A Hybrid Intelligent System for Robot Ego-Motion Estimation with a 3D Camera

Ivan Villaverde and Manuel Graña
Computational Intelligence Group
University of the Basque Country
http://www.ehu.es/ccwintco

HAIS 2008
Hybrid Intelligent Systems for Multi-robot and Multi-agent Systems

Contents

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- Introduction
- ToF 3D Camera
  - Data Preprocessing
- Hybrid Intelligent System
- Experimental Settings and Results
- Conclusions

Introduction

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- Use of new ToF 3D cameras.
- Final objective: full SLAM capabilities on multirobot systems.
- First step: Learn data processing and feature extraction from the 3D data provided by the camera.
- Simple task: ego-motion estimation.

ToF 3D Camera

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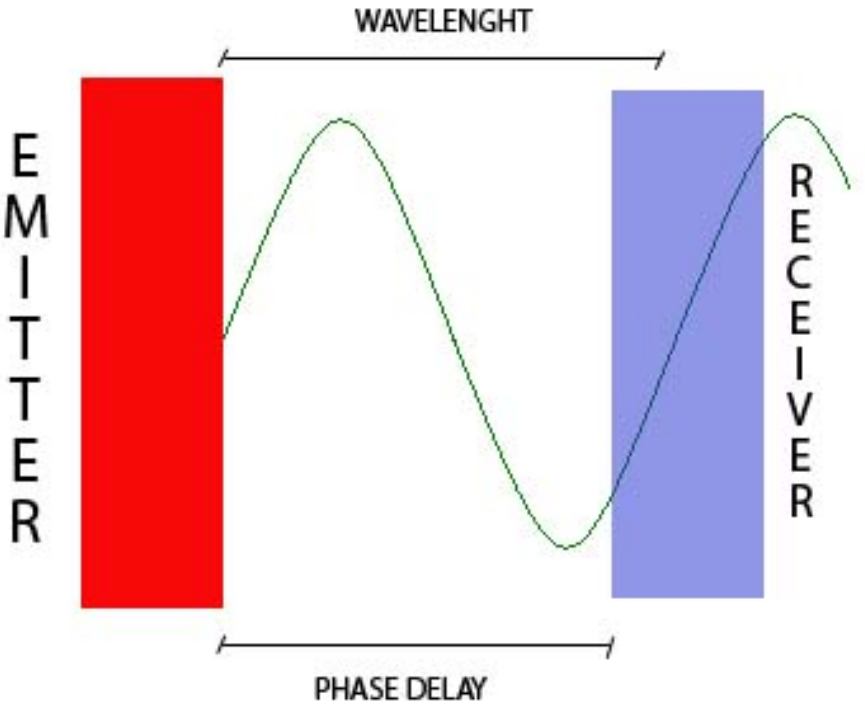
- SwissRanger SR-3000
- Phase measuring Time of Flight principle.
  - Led array illuminates the scene.
  - Known wavelength amplitude.
  - Phase delay used to measure traveled distance.



ToF 3D camera

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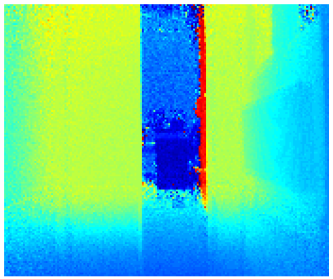

