# The informative content of optical flow features of biological motion

A. Sciutti[1], N. Noceti[2], F. Rea[1], F. Odone[2], A. Verri[2] and G. Sandini[1]

1. Robotics, Brain and Cognitive Sciences Department, Istituto Italiano di Tecnologia, Italy
2. Department of Computer Science, Bioengineering, Robotics and System Engineering, University of Genova, Italy

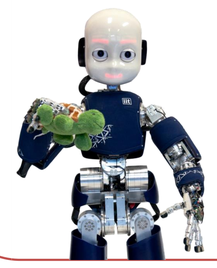
## Abstract

A natural **predisposition towards biological motion**, i.e. motion produced by a living being, is shown **in human neonates** since the earliest stage of the development (Simion et al. 2008). Hence, infants can perceive the presence of other humans moving in their social space, even with the limited visual information available at birth.

We show that **a perspective invariant visual feature, computed from optical flow, could be used to explain this ability** and we **test this hypothesis** through action observation and **using a humanoid robot as an embodied test-bed** of the computational model.

## Goals

To **study and design computational models** of the perceptual primitives supporting **the acquisition of social skills in infants**, with particular reference to the detection of **biological motion**.



In perspective such models can be adopted to support the development of comparable capabilities **in humanoid robots.**

The **iCub humanoid robot** is the reference platform we considered (Metta et al. 2010)

The **image sequences** are processed through an elaboration **pipeline,** to understand whether a *someone* is moving in front of the robot.

## PIPELINE

**Low-level features extraction** → **Spatio-temporal motion segmentation**

**interchangeable**

Based on **Optical Flow**, a "rough" low level measure to mimic the limited amount of visual information available after birth

Motion-based image segmentation is used to build a *saliency motion map* in each frame

### Motion representation

Inspired by **the Two-Third Power Law**, to capture the peculiarities on biological motion

$$A(t) = K(t)C(t)^{1-\beta}$$

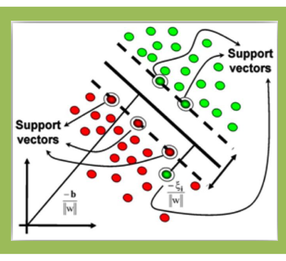
$$A(t) = \frac{V(t)}{R(t)}$$ Angular velocity

$$C(t) = \frac{1}{R(t)}$$ Curvature

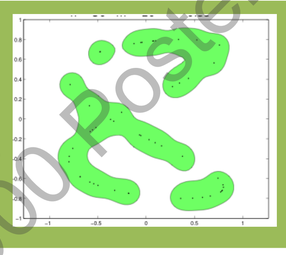
We can extract V(t) directly from the optical flow (e.g. as the *average flow magnitude over a region of interest*) and then compute all the other quantities

### Motion understanding

Based on **Machine Learning**, to model the classes of biological and non biological motion




**Support Vector Machines**



**Spectral Support Estimation** (Rudi et al. 2014)

The motion analysis pipeline has been evaluated on image sequences of biological and non biological motions acquired by the robot cameras.

**Non biological**

Pendulum
Toy car

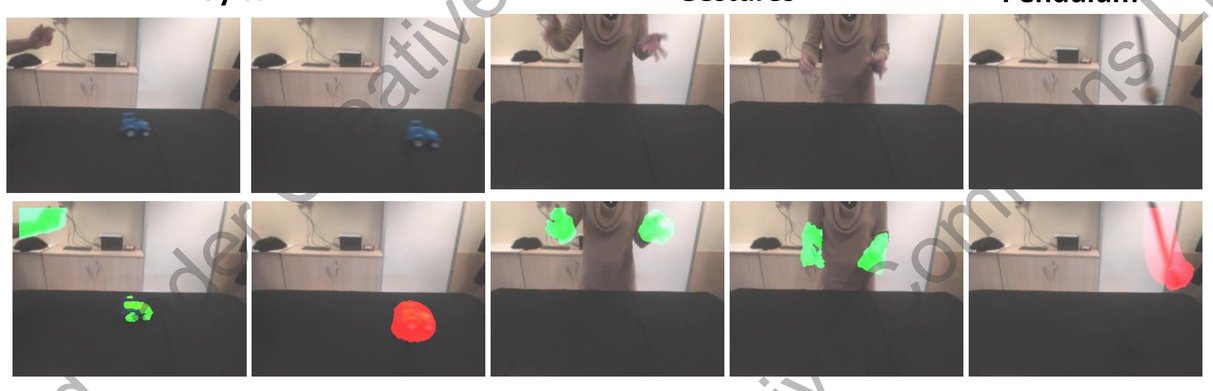
**Biological**

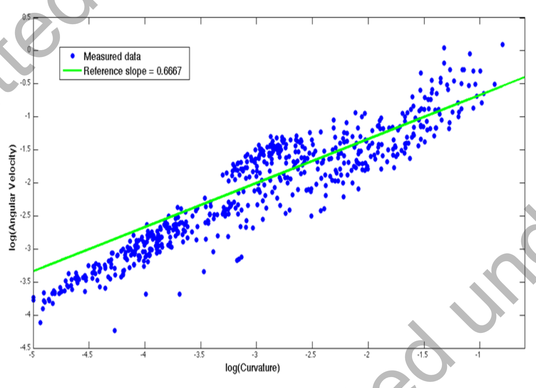
Gestures
Lifting actions

## Detecting biological motion in the scene

It is possible to classify movements in a scene *as **biological** or **non biological*** just on the basis of dynamic features computed from optical flow.

