Cogn Process (2009) 10 (Suppl 2):S208–S211
DOI 10.1007/s10339-009-0290-y

EXTENDED ABSTRACT

Spatial language for route-based humanoid robot navigation

Mohammed Elmogy · Christopher Habel · Jianwei Zhang

© Marta Olivetti Belardinelli and Springer-Verlag 2009

Introduction

A more natural interaction between humans and mobile robots can be achieved if they have a common ground (Kiesler 2005). Natural language interfaces support successful styles of interaction between robots and users. Typical scenarios include the user who instructs a robot to perform actions in an environment, such as moving to locations or manipulating objects. Thus, route descriptions, which are used to guide robots in executing navigation tasks in their surrounding environment, are important for realizing effective human–robot interaction. To provide the route in an effective way, the rules and sequences of commands should be expressed in a very concise way. Natural language uses symbols and syntactic rules to interact with the robots, which possess knowledge representations at the symbolic level. On the other hand, spatial reasoning concerning verbal route descriptions is essential for humans as well as for mobile robots which navigate in unstructured environments. Such reasoning gives robots the ability to comprehend human-like spatial language, which provides the human users with an intuitive interface that is consistent with their innate spatial cognition (Lauria et al. 2001). It can also provide an accelerated learning by using symbolic communication, which was proven by Cangelosi and Harnad 2001.

In the last decades, there has been considerable research on spatial language and spatial reasoning. This motivates the research interest in using spatial language for interacting with artificial navigational agents. Many researchers (e.g., Tschander et al. 2003; Skubic et al. 2004; Tellex and Roy 2006) have proposed frameworks which use natural language commands in simulated or real-world environments. The mobile robot research community has created systems that can understand natural language commands. Many research efforts (Torrance 1994; Simpson and Levine 1997; Bischoff and Jain 1999; Pires and Nunes 2002; Skubic et al. 2004; Schulz et al. 2006) focus on using spatial language to control the robot's position and behavior, or to enable it to answer questions about what it senses.

Route instruction language

We present a spatial language, called route instruction language (RIL), to describe the route between the start and the end points of a humanoid robot's navigation task. RIL is intended as a semi-formal language for instructing robots, to be used by non-expert users via a structured GUI. It provides elementary instruction statements which are converted to a sequence of motion actions. During navigation, this sequence of actions is processed by the footstep planner of the robot to determine the foot placements. Each statement in the RIL constitutes a spatial instruction which relates verbally coded motion concepts to one or more landmarks by use of a suitable spatial relationship. We used four types of basic actions in route instructions: *moving* from one place to another, *turning* or rotating in

M. Elmogy (✉) · C. Habel · J. Zhang
Department of Informatics, MIN Faculty,
University of Hamburg, Vogt-Kölln-Straße 30,
22527 Hamburg, Germany
e-mail: elmogy@informatik.uni-hamburg.de

C. Habel
e-mail: habel@informatik.uni-hamburg.de

J. Zhang
e-mail: zhang@informatik.uni-hamburg.de

place, *verifying* a *view* description, and *determining* the *current position*. In route description, we use an extrinsic reference frame that is based on the robot's viewing perspective to describe all objects and directions with respect to the robot's body.

Table 1 shows a list of RIL commands and their syntactic constraints, which are used in the route description. Commands are formalized to specify motion actions, destinations, directions and landmarks. The RIL instructions are divided into three categories: position, locomotion and change of orientation commands. The position commands are used to specify the current position of the robot during the navigation or to determine the start and end points of the route. The locomotion commands are used to instruct the robot to move in the environment in a specific direction or to follow a path. The last category of RIL concerns change-of-orientation commands which are used to rotate around a landmark or turn in a certain direction.

After describing the route by RIL, the command interpreter analyzes the route description supplied by the user and transforms it to action procedures for the robot. It combines definitions from the lexicon according to the parse structure of the command, creating a script that selects a goal for the humanoid robot. This script is based on the conceptual route instruction language (CRIL) developed by Tschander et al. 2003. The command interpreter consists of a simple parser, a lexical analysis, a syntactic analysis and a semantic analysis. The parser is fed by a text string of the user's route description provided by a keyboard. It separates the text into individual instructions. Each one is split into a sequence of words using space and punctuation characters as delimiters. This list is subjected to lexical analysis where each RIL-expression is looked up in a dictionary to obtain its type. Possible types are command motion concepts, directions, prepositions, and landmarks. The following syntactical analysis has to identify the structure of the sentence by comparing the list of types with a list of prototype command sentences that includes all instructions which are understandable by the robot.