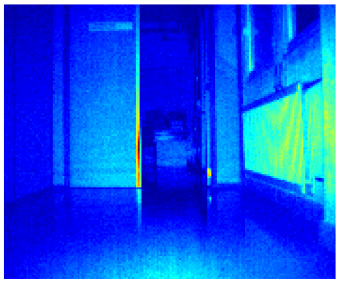

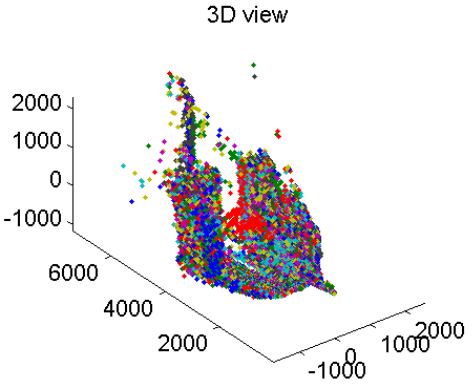

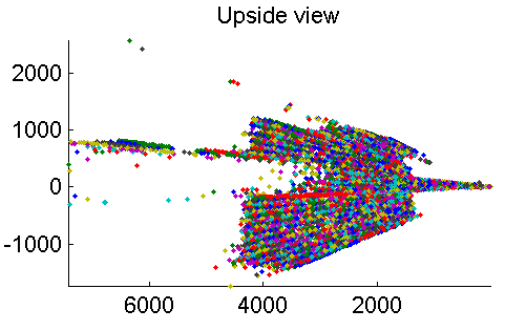

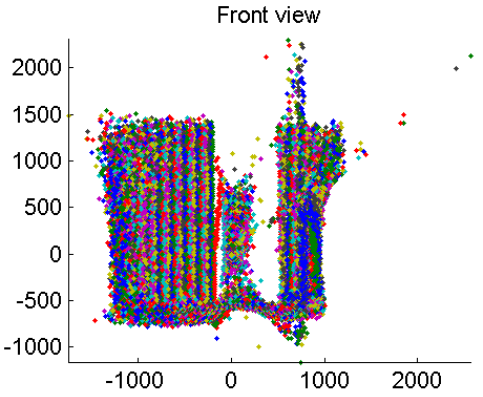

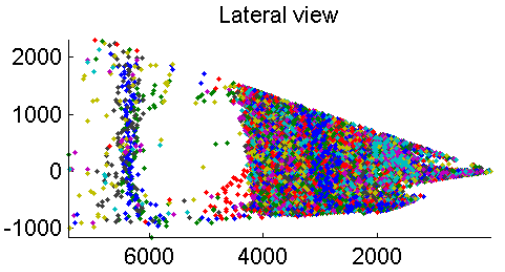

Data Preprocessing

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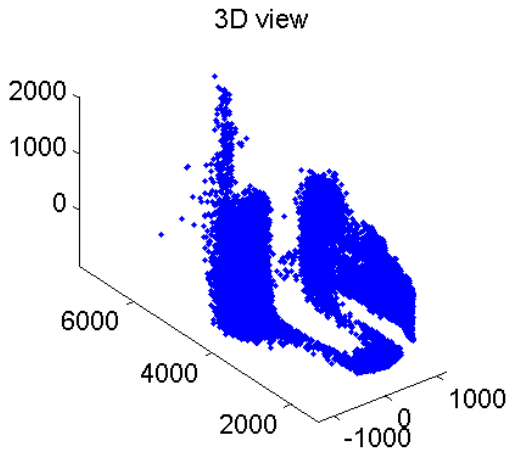
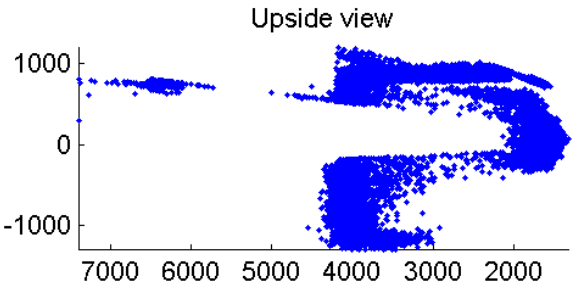
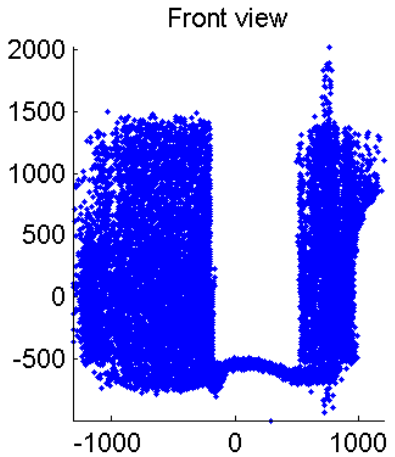
- Pros:
  - Full 3D scene information.
  - On-line operation.
  - On-board operation.
- Cons:
  - Big data size.
  - Ambiguity range.
  - Specular reflections.
  - Measurement uncertainty.

