Spatial cognition in indoor vs. outdoor planning: An experimental approach

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Abstract

The concept of spacescape has been studied by many scholars over time (Golledge, 1998; Lloyd, 2009; Lynch, 1960). Both landscapes and townscapes are knowledge-intensive entities that humans adapt for their life. Because of their dynamic complexity, spatial behaviours are hard to be simulated in mainstream AI robotics. Therefore, a question arises about the basic features, or 'fundamentals', of spacescapes by agents who live in and move through them. In fact, from the one hand, common sense claims that well designed space architectures make space more meaningful for humans than amorphous spaces. Conversely, the drama of social marginality in cities also depends on the abundance of landmarks and symbols, often inappropriate and alienating to poor people.

Yet, a distinction emerges in literature and is worthwhile emphasizing in general. As a matter of facts, spacescape structural, 'fundamental' qualities may be opposed to spacescape 'ornamental' qualities in describing spaces (Goodman, 1951). This sort of ontological representation of space is essential for artificial intelligence and robotics, because of the inherent need of fine-tuning the characterization of space in planning automatic navigation. As there is circularity between AI and cognitive science, it is evident that developing robotic devices may in turn increase knowledge on human behaviours in space. Therefore, space imaging can be of great interest in strategic spatial planning, too, because it enhances the representation of

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the structural, invariant, resilient characters of the environment, for the development and management of human spaces.
The present paper looks at space ontology as made by human agents. In doing this, it follows the cognitive approach used by AI robotics, with integrations coming from the expert knowledge of the planning domain. After an introduction in the first chapter, the second chapter shows two experimentations carried out in the context of space perception, imaging and navigation and discusses some results achieved. Brief conclusions and research perspectives are reported in the final chapter.

Keywords

Spatial cognition, Spatial structures,planning support systems, Questionnaire.

Introduction

The space is conceived with different approaches in different domains (Golledge, 1998; Lloyd, 2009; Wooldridge and Veloso, 1999). On the side of planning studies, the space is addressed (i) as environment and tank of human actions (anthropization), or (ii) as a relevant, active entity per se (i.e., an agent, we could say), whose analysis and modelling reveals parts of human behaviour dependent on it (Fischer, 2000; Lynch, 1960). On the side of cognition studies, the space is largely dealt with not per se, but from the viewpoint of agents who use it to better adapt their spatial behaviours. An example in low-level actions could be the search for food in a space, whereas in higher-level actions an example could be the enjoying of a spatial beauty (Tversky and Hard, 2009). There are integrations of the two sides, in planning and spatial organization influenced by knowledge-based approaches (Mockler, 1989).
The research behind this work explores the modes of conceptualizing and representing space by human agents in

finding a way to reach a spatial objective. It aims at exploring low-level (movement orientation) and high-level (memories and fantasies) behaviours in human-environment interaction activities.

Basing on a questionnaire survey, some experiments have been carried out in the Technical University of Bari (Italy), looking at the initiatives (actions, behaviours) taken by students while walking in different indoor and outdoor environments. In terms of problem setting, the basic problem that experiments investigate is the general mechanism of spatial cognition-perception-decision, operating in a human agent who 'navigates' through a given indoor space-environment, for the execution of a specific task: i.e., finding out and reaching a physical place.

There is a specific problem to be investigated, here. It is the role played in helping the navigation by different components of the space-environment in which the navigation develops. In particular (Goodman, 1951), it is the role played by space 'fundamental' components (i.e., 'structures' or 'essences' such as the walls that limit the space), as well as 'ornamental' components (everything integrates the structure from other –different- functional viewpoints, e.g. furniture). It is also interesting to understand if there are some 'signs' supporting space navigation, acting as 'beacons' (i.e., a monument to which to direct the navigation) or 'landmarks' (e.g., series of partial targets along the way), in order to make up for a structure or geometry that are missing or incomprehensible (Gero and Tversky, 1999; Hirtle, 2003).

Yet, there are profound differences in the context to be investigated. The environment as an indoor space is rather simple to be navigated and does not require but simple attention from the human agent (e.g., navigating a hospital or a hotel). On the contrary, an outdoor space, without any clear form, origin, end, requires particular attention (e.g., a urban fair). A human agent moves randomly in open spaces, overwhelmed by the crowd, or being afraid of getting lost in such complex space-environment.

