Topological Gaussian ARTs with Short-Term and Long-Term Memory for Map Building and Fuzzy Motion Planning

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ABSTRACT

This paper proposes a cognitive architecture for building a topological map incrementally inspired by beta oscillations during place cell learning in hippocampus. The proposed architecture consists of two layer: the short-term memory layer and the long-term memory layer. The short-term memory layer emulates the entorhinal and the ρ is the orientation system; the long-term memory layer emulates the hippocampus. Nodes in the topological map represent place cells (robot location), links connect nodes and store robot action (i.e. adjacent angle between connected nodes). The proposed method is formed by multiple Gaussian Adaptive Resonance Theory to receive data from various sensors for the map building. It consists of input layer and memory layer. The input layer obtains sensor data and incrementally categorizes the acquired information as topological nodes temporarily (short-term memory). In the long-term memory layer, the categorized information will be associated with robot actions to form the topological map (long-term memory). The advantages of the proposed method are: 1) it is a cognitive model that does not require human defined information and advanced knowledge to implement in a natural environment; 2) it can generate the map by processing various sensors data simultaneously in continuous space that is important for real world implementation; and 3) it is an incremental and unsupervised learning approach. Thus, the authors combine their Topological Gaussian ARTs method (TGARTs) with fuzzy motion planning to constitute a basis for mobile robot navigation in environment with slightly changes. Finally, the proposed approach was verified with several simulations using standardized benchmark datasets and real robot implementation.

KEYWORDS
Cognitive Robotics, Gaussian ART, Navigation, Path Planning, Topological Map

1. INTRODUCTION

Social robot is an autonomous robot that interacts and responds with humans or other autonomous physical agents by taking orders from social activities and rules assigned to its responsibility. Social robots provide services to human mainly at home or real social spaces such as shopping malls and convention halls. These services for instance, taking things for elderly person who has difficulty to move around, guiding visitors who seems to be lost, or giving shop recommendations to customers who appear to be interested. The capability of simultaneously determining a robot location and
mapping its environment is a fundamental requirement to develop fully autonomous social robots (Montemerlo et al., 2002).

Previous work in the field of intelligent robotics has proposed multi-strategy learning that integrates multiple inference types and/or computational mechanisms into one learning system (Tecuci, 1994). Examples include the integration of symbolic and numerical learning, hybrid computation of discrete and continuous space, integration of stochastic and deterministic heuristic search, path planning and behavioral learning (Bianco & Cassinis, 1996), and reinforcement learning based on value and policy iteration.

In robotic mapping, representations of the world are divided into 3 groups which is metric maps, topological maps and hybrid models (Tomatis et al., 2003). For the metric mapping, the environment is represented as a set of objects with coordinates in a 2D space. The map generation is based on a grid occupancy or feature map approach (Leivas et al., 2010). The grid occupancy method is mapping the environment to a set of cells. Based on a combination of sensor scans, each cell is given a probability that determines whether the cell is occupied or not. However, this approach suffers from high computational cost of feature calculation. The features map approach consists of constructing maps that contain information about basic geometric shapes or objects, such as lines and walls (Chatila & Laumond, 1985). In addition, metric map methods are vulnerable to inaccuracies in both map-making and the dead reckoning abilities of the robot. Therefore, in large environments the problem of drift in odometry makes it difficult to maintain the global consistency of the map.

On the other hand, topological paradigm map the environment into a set of definite places (Kuipers & Byun, 1991) and store information of robot traverse from one area to another. Nodes (places) are defined by sensory information gathered from the environment. Next, the robot’s traverse information for the connected nodes are stored in links. Thus, it is a set of connected nodes for representing the environment that only consists of certain crucial areas that will be used for navigation.

However, one of the drawback of topological approach is the lack of rigid correlation representation. For example, Kuipers & Byun (1991) represents nodes as places defined by sensor data and edges as links between places defined by control actions. Besides, Thrun (1998) defined the map by dividing a probabilistic occupancy grid to areas separated by thin passages corresponding to a local clearance measurement. Since difference definition lead to different topological architectures, it is difficult for a robot or a human operator to generate a topological map during navigating a big-scale environment. Another drawback of the topological map is the online detection and recognition of topological nodes. Several types of artificial landmarks (such as ultrasonic sensors, visual patterns or reflective devices) are introduced to overcome the problem, however there are no artificial landmarks in real environment.

Another group of researchers have targeted on emulating the animals’ biological systems of mapping and navigation (Milford & Wyeth, 2010). The hippocampus of rats is one of the most researched brain regions of any mammal. Previous work with rats identified place cells in their hippocampus that appeared to respond to the animal’s spatial location (O’Keefe & Dostrovsky, 1971). Place cells in the CA1 area of the hippocampus fire whenever the animal is in a specific part of the environment. Different place cells are activated in different places in the environment, and together provide an ensemble code for spatial self-localization. Besides, researchers discovered that beta oscillations happen during the hippocampal place cell learning in new environments (Berke et al., 2008). Beta oscillations describe the place cells learning as spatially selective groups from the response between the entorhinal cortex and the hippocampus. The objective of the Psikharpax project is to develop an artificial robotic rat contains mapping and navigation algorithms that emulate place cells (Meyer et al., 2005). Other approaches focus on grid cells (Giovannangeli & Gaussier, 2008) to enable navigation and mapping on a robot in a larger place. Weitzenfeld and Barrera (2008) have developed a system that is capable of learning and forgetting specified locations and can travel from one place to another on their map.
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