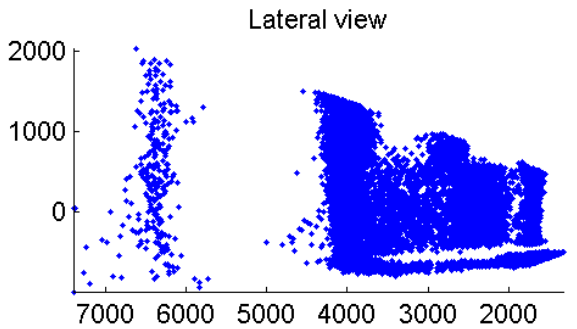
Data Preprocessing

- Filtering: Confidence value $C_i = I_i \times D_i$









Hybrid Intelligent System
Self Organizing Map

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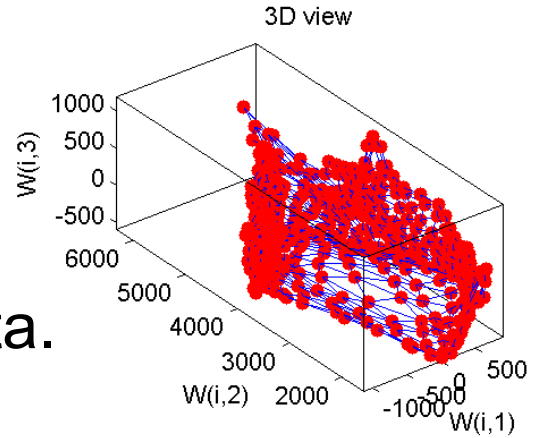
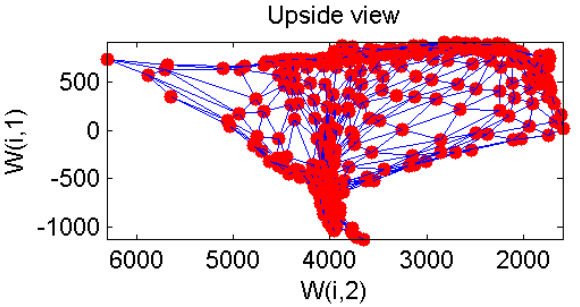
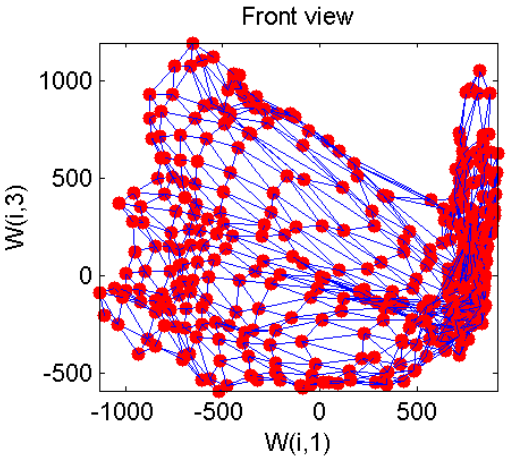
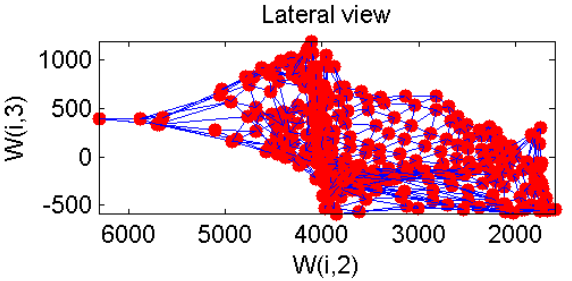
- First step: Self Organizing Map used to fit the data.
  - Grid *G*.
  - Keeps the spatial shape of the 3D data.
  - Reduces data amount to a fixed, small size.









Hybrid Intelligent System
Ego-motion Estimation

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- Robot at time *t*:
  - Position: $P_t = (x_t, y_t, \theta_t)$
  - Observed Grid: G_t
- Time *t+1*:
  - G_{t+1} obtained from the camera.
  - P_{t+1}?

Hybrid Intelligent System
Ego-motion Estimation

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- P_t and P_{t+1} are close.
- Same environment, but from different PoV.
  - Most objects visible from P_t should be also visible from P_{t+1}.
  - G_{t+1} should be similar to G_t, after a slight transformation.
  - Transformation gives the spatial relation between P_t and P_{t+1}.
- Objective: calculate the transformation T between G_t and G_{t+1}.

