Synthesis of Distributed Cognitive Systems: Interacting Maps for Sensor Fusion

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Introduction

Environmental interaction is a significant aspect in the life of every physical entity, which allows determining its internal state and acquiring new behaviors by creating a consistent and coherent internal representation of the true external world. In our project we propose advancing the idea of interacting maps for sensory interpretation with focus on multisensory fusion.

The core idea is to implement a neuro-biologically inspired method for real-time interpretation of sensory stimuli in mobile robotic systems (e.g.: UAVs, Fig.1) different from existing approaches that are computationally expensive and problem dependent in multi-sensory contexts [1].

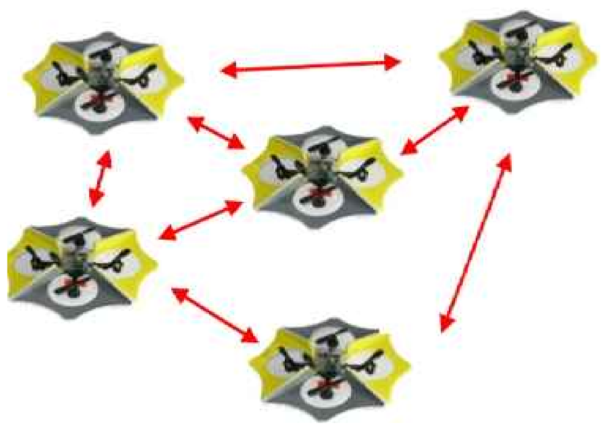

Fig. 1 Sample validation scenario

Method

Design principles:

- distributed and hierarchical stimuli processing [2],
- recurrent modular network design composed of many functional units,
- each unit encodes a pixel based representation of a modality (knowledge map),
- the dynamics is given by mutual influence between the maps,
- interaction based on hand designed or learned relationships,
- inter-merged information storage and processing,
- support for self creating and specializing systems.

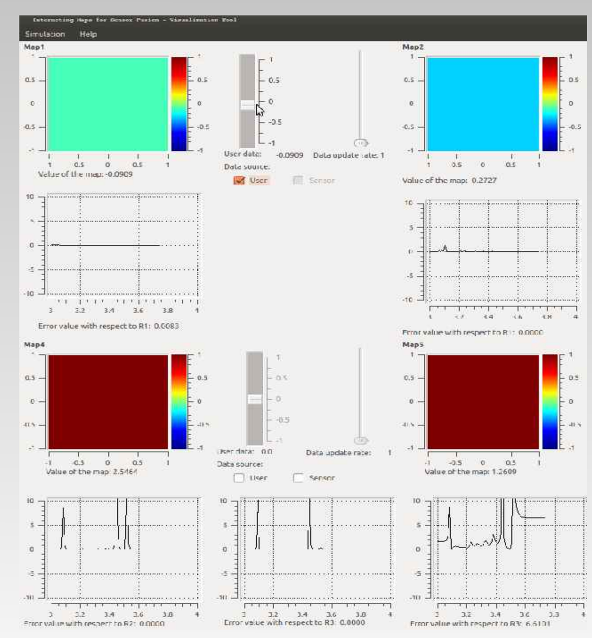

Fig. 2 Software demonstration tool

Experimental Setup

Exemplary toy-system

In a typical scenario the network is randomly initialized and each map can be connected to a specific sensor that it represents.

Processing mechanism:

In the example in Fig.3 each map (M1 - M8) is 1D, representing a single value and the maps are linked by 3 simple algebraic relations (R1 - R3).

- the initial values of the network are randomly chosen
- at each iteration the value in each map will slowly drift in the direction that minimizes the disagreement between the two sides of the mathematical relationship
- the network slowly relaxes into a stable state in which each relationship is approximately satisfied
- an external input (here connected to M1) allows variations in the network's resting state.

