\_angle * [pxL_u\ pxL_v\ pxR_u\ pxR_v] = [eyes_{tilt}\ eyes_{version}\ eyes_{vergence}]$$

3. ***Foveal display:*** Move the center of the video texture to a new UV coordinates pair, calculated by the *forward model* with the eyes encoders angular values. This moves the video texture in the virtual world to a coherent position for the robot and cues on the pilot side.



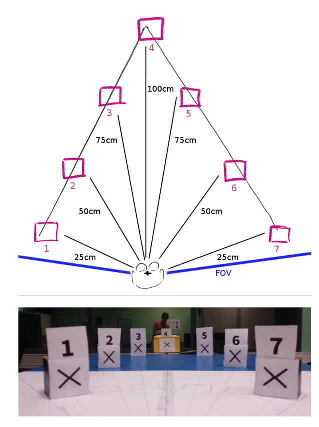
Overall controls methods

4. Platform validation

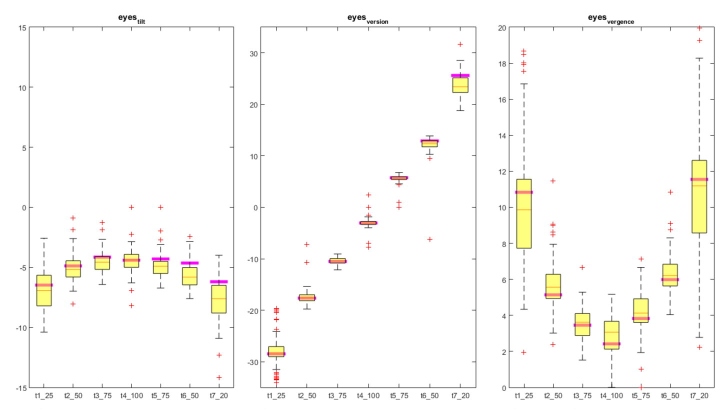
4.1 Setup & protocol

Setup : 7 target at various distance (25 to 100cm)
Protocol : For the reference condition (Ideal target angles determined semi-automatically) and the pilot, every target has been seen 8 times. On 4 passes (left->right, front->back, right->left, back->front) repeated two times.
Subjects : 13 subjects (3 women, 13 men), aged between 22-56 yo. No prior experience of virtual reality before for most of them (13 unexperienced VR).

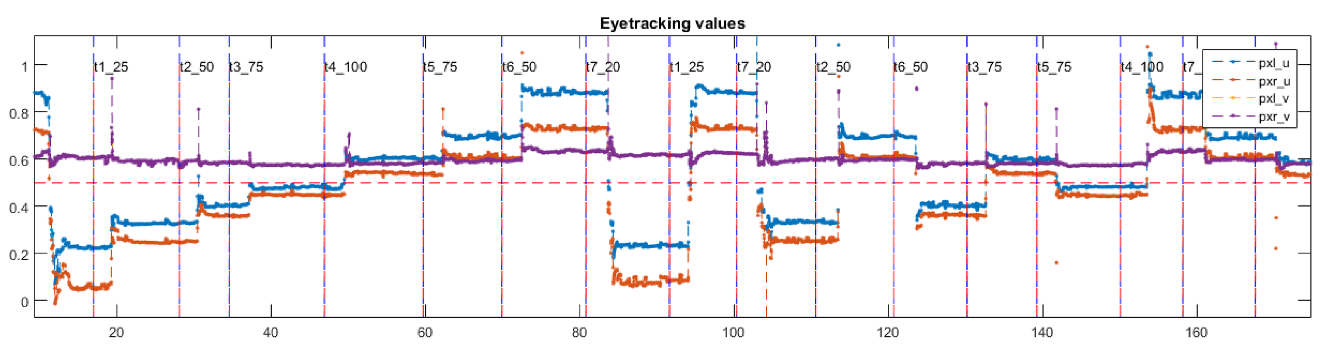
4.2 Results

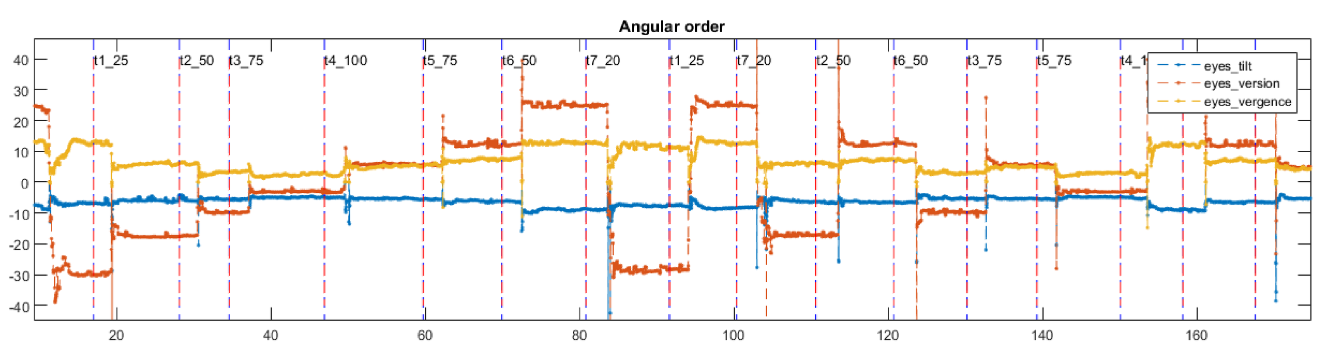


SGCS characterisation setup



Encoders angle values for all subjects. The reference is in magenta





Temporal pilot values for one subject

5. Discussion & future works

Discussion: Our SGCS control method is able to move the robotic eye in coherence with the orientation of the human eye (the camera optical axis is aligned with the human gaze). The cameras are looking where the human is looking with respect of tilt, azimut, and vergence.
Future works: * Hypothesis: Control of vergence improves perception and evaluation of depth in the near and medium field while maintaining oculomotor cues and reducing the accomodation-vergence conflict.
* Improve the reactivity of the control method: detection of fixation and saccade.

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