Hybrid Intelligent System
Evolution Strategy

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- An ES is used to search for the transformation T.
- Individuals h_i are hypothesis of position $P_{t+1,}$ and their traits the parameters of the transformation T_i between P_t and hypothesized P_{t+1}.

$$h_i = (x_i, y_i, \theta_i) \qquad T_i = \begin{bmatrix} \cos(\theta_i - \theta_t) & -\sin(\theta_i - \theta_t) & x_i - x_t \\ \sin(\theta_i - \theta_t) & \cos(\theta_i - \theta_t) & y_i - y_t \\ 0 & 0 & 1 \end{bmatrix}$$

Hybrid Intelligent System
Evolution Strategy

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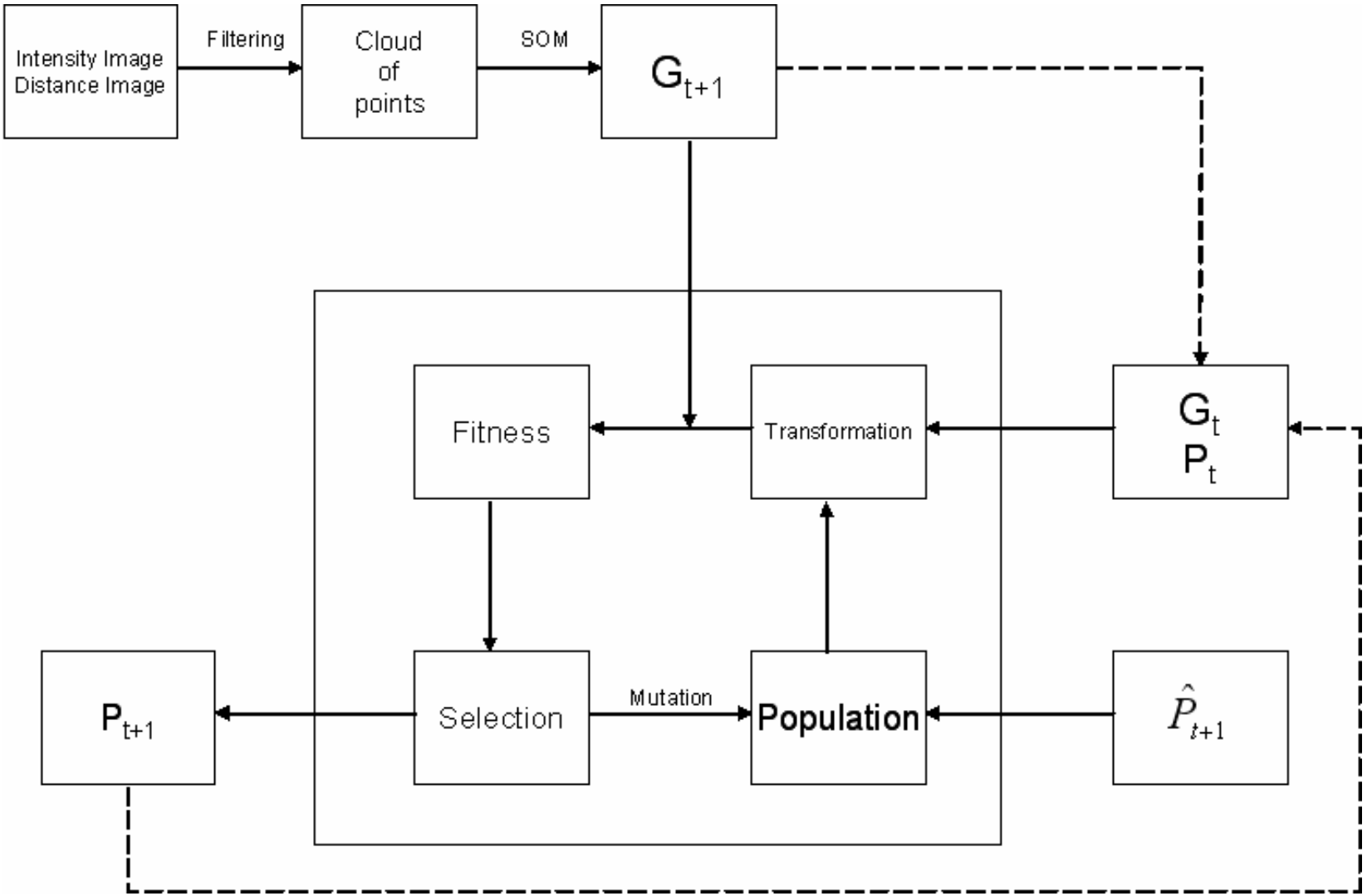
- For each hypothesis h_i we have a prediction of the observed grid:

$$(\hat{G}_{t+1})_i = T_i \times G_t$$

- Fitness function as a matching distance between grids:

$$e(h_i) = \left\| (\hat{G}_{t+1})_i - G_{t+1} \right\|^2$$

Hybrid Intelligent System
Algorithm Flow Diagram



Experimental Settings

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- Pre-recorded walks.
  - Odometry and optical views as reference.
  - Very noisy 3D images due non-optimal configuration.
- Experiment result: Sequence of consecutive robot positions.
- 20x20 SOM Grid.
  - SOM Toolbox with default parameters.

