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Simon Forest, Mathieu Lefort, Jean-Charles Quinton

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Biological constraints in neural field models of sensor fusion

Simon Forest, Mathieu Lefort, and Jean-Charles Quinton simon.forest@liris.cnrs.fr

Objectives

- Improve the way social robots interact with people, starting with the way they perceive their environment
 - Particular focus on multimodal merging + role of active perception
 - Sensor fusion performed very efficiently in human brains \Rightarrow inspiration from psychology and neuroscience (e.g. the ventriloquist effect, where one modality takes over another for determining the perceived location of a sensory cue)
- \Rightarrow Create a computational model that accounts for human “biases” (such as the ventriloquist effect) and, in the longer term, includes active perception in order to support the development of more natural interactions (e.g. with a human environment)
- Part of the AMPLIFIER project \Rightarrow applications to social robotics + validation by psychophysical experiments

Hypotheses

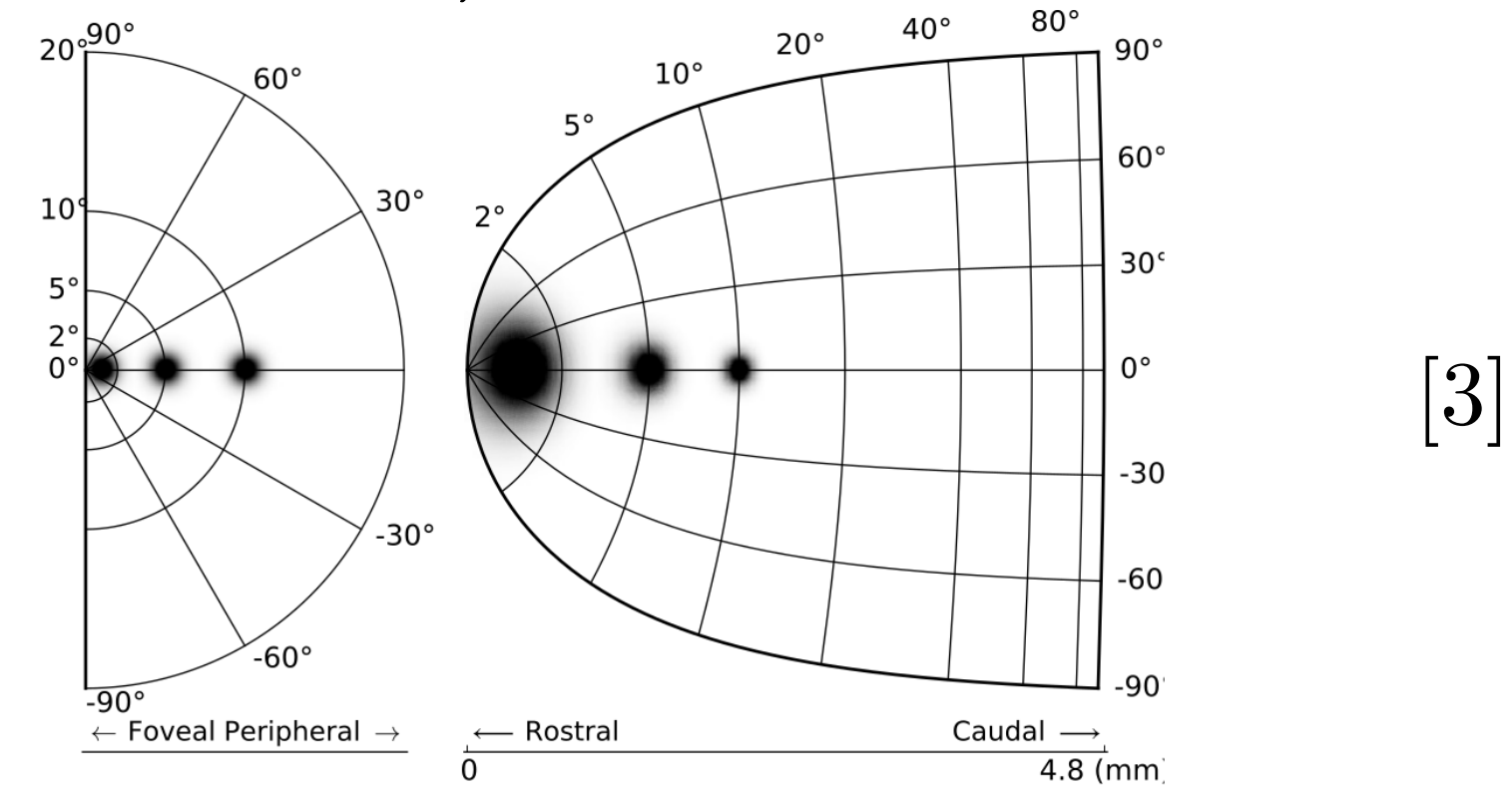
Model inspired from the superior colliculus (SC):

