A bio-inspired evaluation methodology for motion estimation

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Evaluation of neural computational models of motion perception currently lacks a proper methodology for benchmarking. We propose an evaluation methodology based on human visual performance. The proposed standardised tools allow to compare different approaches, and to challenge current models of motion processing in order to define current failures in our comprehension of visual cortical functions. We built a database of stimuli to depict input test cases corresponding to displays used in psychophysical settings or in physiological experiments. Since different kinds of models have different kinds of representation and granularity, we had to define generic outputs for each considered experiment as well as correctness evaluation tools. Amplitude of pursuit or direction likelihoods are two examples. We probed several models of motion perception by utilising the proposed benchmark. As a whole we provide here a valuable tool to unravel the fundamental mechanisms of the visual cortex in motion perception.

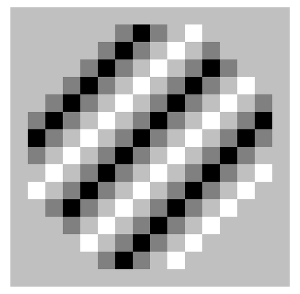
Goals

- Extend optical flow evalution methodologies
- Set up a bio-inspired benchmark
  - Evaluate existing motion models
  - Highlight failures in our understanding
- Propose an extensible methodology

Baker et al. (2007)

Difficulties

- Computer stimuli are not real stimuli
  - Discretisation problems
- Experimental data is complex
  - Need to extract comparable data
- Models exhibit a wide range of variety
  - Motion or time representation differs widely



Stimuli set

- We consider a set of stimuli from the literature
  - Choosen for their fundamental properties

  - Two main categories: line-drawings and gratings
- We define read-outs to evaluate model outputs
  - We extract ideal observers for each stimulus

From models to biology

Tested models

- Bio-inspired motion processing models — *Simoncelli & Heeger (1998)*, *Bayerl & Neumann (2004)*, *Tlapale et al. (2008)*
- Computer vision methods for optical flow — *Lucas & Kanade (1981)*, *Horn & Schunk (1981)*

Defining read-out

- We provided algorithms to provide comparable results
- For instance, with a distributed velocity likelihood model, we define a smooth-pursuit like movement $\mathcal{W}$ as:

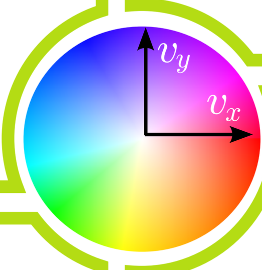
$$w(t,x) = \frac{\int_V p(t,x,v) v \mathrm{d}v}{\int_V p(t,x,v) \mathrm{d}v}$$

$$\frac{\partial \mathcal{W}}{\partial t}(t) = \int_\Omega w(t,x) \mathrm{d}x - \mathcal{W}(t)$$

where p is the velocity likelihood, V the velocity space, and Ω the retinotopic space

Comparing results

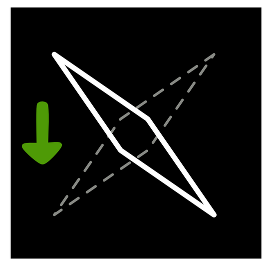
- The literature often provides data together with a *fitting function*
- We use the parameters associated with the fitting functions to quantify the results

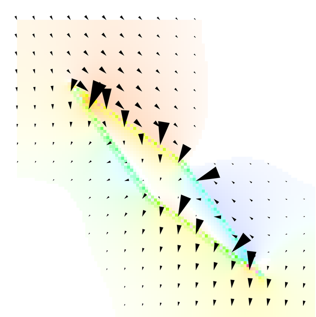


Results

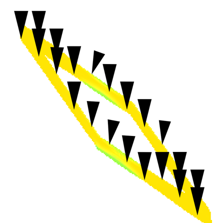
Translating diamonds

Masson & Stone (2002)





Horn & Schunk (1981)

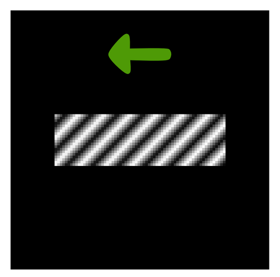


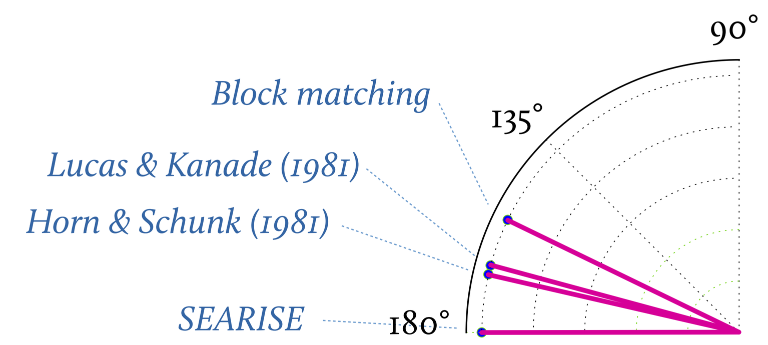
Tlapale et al. (2008)