Also, different perspectives need to be taken into account in setting up and discussing our research. In terms of agent-based

approach, the navigating task may involve a basic individual agent's perspective, isolated while performing her task. Yet there are (even more frequent) social, multi-agent perspectives, ranging from the task by an agent assisted by adviser-agents to non-isolated agents immersed in an organization of spatial learning.
Different degrees of difficulty are linked to different contexts, but also multiform reasons of interweaved cognitive and imaging interest. The following chapters will give an account of the experiments developed with engineering students, mostly with a multi-agent approach, in two different environments. Both sessions have occurred in supposedly monodimensional spaces. The first one is a confined, indoor university corridor, whereas the second one is an outdoor walking corridor of a main urban street.
After the present introduction, the second chapter shows two experimentations carried out in the context of space perception, imaging and navigation and discusses some results achieved. Some final considerations and research perspectives are developed in the last chapter.

Space imaging in practice

Exploring an indoor space: A university corridor

The experiment focuses on a human agent-navigator looking for and scanning a corridor serving the professors' rooms in a department of the Technical University of Bari. A corridor is usually considered a well structured space-environment, i.e., simply shaped (e.g., not crossed along its way by other corridors) and where the agent can perform simple actions –such as asking an occasional agent-adviser for a room, or carrying out a trial-and-error approach to explore the space-environment and find her way. It was then supposed that a low degree of complexity would stimulate a more focused and contextual analysis and report by students, with little distractions from the given task.
A questionnaire was made available to students, asking them some questions under two slightly different contextual situations:

finding a desired professor's room, and finding a given professor's room.

The questionnaire layout is illustrated in fig. 1. It involved 260 students of the Urban planning course, aging about 20, and was delivered through the university didactical web portal. Related answers were delivered and collected by email.

QUESTIONNAIRE

Situation 'A': You are at DAU (Town Planning Dept) and decide to visit a professor in that department, crossing the space in between.

Question A1: Find out the professor you want to know and declare the reasons for your visit.

Question A2: Describe the actions you carry out to reach the professor of your interest

Question A3: Describe in detail the "substantial elements" of the space in which you move, being of help or obstacle for your reaching the professor of your interest *("substantial elements" are intended as spatial elements and their physical qualities, or substances such as materials, dimensions, physical barriers/helpers etc…)*

Question A4: Describe in detail the "ornamental elements" of the space in which you move, conditioning the actions in your reaching the professor of your interest *("ornamental elements" are intended as objects, shapes, colours, lights, aesthetics etc…)*

Question A5: Describe in detail your general sensations and preferences concerning the "substantial elements" and the "ornamental elements" of the space in which you move.

Situation 'B': You are at DAU and decide to visit professor Selicato in his room, crossing the space in between.

Question B1: Describe the actions you carry out to reach the professor of your interest

Question B2: Describe in detail the "substantial elements" of the space in which you move, being of help or obstacle for your reaching professor Selicato.

Question B3: Describe in detail the "ornamental elements" of the space in which you move, conditioning the actions in your reaching professor Selicato.

Question B4: Describe in detail your general sensations and preferences concerning the "substantial elements" and the "ornamental elements" of the space in which you move.

Figure 1 – Excerpt from the survey framework

In the analysis of answers, a double-level approach was carried out, for data robustness. A first statistical analysis focused on answer texts, question categories and the gender profiles of respondents. Features as 'essences' and 'ornaments' were singled out from answers delivered as recurrent keywords.
Proper statistical analysis by text-mining software was devoted to the frequencies, the deviations, the grouping, the clustering of keywords in texts. They were further cross-analyzed with the concepts of 'landmark' and 'beacon' (Kelly and Bischof, 2008). In the end, such approach was unable to minimize the biases of word excerpting from discourses (Warren and Gibson, 2002). Because of that reason, a second, complementary analysing approach aimed at contextualizing the findings of the statistical analysis in the text of the answer protocols. This approach was carried out visually, with no software support but a traditional page-by-page reading and rescue of a sample of answers. The next table shows the results of an analysis clustered on the gender profiles of respondents.