- Subcortical region involved in both multimodal merging and saccade generation
- Receiving visual, auditory, and even somatosensory inputs
- Aligned receptive fields: visual, auditory and somatosensory signals at a same location activate the same region of the SC

Reproducing the topology of the SC with a logpolar transformation:

$$\begin{cases} x = B_x \log \left(\frac{\sqrt{\rho^2 + 2A\rho \cos \phi + A^2}}{A} \right) \\ y = B_y \arctan \left(\frac{\rho \sin \phi}{\rho \cos \phi + A} \right) \end{cases}$$

Since the retina has a denser distribution of sensors at its center, visual cues will activate more SC neurons when they are close to the fovea than at the periphery.



[3]

Model

Based on dynamic neural fields [1]:

$$\tau \frac{\partial U(\mathbf{x}, t)}{\partial t} = -U(\mathbf{x}, t) + I(\mathbf{x}, t) + \int_{SC} W(\|\mathbf{x} - \mathbf{x}'\|) f(U(\mathbf{x}', t)) d\mathbf{x}' + h$$

$$W(\Delta \mathbf{x}) = A_+ \exp\left(-\frac{\Delta \mathbf{x}^2}{\sigma_+^2}\right) - A_- \exp\left(-\frac{\Delta \mathbf{x}^2}{\sigma_-^2}\right)$$

- Mesoscopic modeling of the SC
- Able to merge conflicting signals and/or select one of them
- Succeeds in qualitatively reproducing psychophysical experiments on the ventriloquist effect

References

- [1] S.-I. Amari. Dynamics of pattern formation in lateral-inhibition type neural fields. *Biological Cybernetics*, 27(2):77–87, June 1977.
- [2] J.-C. Quinton and L. Goffart. A unified dynamic neural field model of goal directed eye movements. *Connection Science*, 30(1):20–52, Jan. 2018.
- [3] W. Taouali, L. Goffart, F. Alexandre, and N. P. Rougier. A parsimonious computational model of visual target position encoding in the superior colliculus. *Biological Cybernetics*, 109(4):549–559, Oct. 2015.

The AMPLIFIER project

“Active Multisensory Perception and LearnIng For InteractivE Robots”

An interdisciplinary project with three main components:

- Gathering psychophysical data on sensor fusion, and in particular the role of active perception (e.g. eye movements)
- Building biologically-inspired computational models of multimodal merging, in adequation with the new data
- Using this model to enhance robot perception and improve their social interactions

