# Solving Navigation Tasks with Learned Teleo-Reactive Programs

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## I. INTRODUCTION

Programming a robot to perform tasks in dynamic environments is a complex process. Teleo-Reactive Programs (TRPs) [1] have proved to be an effective framework to continuously perform a set of actions to achieve particular goals and react in the presence of unexpected events, however, their definition is a difficult and time-consuming process. In this paper, it is shown how a robot can learn TRPs from human guided traces. A user guides a robot to perform a task and the robot learns how to perform such task in similar dynamic environments. Our approach follows three steps:

- **Transforms traces** with low-level sensor information into high-level traces based on natural landmarks. A natural landmark identification process [3] is applied to produce a smaller set of more meaningful information consisting of discontinuities, corners and walls (see Fig. 2(a)).
- **Learns basic TRPs**. High-level traces and background knowledge are given to the ILP system ALEPH [4]. The output is a set of TRPs that express when to perform an action to achieve simple tasks, e.g., *avoid* (see Fig. 2(c)). Learned concepts (e.g. *front-zone, orientation-zone*) are used as background knowledge.
- **Learns hierarchical TRPs**. We introduce FOSeq, an algorithm to learn TRPs that is able to produce particular sequences of actions satisfying a specific goal e.g., goto (see Fig 2 (c)).

The learned TRPs were used to solve navigation tasks in different unknown and dynamic environments, both in simulation and in a service robot called Markovito. Figure 1 shows the process for learning basic and complex TRPs.

## II. FOSEQ: LEARNING COMPLEX TRPs

The user controls the robot to achieve a particular goal, e.g., go to a specific area. The low-level information from the sensors is transformed into a high-level trace of state-action
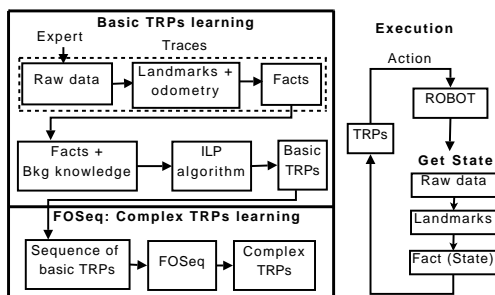


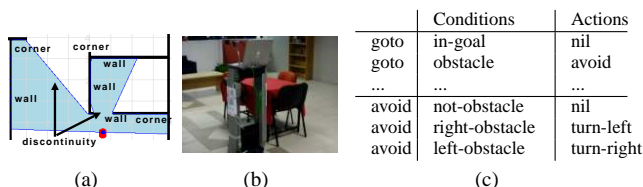| | Conditions | Actions |
|---|---|---|
| goto | in-goal | nil |
| goto | obstacle | avoid |
| ... | ... | ... |
| avoid | not-obstacle | nil |
| avoid | right-obstacle | turn-left |
| avoid | left-obstacle | turn-right |

(a)     (b)     (c)

Fig. 2. (a) The landmark identification process recognizes walls, corners and discontinuities (b) Markovito visiting several places using a learned TRP (c) Some conditions and actions for the goto and avoid TRPs

pairs from which applicable TRPs, previously learned, are identified and replaced in the sequence. FOSeq is then used to learn how to produce similar sequences. Given a set of sequences of TRPs, FOSeq:

- Learns a grammar for each sequence. FOSeq identifies repeated elements in the sequence to construct a grammar.
- Evaluates the sequences with each learned grammar. The evaluation is based on the percentage of the sequence that can be generated by the grammar.
- Selects the best evaluated grammar and a list of candidates to be generalized. The candidates are those that are likely to improve the evaluation of the best grammar.
- Applies a generalization process to the selected grammars. It uses adaptation rules to modify/add a new rule.
- Transforms the grammar into a logic program.

## III. EXPERIMENTS

The learning process was performed using simulation in the Player/Stage robot platform [2]. The TRPs were tested in simulation and as the navigation module of a PeopleBot ActivMedia robot called Markovito. To perform the navigation tasks it used a sonar ring and a Laser SICK LMS200. The tasks to accomplish were: (i) following a human under user commands, (ii) navigating to several places in the environment designated semantically (see Fig. 2(b)), (iii) finding one of a set of different objects in a house and (iv) delivering messages and/or objects between different people. The first three tasks are part of the RoboCup@Home challenge.

## REFERENCES

[1] S. Benson and N. J. Nilsson, Reacting, Planning, and Learning in an Autonomous Agent, *in Machine Intelligence*, vol. 14, 1995, pp. 29-62.
[2] R. Vaughan and B. Gerkey and A. Howard, On device abstractions for portable, reusable robot code, *Proceedings of the IEEE/RSJ Intl. Conf. on Intelligent Robots and Systems (IROS) http://playerstage.sourceforge.net*, Las Vegas, Nevada, 2003.
[3] S. Hernández and E. Morales, Global localization of mobile robots for indoor environments using natural landmarks, *IEEE International Conference on Robotics, Automation and Mechatronics (RAM)*, 2006.
[4] A. Srinivasan, *The Aleph 5 Manual*, 2005.



Fig. 1. An overview of how to learn basic and complex TRPs