Dora The Explorer: A Mobile Robot Motivated By Curiosity

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Overview

Dora the Explorer is a mobile robot with a sense of curiosity and a drive to explore its world. Given an incomplete tour of an indoor environment, Dora is driven by internal motivations to probe the gaps in her spatial knowledge. She actively explores regions of space which she hasn't previously visited but which she expects will lead her to further unexplored space. She will also attempt to determine the categories of rooms through active visual search for functionally important objects, and through ontology-driven inference on the results of this search.

Motivation-driven Memory Architecture

Dora's knowledge gathering is performed by following plans generated at run-time. Embedding planning into a heterogeneous robot system which itself is embodied in a dynamic, unpredictable world, requires a supporting architecture. The whole system is divided into function-based subarchitectures, each of which contain processing components sharing information via a working memory (WM). In this concept, knowledge gaps in representations found in the working memory give rise to goals to fill these gaps: Dora is motivated to extend her knowledge. However, in a system exploring larger amounts of space there are numerous goals to consider for taking actions on. Dora features a three-stage motivation model in which (i) goals are generated from gaps in knowledge; (ii) they may pass (become *surfaced*) an attention filter that decides whether or not the goal is of general interest to the system right now; and (iii) a set of *active* goals is actually scheduled as a conjunctive goal to be planned for. The decision which goals to pursue next is driven by weighing predicted information gain and assumed costs to achieve this goal.

[Nick Hawes, Hendrik Zender, Kristoffer Sjöö, Michael Brenner, Geert-Jan M. Kruijff and Patric Jensfelt. "Planning as an Architectural Control Mechanism". Workshop on *Hybrid Control of Autonomous Systems (HYCAS)*, IJCAI, 2009.]

CogX Project

Cognitive Systems that Self-Understand and Self-Extend

The high level aim of the CogX project is to develop a unified theory of self-understanding and self-extension with a convincing instantiation and implementation of this theory in a robot. By self-understanding we mean that the robot has representations of gaps in its knowledge or uncertainty in its beliefs. By self-extension we mean the ability of the robot to extend its own abilities or knowledge by planning learning activities and carrying them out.
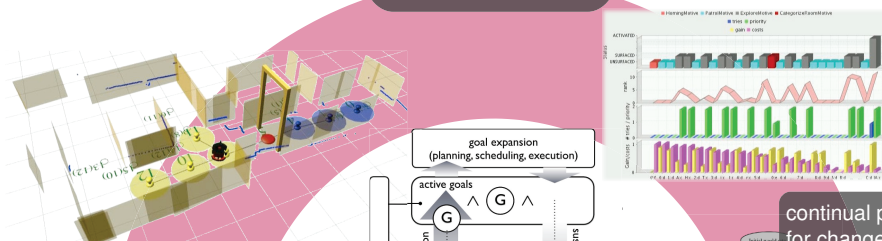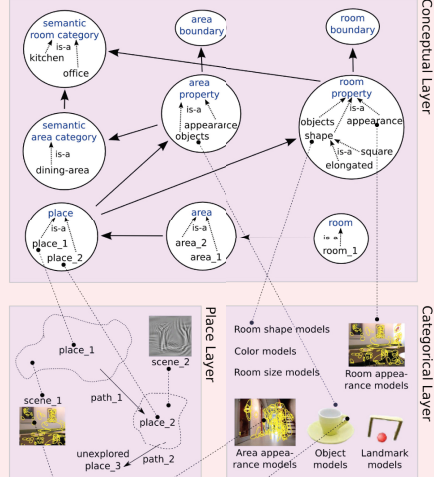
`http://cogx.eu`

Spatial Representation

Dora's spatial representation must facilitate navigation, reasoning, and communication (between robot and humans as well as between components in the system). Therefore, it goes beyond purely metric or sensorial information but features a hierarchy of abstraction layers. On the conceptual layer relations between places, objects, properties, and landmarks are established facilitating spatial inference.
In Dora a representation is inherently incomplete with *gaps* being explicitly represented in order to support the autonomous self-extension of its knowledge.

[A. Pronobis, K. Sjöö, A. Aydemir, A. N. Bishop, and P. Jensfelt, "A framework for robust cognitive spatial mapping", *International Conference on Advanced Robotics*]

Continual Planning

Symbolic planning in Dora serves two major needs of the system: (i) to plan for actions that actually accomplish the goals scheduled by the motivation management, and (ii) to continuously adapt plans to changes in the real world. A *temporal fast-downward* planning algorithm is employed to achieve efficient plans and timely plan delivery.
Assertions in the continual planning approach allow the system to plan with gaps in the knowledge and to extend these gaps by selecting appropriate actions.

[Brenner & Nebel, *JAAMAS*, 2009]

Object-based Categorization

Exploiting a symbolic representation of spatial units and their connectivity (e.g., rooms that contain places and objects) allows symbolic reasoning to maintain (create, merge, split, remove) room symbols and to infer room categories on the basis of objects found. The active visual search for objects using a pan-tilt-camera mounted on the robot is implemented as a generalized art gallery problem. Dora tries to efficiently scan a room for objects by analysing her multimodal spatial representation to generate probabilistic view plans. The exploration of places she has not been at before and the search for objects are actions to self-extend her representation.

Objects and related place categories are based on the Open Mind Indoor Common Sense database (by Honda Research Institute USA Inc. http://openmind.hri-us.com)

the goal management architecture generates and schedules goals, passing activated goals on to symbolic planning

the spatial representation comprises *gaps* in knowledge

continual planning accounts for changes during execution

Dora explores new places and categorizes new rooms based on the objects found in them

Dora is being given an incomplete tour by a human

Cereals?! This must be a kitchen!