A Role for Cortical Spiral Waves in Visual Attention?

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General Hypotheses:

Perception is mediated by the inducement of dynamical states of the perceiver by the perceived and vice versa, not by static information processing or data analysis.

Human bodies, behaviour and sensory systems have co-evolved mechanisms to facilitate this process.

Adaptive function in the brain is mediated by the emergent dynamics of neural populations, rather than by isolated local computations.

Experimental Questions:

How can we use humanoid robots to contribute to scientific understanding of action-perception dynamics?

How do neural, morphological and environmental dynamics combine to generate adaptive behaviour?

What kinds of travelling wave activity are induced by particular patterns in stimuli?

What functional roles might be performed by travelling wave activity in visual cortex?

How can morphological computation and interaction dynamics relieve the cognitive load traditionally placed on 'neural representations' and 'internal models'?

Exploiting pattern to facilitate perception

Spiral waves can be induced in physical media by phase imprinting and via dynamical instabilities [1].

We are asking whether a similar mechanism might be at work in visual perception. The morphology of human eyes is particularly salient to centre-surround filters.

Spiral contours are common features of human morphology. Can we exploit this feature to direct attention to people?

Figure 1 shows the different dynamics induced by a nose versus simpler bar patterns. Dynamical instabilites in morphological reaction-diffusion processes provide a mechanism for the formation of such patterns.

The communication is mediated by similar underlying population dynamics.

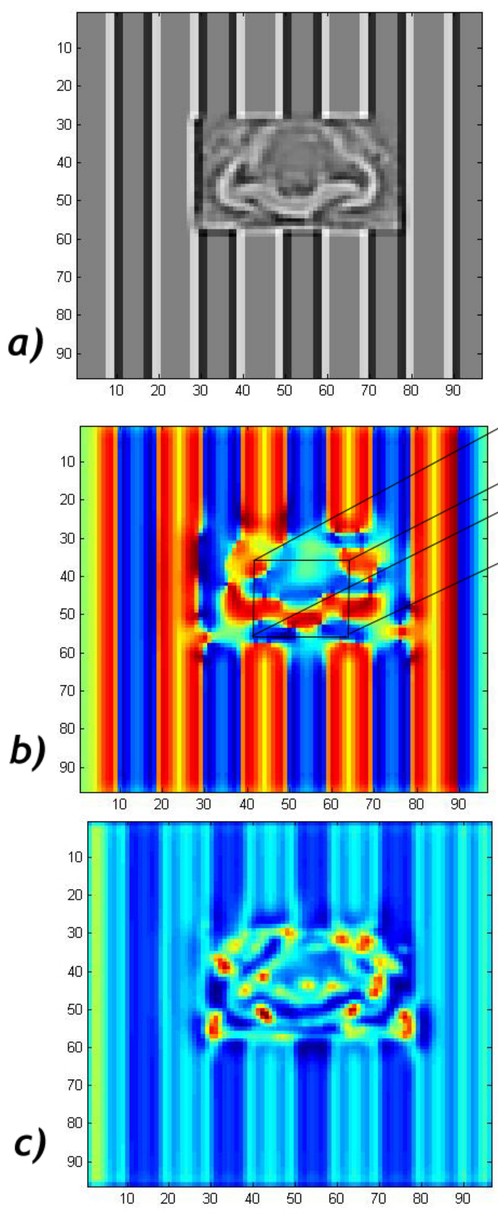

Figure 1.0
a) Contrast image
b) Phase snapshot
c) Frequency map

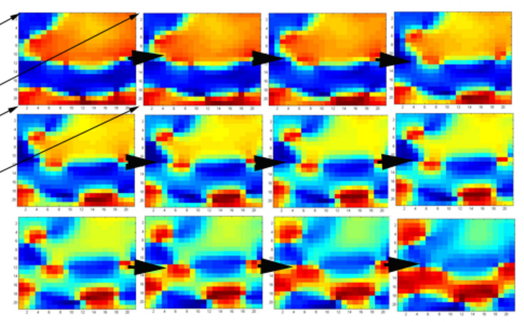

Figure 1.1

Phase maps of the temporal evolution of spiral waves in a subregion of the sensory medium. Spirals increase the local frequency so the nose region 'pop's out' in the frequency map 1(c).