**Toy car** **Gestures** **Pendulum**

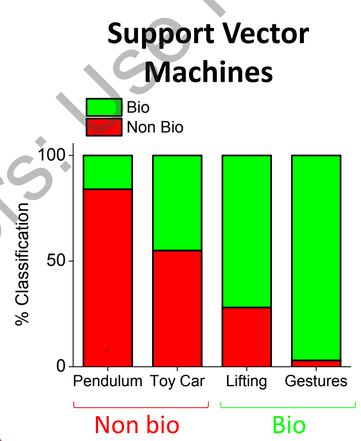




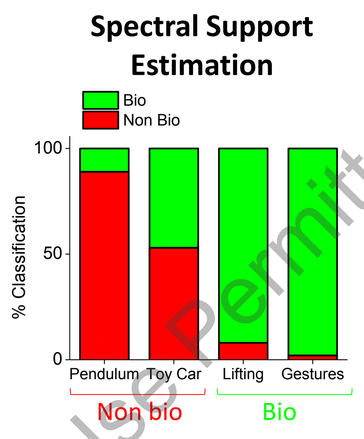

The analysis of the biological clips confirms that also the simplified representation of motion derived from optical flow reflects rather accurately the **two-third power law** (Viviani & Stucchi, 1992).

By describing motion with feature vectors of 4 redundant components at each time instant t **[V(t), C(t), R(t), A(t)]** and concatenating such vectors over a time window of width T, it is possible to **reliably classify biological motion** with different machine learning techniques.

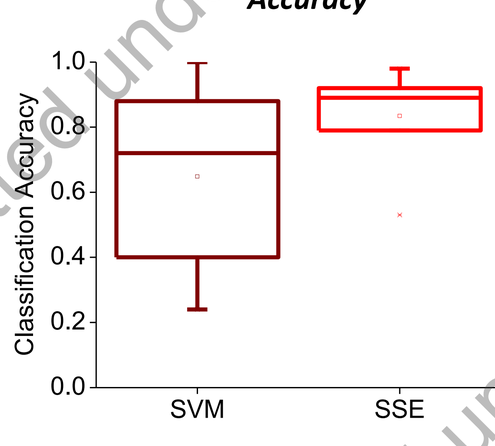
**Support Vector Machines**




**Spectral Support Estimation**

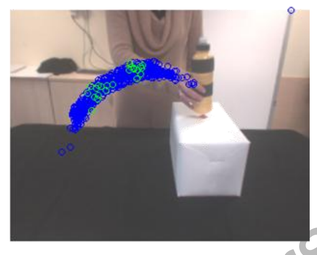



***Accuracy***



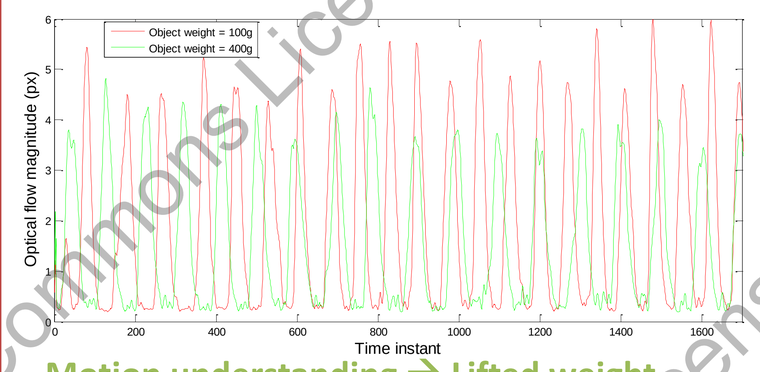

## Understanding action properties for interaction

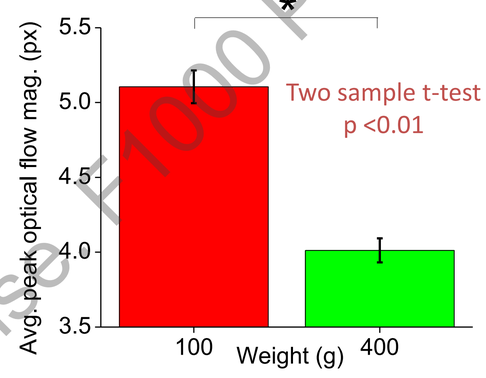
We frequently estimate the weight of objects passed to us during everyday interactions with others. This information makes the interaction fluid, allowing the observer to prepare in advance his own action (Sciutti et al. 2014).
Here we show that from the simplified description of agent motion proposed, it is also possible to extract these subtle action properties supporting interaction.



### Motion features → Optical flow

The peak magnitude of optical flow can be a proxy for the lifting speed, which varies significantly with lifted weight (Hamilton et al. 2007).




### Motion understanding → Lifted weight


The average accuracy in detecting the weight over 3 subjects is around **70%,** (71% validation, 66% testing),a very nice result considering the simplicity of the analysis performed (e.g. no a priori segmentation of different moving parts of the body).

## Take home message

We modeled **the ability to perceive the presence of biological motion** in the visual scene and understand some of its main properties starting from **low-level measurements** (e.g. optical flow). This finding paves the way to modeling the development of social attitudes proper of the visual processing of human infants .

## References

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