

A Semantic Map for Indoor Robot Navigation Based on Predicate Logic

Hengsheng Wang, Central South University College of Mechanical Electrical Engineering, Changsha, China

Jin Ren, Central South University College of Mechanical Electrical Engineering, Changsha, China

ABSTRACT

Interacting with mobile robots through natural language is the main concern of this article, which focuses on the semantic meaning of concepts used in natural language instructions to navigate robots indoors. Assuming the building structure is the prior knowledge of the robot and the robot has the ability of navigating itself locally to avoid collision with the environment, the building structure is represented with predicate logic on SWI-Prolog as the database of the indoor environment, which is called semantic map in this paper, in which the basic predicate clauses are based on two kinds of entities, namely 'area' and 'node.' The area names (in natural language convention) of indoor environment are organized with an ontology and are defined in the semantic map which includes the geometric information of areas and connection relationships between areas. With the semantic map database, functions for robot navigation, like a topological map, path planning, and self-localization, are realized through reasoning by properly designed predicates based on constraint satisfaction problem (CSP). An example building is given to show the idea proposed in this article, the real data of which was used to establish the semantic map, and the predicates for navigation functions worked well on SWI-Prolog.

KEYWORDS

Human Robot Interaction, Logic Programming, Robot Navigation, Semantic Map, SWI-Prolog

1. INTRODUCTION

Interacting with mobile robots has been one of the main concerns in the community of robotics research. The most natural way for the interaction might be with natural languages, just like humans do in everyday life. (Wang, Ren, & Li, 2016) proposed a scenario of directing remote mobile robots with Chinese natural spoken language. The intention was to get robots properly trained other than to train human operators for the purpose of communication and interaction in between, which should be more practical in emergent rescue situations where robots are deployed and domain experts, other than skilled operators, give instructions to robots for emergent operations. It is also the similar case for elder-care robots, or other home service robots, where the demand for interaction skill with robots should not become a barrier to the user. To remotely navigate a mobile robot inside of a building, the navigation instructions in Chinese natural spoken language were handled with the three-layer-CRF model, and the navigation elements, including Action, Start Place, End Place, Direction, Speed and Distance, in the instruction were extracted.

The centre of this paper is semantic map, in which the semantic meanings of navigation elements are investigated, especially the place names, in the instruction. By systematically defining the place names inside the building where the robot is navigated, and representing the corresponding facts

DOI: 10.4018/IJKSS.2020010101

and rules with the expressions based on predicate logic, the robot will have a conceptual system in accord with humans semantically. In this way, the robot will understand the place names with the meanings that the instruction really means in some sense, which makes it available to build an effective human-robot interface. Many navigation instructions, like ‘go to room 601’, ‘turn left at the intersection ahead’, ‘stop in front of the elevator ahead’, etc., have place names included which have coordinates that can be directly obtained from the map (like ‘room 601’), or indirectly inferred from the current position and the map (like ‘the intersection ahead’).

Basically, the place names in the instructions are considered as the prior knowledge about the building where the robot is located. This knowledge is like the map to humans who want to go around finding a place inside the building. Robots should know this knowledge in advance to navigate around according to the instructions, instead of randomly search for the goal. In this paper, the knowledge is represented with predicate clauses which function as a database of the map for robots to search a target place or to infer a shortest path to the target. Specially, the elements of semantic map are organized based on ontology (Van Harmelen, Lifschitz, & Porter, 2008; Lim, Suh, & Suh, 2010; Catania, Zanni-Merk, de Beuvron, & Collet, 2016) and expressed with the predicate clauses with SWI-Prolog format (O’Keefe, 1990; Wielemaker, Schrijvers, Triska, & Lager, 2012; Bramer, 2013).

With the semantic map as the database of building structure in the form of predicate clause, rooms, neighbourhood relations among rooms, corridors, staircases, etc. can be defined upon which logic operations are based for robot localization and path planning sort of navigation functions. Note that the intelligence here involves two levels, the logic inference in higher and the reflective inference in lower. Of the two levels, the higher one of artificial intelligence is the focus of this paper, which assumes the robot could autonomously move around locally.

The main contributions of this paper are as follows: (i) unlike the SLAM-related methods (Simultaneous Localization and Mapping), the semantic map in this paper is represented and built in a top-down manner rather than a bottom-up way, which is more suitable for the high-level intelligent function of practical applications; (ii) in the semantic map, the building structure is organized with ontology and represented with predicate logic as the database of the indoor environment, including the geometric information of areas and connection relationships between areas, where the basic predicate clauses are based on two kinds of entities including ‘area’ and ‘node’; (iii) with the semantic map database, functions for robot navigation, such as topological map, path planning and self-localization, are realized through reasoning by properly designed predicates based on Constraint Satisfaction Problem.

The rest of this paper is as follows. After discussing the related work in Section 2, Section 3 introduces a school building taken as an example for the establishment of semantic map. The database of semantic map is used in the next Section 4 to build functional predicates in the context of natural language navigation. The following Section 5 focuses on a logic programming solution to the problem of judging the position of a point relative to a polygon which is frequently faced with in robots’ localization. Section 6 concludes the work.

2. RELATED WORK

As a natural bridge between human and robot, semantic map was mainly based on a labelled graph from robotic visual perception and processing, and eventually built in a bottom-up way, where sensor data was usually captured by various devices, such as a 3D laser scanner (Nüchter & Hertzberg, 2008; Blodow et al. 2011), a wearable omnidirectional camera (Rituerto, Murillo, & Guerrero, 2014) and an RGB-D camera (Stückler et al. 2015; Ruiz-Sarmiento, Galindo & Gonzalez-Jimenez, 2015). (Kostavelis, Charalampous, Gasteratos, & Tsotsos, 2016) proposed a spatial-temporal coherent integrated framework, which formed the semantic map in a bottom-up fashion, and passed high-level orders to the local navigation data of robots recursively in a top-down manner. (Zhao, Mei & Pan, 2015) presented a visual-voice interactive approach to the construction of a grid-semantic map for the

19 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage: www.igi-global.com/article/a-semantic-map-for-indoor-robot-navigation-based-on-predicate-logic/247975

Related Content

In Conclusion

Lars Taxén (2010). *Using Activity Domain Theory for Managing Complex Systems* (pp. 304-309).

www.irma-international.org/chapter/conclusion/39683

An OMA DM Based Framework for Updating Modulation Module for Mobile Devices

Hui Zhang, Xinheng Wang and Muddesar Iqbal (2011). *International Journal of Adaptive, Resilient and Autonomic Systems* (pp. 13-23).

www.irma-international.org/article/oma-based-framework-updating-modulation/55451

Distributed Query Plan Generation using Bacterial Foraging Optimization

Jay Prakash, Neha Singh and T.V. Vijay Kumar (2017). *International Journal of Knowledge and Systems Science* (pp. 1-26).

www.irma-international.org/article/distributed-query-plan-generation-using-bacterial-foraging-optimization/169899

A New Method for Ranking Intuitionistic Fuzzy Numbers

Cui-Ping Wei and Xijin Tang (2011). *International Journal of Knowledge and Systems Science* (pp. 43-49).

www.irma-international.org/article/new-method-ranking-intuitionistic-fuzzy/53044

Optimization of WS-BPEL Workflows through Business Process Re-Engineering Patterns

Jonas Buys, Vincenzo De Florio and Chris Blondia (2012). *Technological Innovations in Adaptive and Dependable Systems: Advancing Models and Concepts* (pp. 345-361).

www.irma-international.org/chapter/optimization-bpel-workflows-through-business/63590