To build the topological map, the resulting motion actions, spatial relations, and landmark features are grounded first to a symbolic representation. Many researchers (Harnad 1990; Chella et al. 2004) have worked on the symbol grounding problem to solve the problem of integrating symbolic and non-symbolic processes in an intelligent system. In our system, the symbolic representation is grounded to the resulting non-symbolic representation from the command interpreter stage. The motion actions and landmarks, which result from processed route description, are categorized to symbols. The resulting symbolic representation consists of symbol strings describing the route description and the relationships between different components. This representation is then used to build a topological map for the processed route description. This map is a graph-like description of the route where nodes correspond to significant, easy-to-distinguish landmarks, and arrows correspond to actions or action sequences that connect neighboring places. The topological map presents a qualitative description of the robot's workspace. It represents interesting places and not the entire environment. Figure 1 shows an example for a route description in a miniature city and its resulting topological map. Detailed information about the miniature city and topological map is given in Elmogy et al. 2008.

Experimental results

We carried out an experiment to test the usability of RIL for communicating a route description to a robot. Ten participants took part in the experiment (age 22–35 years). None of the participants had any background knowledge on route instructions and robotics. First, we gave them a description of the RIL syntax, a map of the miniature city, and an example of a suitable route description. We asked

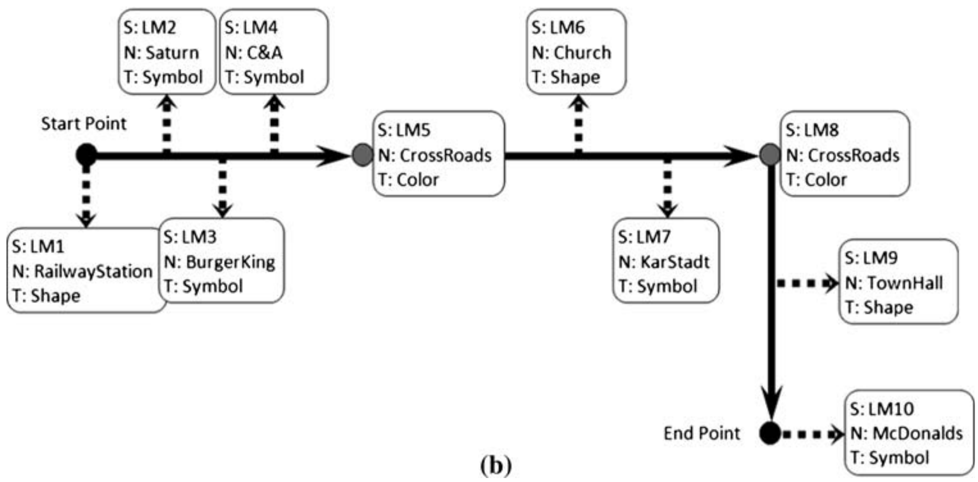
Table 1 The RIL command types and syntaxes

Command type	Command name	Syntax
Position	$START()	$START ([Pre1|Direction], Landmark1, [Pre2], [Landmark2])
	$STOP()	$STOP (Pre1|Direction, Landmark1, [Pre2], [Landmark2])
	$BE()	$BE (Pre1|Direction, Landmark1, [Pre2], [Landmark2])
Locomotion	$GO()	$GO([Count], [Direction]| [Pre1], [Landmark1], [Pre2], [Landmark2])
	$CROSS()	$CROSS ([Pre1], Landmark1, [Pre2], [Landmark2])
	$PASS()	$PASS ([Pre1], Landmark, direction, [Pre2], [Landmarket2])
	$FOLLOW()	$FOLLOW ([Landmark1], Pre, Landmark2)
Orientation Change	$ROTATE()	$ROTATE (Direction, Pre, Landmark)
	$TURN()	$TURN ([Count], [Pre1], Direction, [Pre2], [Landmark])