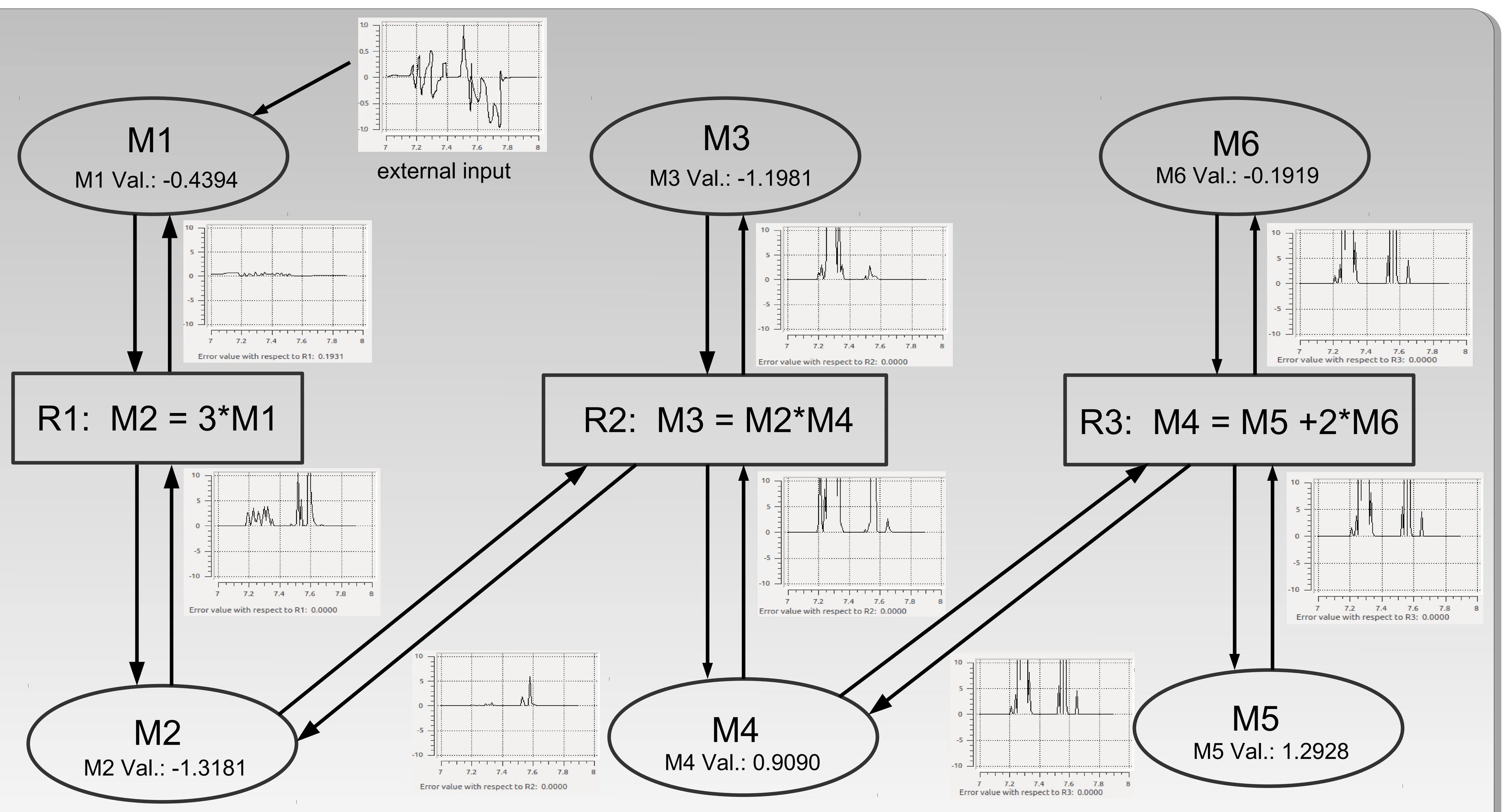

Fig. 3 Demo network for 1D data processing

Future development

The next step is to extend the network to process multi dimensional data and more complex relations.

A first scenario will be robot orientation detection, Fig. 4, which will fuse IMU data (e.g. gyro and compass), visual data (e.g. horizontal optic flow) and robot odometry data (e.g. wheel velocities). The depicted network will be able to enhance the precision and processing time in detecting the heading of the robot in a cluttered environment.

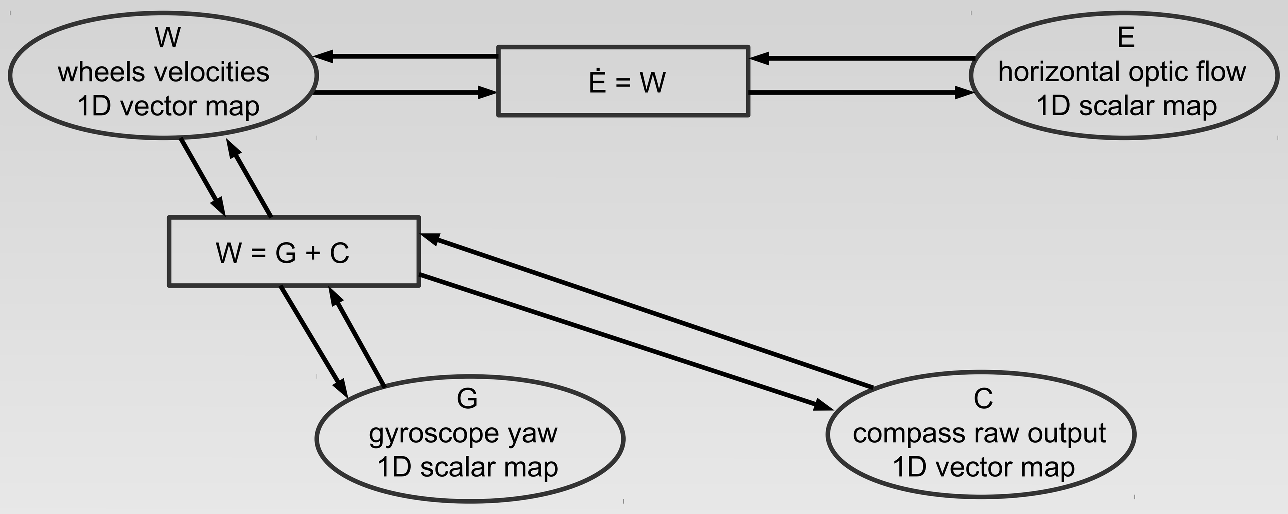

Fig. 4 Orientation detection network architecture for a mobile robot

The features shown by the simple scenarios will emerge also in more complex networks that will exhibit complex capabilities:

- fault tolerance - inferring one unavailable quantity from others
- decision making - choosing between representations when facing inconsistent or noisy data
- inference - learn the relationships between the represented modalities from data

A second scenario will be a fast visual interpretation setup, Fig. 5. The synthesized distributed system will be deployed and will unfold so that the created units will specialize on a certain feature. The units local interaction dynamics are following the same rules as in the simple toy-system, but they will be built on top of more complex (multi-dimensional and nonlinear) relationships. The network will be fed with timed information about light intensity changes from a neuromorphic sensor and will converge to a stable state in which we can extract a global representation of the visual scene.

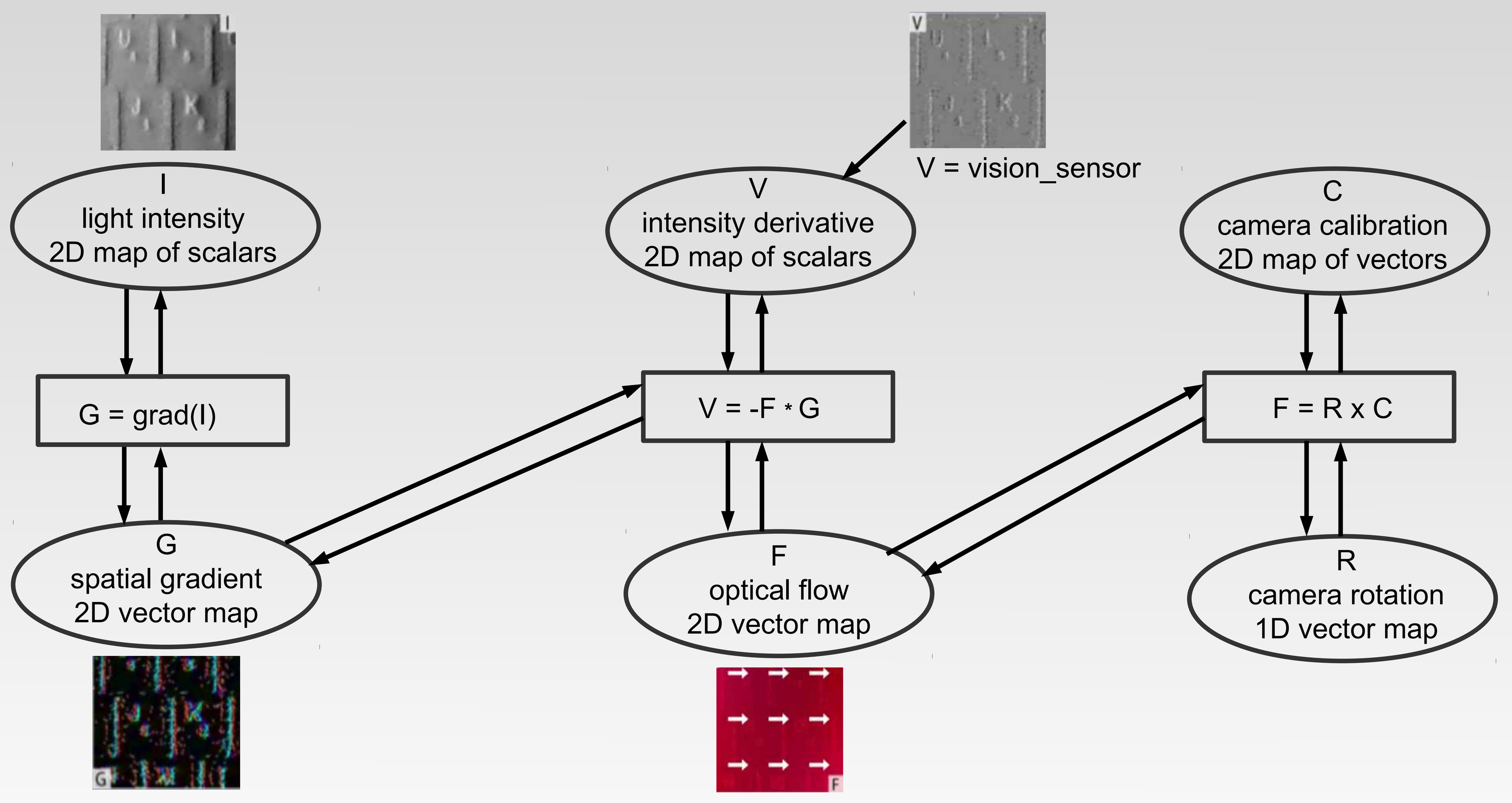

Fig. 5 Visual interpretation network architecture and inferred quantities of the represented features

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