More information: <https://projet.liris.cnrs.fr/amplifie/wiki/>

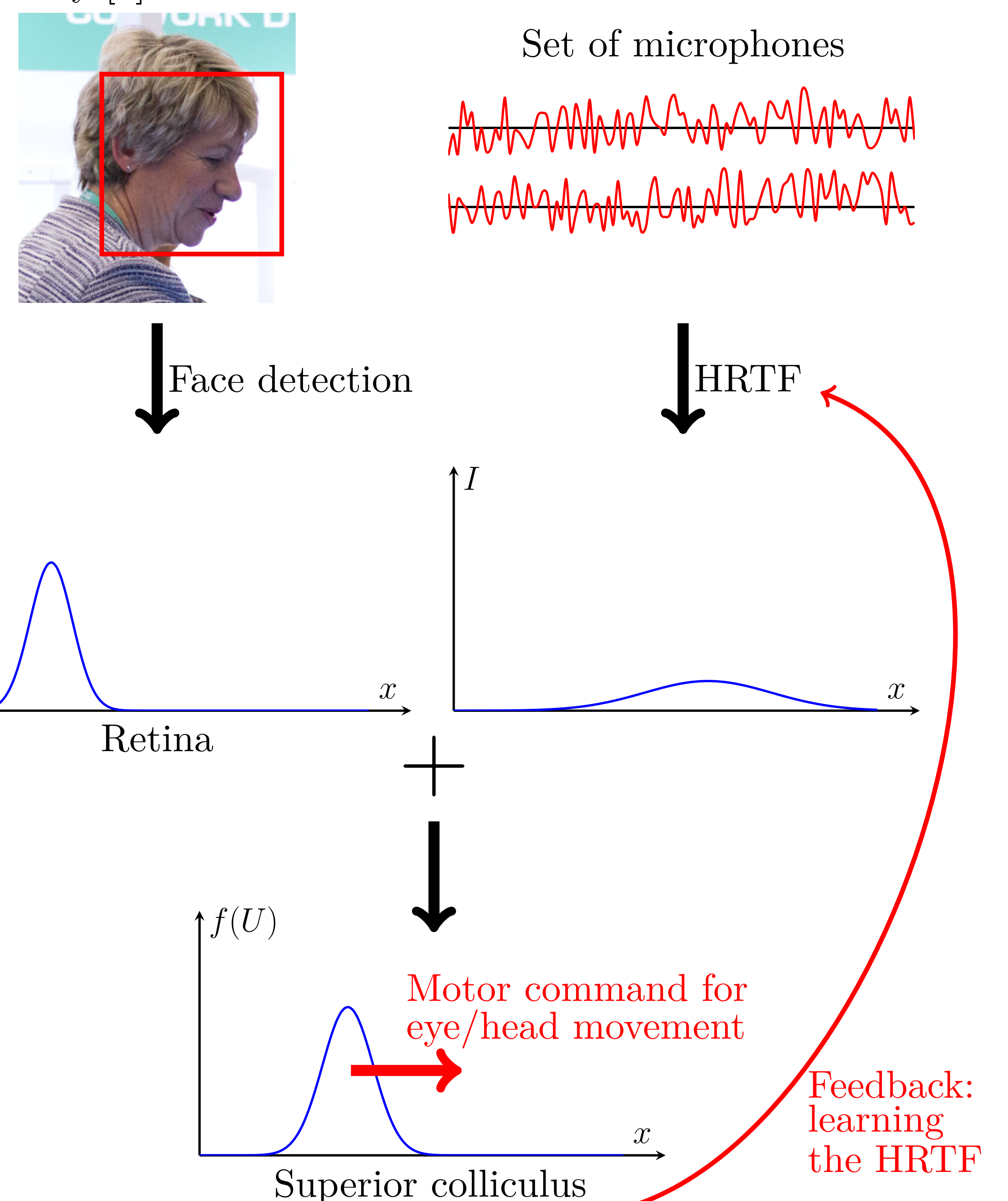
Perspective application



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Example: A woman is interacting with a robot, which has to turn its head towards her for natural social interactions.

1. The model receives inputs from the camera and microphones and merges it.
2. The perceived location of the signal can be used to finetune the head-related transfer function (HRTF), specific to each subject.
3. The model can generate saccades (or head movements) autonomously [2].



Upcoming work

- Retrying and improving the model with the upcoming data from AMPLIFIER
- Applications to social robots: testing the model and comparing it to unimodal perception methods
- Completing the model with decision-making and saccades generation
- Long-term: developmental learning of sensori-motor patterns for more natural interactions