Fig. 1 **a** Route description using RIL from the railway station to the McDonalds restaurant in the miniature city. **b** The generated topological map of the route description

```
SSTART( RailwayStation, right)
SGO( forward, into, Street)
SPASS( Saturn, left)
SPASS( BurgerKing, right)
SPASS( C&A, left)
SBE( at, CrossRoads)
SGO( forward, into, Street)
SPASS( Church, left)
SPASS( Karstadt, right)
SBE( at, CrossRoads)
STURN( right)
SGO( forward, into, Street)
SPASS( TownHall, left)
SSTOP( McDonalds, left)
```

(a)



(b)

them to describe a route between the railway station and the McDonald's restaurant in the miniature city as depicted in Fig. 1b. Most of them described the route correctly and 80% of the participants stated that the RIL is simple and easy to learn. 70% of the participants agreed that it is better to provide the commands of RIL with many optional parameters than to restrict them with a single syntax.

Discussion

We presented RIL, a semi-formal language to be used by non-expert users to instruct humanoid robots. Based on RIL, we designed and realized an intuitive interface to mobile robots preventing misunderstanding and ambiguities in route descriptions. Starting from a set of commands, the command interpreter stage performs the analysis of route instructions and its lexicon relates the internal procedures to perceptual objects and specifies actions that can be carried out by the humanoid robot. Finally, processes of perceptual anchoring ground symbolic representations concerning the robot's motion actions and perceived landmarks. The resulting symbolic script is used as an initial path for the humanoid robot to plan its motion and footstep places. It is also used to generate a topological map for the route description to get a qualitative description of the robot's workspace.

References

Bischoff R, Jain T (1999) Natural communication and interaction with humanoid robots. The Second International Symposium on Humanoid Robots, Tokyo

Cangelosi A, Harnad S (2001) The adaptive advantage of symbolic theft over sensori-motor toil: grounding language in perceptual categories. Evol Commun 4:117–142

Chella A, Coradeschi S, Frixione M, Saffiotti A (2004) Perceptual anchoring via conceptual spaces. The AAAI-04 Workshop on Anchoring Symbols to Sensor Data

Elmogy M, Habel C, Zhang J (2008) Robot topological map generation from formal route instructions. Workshop proceedings of the 2008 European conference on artificial intelligence (ECAI), 6th international cognitive robotics workshop (CogRob08), Patras, Greece

Harnad S (1990) The symbol grounding problem. Phys D 42(1–3): 335–346

Kiesler S (2005) Fostering common ground in human–robot interaction. IEEE International Workshop on Robots and Human Interactive Communication (ROMAN)
Lauria S, Bugmann G, Kyriacou T, Bos J, Klein E (2001) Training personal robots using natural language instruction. IEEE Intell Syst 16:38–45
Pires G, Nunes U (2002) A wheelchair steered through voice commands and assisted by a reactive fuzzy-logic controller. J Intell Robot Syst 34(3):301–314
Schulz R, Stockwell P, Wakabayashi M, Wiles J (2006) Towards a spatial language for mobile robots. The 6th international conference on the evolution of language, pp 291–298
Simpson R, Levine S (1997) Adaptive shared control of a smart wheelchair operated by voice control. The 1997 IEEE/RSJ international conference on intelligent robots and systems
Skubic M, Perzanowski D, Blisard S, Schultz A, Adams W, Bugajska M, Brock D (2004) Spatial language for human–robot dialogs. In: Systems, man, and cybernetics, Part C: applications and reviews. IEEE Trans 34:154–167
Tellex S, Roy D (2006) Spatial routines for a simulated speech-controlled vehicle. The 1st ACM SIGCHI/SIGART conference on human–robot interaction (HRI ‘06), pp 156–163
Torrance MC (1994) Natural Communication with Mobile Robots. Master Thesis, MIT Department of Electrical Engineering and Computer Science
Tschander LB, Schmidtke H, Habel C, Eschenbach C, Kulik L (2003) A geometric agent following route instructions. In: Spatial cognition III. Springer, Berlin, pp 89–111