Increasing evidence suggests a functional role for travelling waves in visual cortex

[3] recently reported existence of spiral waves in visual neo-cortex, and found that spiral centres drifted much faster in vivo than in vitro, suggesting active modulation in the intact brain. Our work is exploring potential functional roles for these cortical population dynamics.

Applications

We are applying the model to visuo-motor control and active perception [4]. The newly emerging face-to-face paradigm is designed to explore infants' understanding of the interactions of others [2].

Infants observe two inter-actors who are either facing each other or facing away from each other, and infants' gaze shifts between the actors are recorded. Depending on experimental conditions, infants enact a behavioural distinction between conditions from as young as 6 months.

We used stimulus images from face-to-face studies to see if this behavioural distinction could be reproduced using simple action-perception dynamics. We added a simple motor interface which couples eye movement to travelling wave activity in a simulated oscillatory sensory surface.

The model produces more gaze shifts in the social condition, demonstrating both the utility of the spiral wave attention mechanism and the ability of active perception to produce behavioural sensitivity which would in general be viewed as requiring high level cognitive functions.

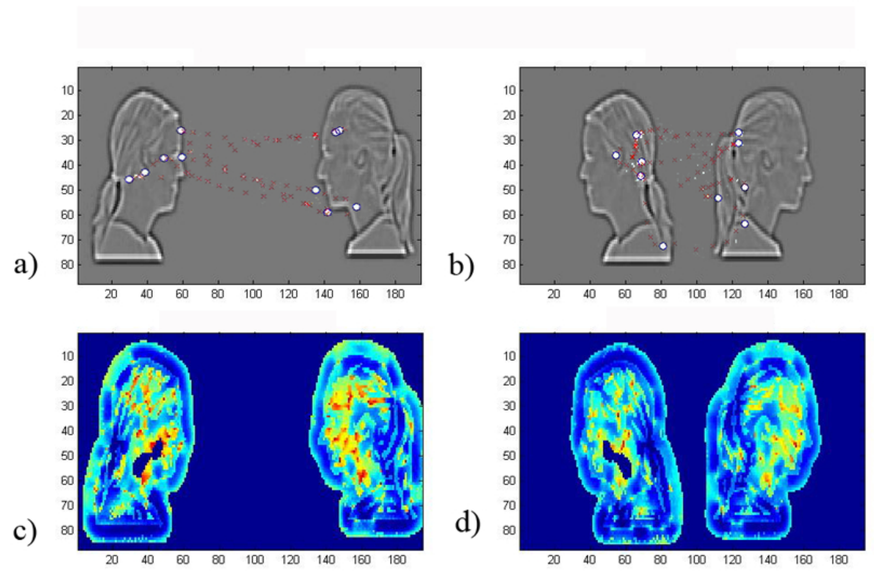

Figure 2 - *Pictorial demonstration of the face-to-face experiments. (a) and (b) show the stimuli with eye movements overlaid. The circles indicate fixation locations*

References

[1] J. Williams and M. Holland. Preparing toplogical states in Bose-Einstein condensates. Nature, 401(6753):568-572, 1999.

[2]E.-M. Augusti, A. Melinder, and G. Gredeback. Look who's talking: pre-verbal infants perception of face-to-face and back-to-back social interactions. Frontiers in Psychology, October, 2010.

[3] X. Huang, W. Xu, J. Liang, K. Takagaki, X. Gao, , and J. Wu. Spiral wave dynamics in neo-cortex. Neuron, 68:978-990, December 2010.

[4] N. Wilkinson, G. Metta and G. Gredeback. Modelling the face-to-face effect: Sensory population dynamics and active vision can contribute to perception of social context. EpiRob-ICDL Conf. (Submitted) 2011.