- *Goal:* Evaluate perception of 2D cues

Quantitative measurement: Change in eye position
Fitted function: $f_{A,\tau,B}(t) = A \exp(-t/\tau) + B$

Barberpole



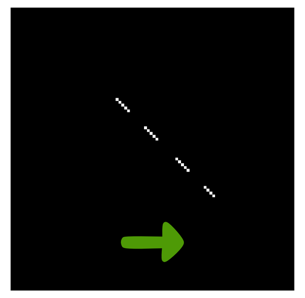


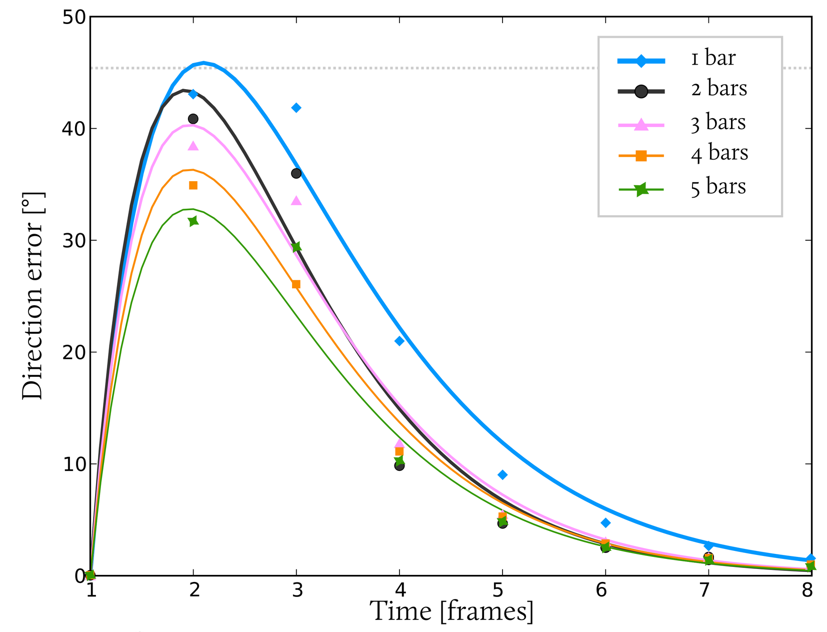
- *Goal:* Evaluate aperture geometry influence on integration

Quantitative measurement: Final perception
Expected result: Motion parallel to the longest border

Results (2)

Dashed bar





- *Goal:* Evaluate dynamics of 2D cues

Example results

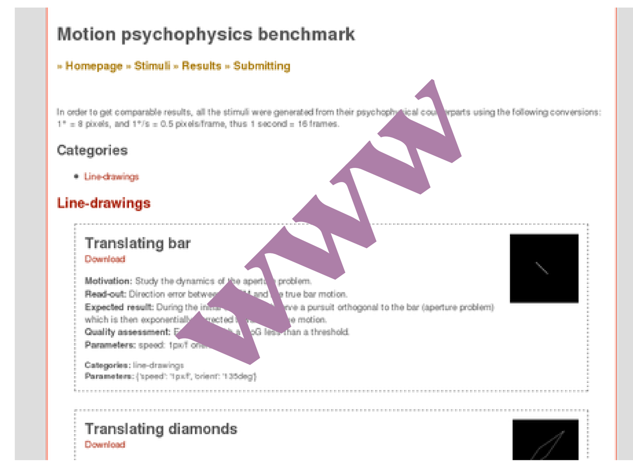
	bbpole	tdiams	sgrats	dbars
Lucas & Kanade (1981)	✔	✘	✘	✘
Horn & Schunk (1981)	✔	✘	✘	✘
Simoncelli & Heeger (1998)	✔	✘	✘	✘
SEARISE	✔	✔	✘	✔

- Existing models do not consider carefully the dynamics

Use the benchmark!

Evaluate your model

1. Visit the benchmark website
2. Select a set of stimuli
3. Run your model of them
4. Submit formatted results



Submit your stimuli

- Boosts dissemination of your work
- Allows the community to access comparable data
- Facilitates alternate explanation for the stimuli

Bibliography
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http://www-sop.inria.fr/neuromathcomp/software/motionpsychobench