Experimental Settings

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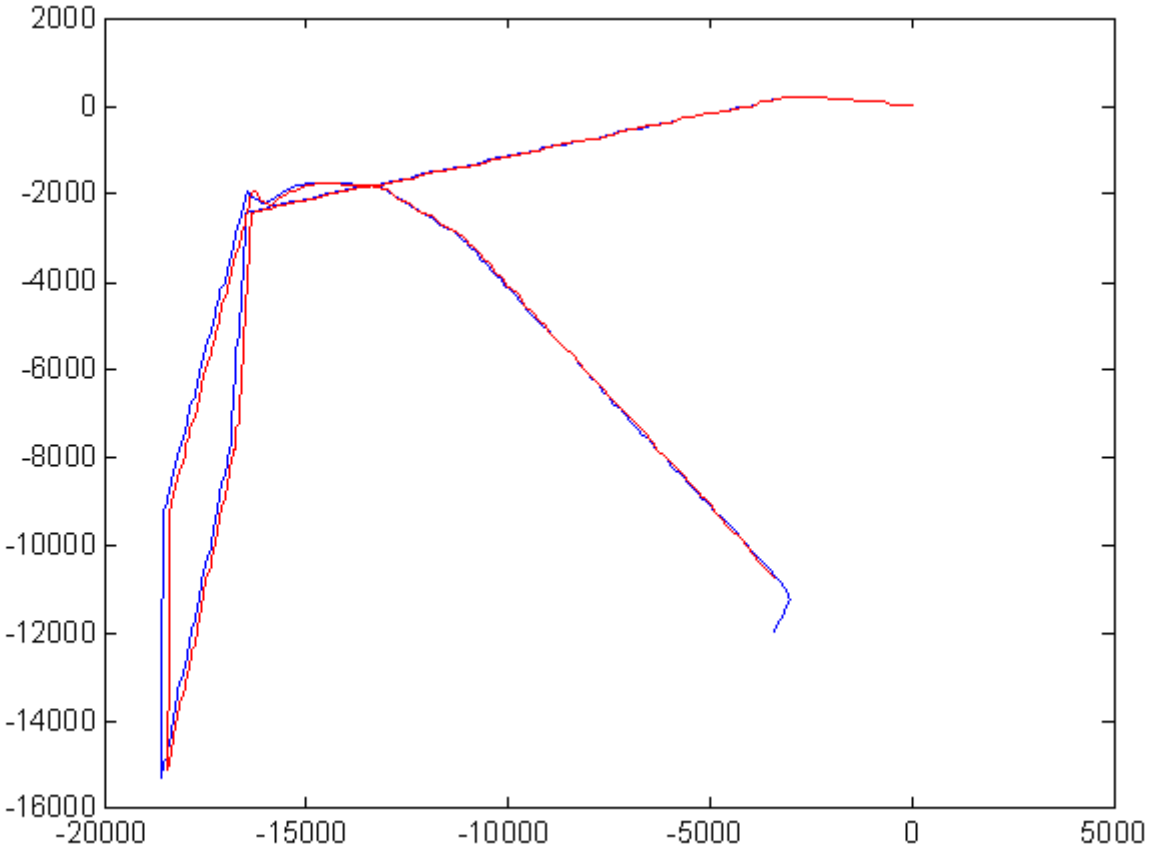
- Evolution strategy implementation:
  - Population of 20 individuals.
  - New generation:
    - The 1/3 best fitted directly.
    - Remaining 2/3 by adding Gaussian perturbations to best fitted.
  - Fitness function: node to node euclidean distance between G_{t+1} and $(\hat{G}_{t+1})_i$
  - Stop condition: no improvement in the new generation.

Experimental Results



Conclusions

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- Mobile robot ego-motion estimation algorithm.
  - 3D camera measurements.
  - Hybrid intelligent system.
    - SOM
    - ES
- Current work improving results.
  - Cloud of points fitted with a Neural Gas.
  - More efficient genetic algorithm.
- Future work:
  - Integration in a Kalman or particle filter SLAM architecture.
  - 3D environment reconstruction.

Questions, by Oberazzi
http://www.flickr.com/photos/oberazzi/318947873/