Robotic Mapping: an architectural approach

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The problem

Building an environment map by means of a mobile entity based on low-cost sensors

Low-cost sensors have limited accuracy, precision and efficiency
Our idea

• Use of multiple, heterogeneous sensors

• «smart» management of sensor activations in a context-aware approach
Our approach

• Our idea has been reified in a modular architecture which carefully separates the activities of:

  - Sensing
  - Integration
  - Planning
  - Control
Our prototype

- Directionable Laser Range Finder
- RGB Camera
Sensor Component

It contextualizes data produced by the associated physical sensor as an occupancy map.

\[
\text{SOM: Sensor Occupancy Map}
\]

\[
\text{cell}[^i][^j] = P(H|s_n)
\]
Sensor Component

Data Acquisition

Raw Data

Map Update

SOM

ActivityInitial

ActivityFinal

Laser orientation

Entity frame of reference

World frame of reference
Sensor Component

ActivityInitial → Data Acquisition

Raw Data → Map Update

Map Update → SOM

ActivityFinal

Edge

Camera FOV

Entity frame of reference

World frame of reference
World Map Builder

It integrates and fuses environment representations from different sensors producing a single environment map.

**WOM** (World Occupancy Map) generated by fusing several **SOMs**
Application Strategy

It implements the application strategy for the map construction

**WRM** (World Relevance Map)
**SAP** (Sensor Activity Planner)

It manages the activation of the associated sensor by evaluating a trade-off between activation costs and benefits.

**SCM** (Sensor Cost Map)

- It spatially contextualizes the computational cost (either static or dynamic) of activations of the associated sensor.
SAP (Sensor Activity Planner)

SAM (Sensor Attractiveness Map)
- It defines the areas that must be analyzed by the associated sensor

Attractive cell
SAP (Sensor Activity Planner)
Complete architecture
A concrete example

Start-up situation

WOM

WRM

Laser SOM

Camera SOM
A concrete example

Activation of both sensors and update of the corresponding SOMs
A concrete example

Update of the world model and relevance map
A concrete example

Activation of the laser sensor

WOM

WRM

Laser SOM

Camera SOM
A concrete example

Update of the world model and choice of a new strategy
Conclusions and comments

• The proposed architecture is:
  – Scalable
  – Modular
  – Open
  – Independent of application strategies

• Future developments:
  – Extensive experimentations
  – Integration with additional sensor typologies
  – Application to real-life cases
Questions & Answers

• Q1 : what are the problems of software development in robotics that can be considered "solved"?

Allowing for the application of low-cost/low-performance sensors to the problem of robotic mapping. In fact, such a problem is known to involve large amounts of data to be elaborated and fused.

• Q2 : what are the solutions to these problems that can be considered best practice and why?

Separation of concerns, which allows to dominate the problem’s complexity by decomposing the system in sub-components.

• Q3 : to what extent the solutions to these problems are robotic-specific?

The approach is general and should be used every time a system is made of multiple activities. The specific approach is aimed at solving a robotic-specific issue.
Questions & Answers

• **Q4 : what problems of software development in robotics remain to be solved?**

  The definition of a sensible strategy for every decisional component.

• **Q5 : why state-of-the art software technology is not adequate to solve these problems?**

  To the knowledge of the authors, no solutions to the robotic mapping problem exist which exploit both an architectural approach and the use of low-cost sensors.

• **Q6 : what are the promising research directions to solve the open problems?**

  Performing thorough experimentationations to test the validity of the approach and devise correct strategies for the decisional components.