	men	womer
WOOD	822	1825
DOORS	1182	1079
GLASS	591	1233
FRAMES	539	1131
CORRIDORS	796	694
STEEL	462	1028
HANDLES	334	1130
SEGRETERIA	1002	462
SPACE	797	539
ROOMS	693	411
LIBRARY	514	514
WALLS	385	616
OFFICES	796	205
HALL	411	436
ROOMS	539	231
FURNITURE	359	308
ENTRANCE	436	128

	men	womei
DOORS	1440	720
MODELS	976	771
WALLS	848	565
NOTICE BOARD	745	616
CHAIRS	822	488
FURNITURE	591	385
STUDY ROOMS	359	514
LIGHT	565	282
WOOD	513	308
FLOOR	565	205
TABLES	436	334
WINDOWS	411	308
PICTURES	411	308
PLANTS	385	308
GLASS	308	231
ENQUIRY DESK	385	128
NAMEPLATES	179	334
IMAGES	359	102
POSTERS	154	308

Table 1 – Some statistical descriptors of essences (l) and ornaments (r)

Descriptors such as standard deviation show that the two groups generally disagree on the nature of spatial elements, as statistically expected. Overall, table 2 synthesizes a top-down ranked list of spatial elements (Borri and Camarda, 2009).

- Ornaments: **doors**, models, **walls**, notice board, chairs, **furniture**, **rooms**, light, **wood**, floor, tables, windows, pictures, plants, **glass**.
- Essences: **wood**, **doors**, **glass**, frames, corridor, steel, handles, enquiry room, space, **rooms**, library, **walls**, offices, hall, **furniture**.

Table 2 – Most cited essences and ornaments in the survey.

A number of elements are present both as ornaments and as essences (in bold in table 2), although the lists have been previously adjusted to minimize biases. This can be explained by the fact that each of those elements is recurrent and plays a major role in characterizing built spaces, both as primary structures and as ornaments.

The last analysis implemented in the study has concerned the landmark/beacon (L/B) character of spatial elements (Kelly and Bischof, 2008). The fundamental question to be addressed will then concern the possibility that cooperatively perceived spatial elements are somehow credited to L/B features. In situation 'A' the target professor was surely known to respondents, since the questionnaire asked to select her/him at the beginning. In situation 'B', the target professor is designated by the questionnaire and, in many cases, unknown. Hence, situation A is more suitable to identify beacons, whereas situation B is more suitable to identify landmarks.

Particularly enquiry desk and occasional students can reasonably play landmark roles for the navigating agents, even with clearly different features, whereas occasional students and nameplates are the most cited targets and can act as beacons.

Exploring an outdoor space: An urban street

After the indoor experiment, the research has moved forward focusing on an outdoor streetscape, i.e., a walking corridor of downtown Bari, Italy. In comparison with the indoor case, an urban street shows increasing complexities and diverse problems (Lawton, 1996), whose allegedly richer impact on navigation features is worth analyzing here.

The survey approach replicates the previous one, with urban spaces and elements instead of rooms and office partitions. The two situations changed only in the type of target to be reached. Therefore texts appear as follows, with all the remainder unchanged:

- Situation 'A': You are in Bari, at the crossroads between via Sparano and via Nicolai, and decide to go north, to a shop in via Sparano, crossing the space in between.
- Situation 'B': You are in Bari, at the crossroads between via Sparano and via Nicolai, and decide to go north, to the Art Desco bar in via Sparano, crossing the space in between.

The new questionnaire was answered by 117 out of 150 students of a Town planning course program in the Technical University of Bari through the web. Again, a mono-dimensional space was chosen, in order to attain a well structured environment (Haazebroek et al., 2011) and facilitate the agents' navigation and analysis.

Even here, a statistical analysis was carried out on answer protocols, aiming at singling out some features of the navigated environment, particularly 'essences' and 'ornaments' (Goodman, 1951) and 'landmark' and 'beacon' (Kelly and Bischof, 2008), for significant clues. The approach aimed at understanding the agents' interpretations of spatial elements in navigating a simple urban environment. The environment is a typical pedestrian streetscape of a lively Italian city, dating back to 1800 but heavily rebuilt along centuries. It is about 1km long and 20m wide, full of people all day, with several stylish shops, shaded benches along the street and many driveway crossings.

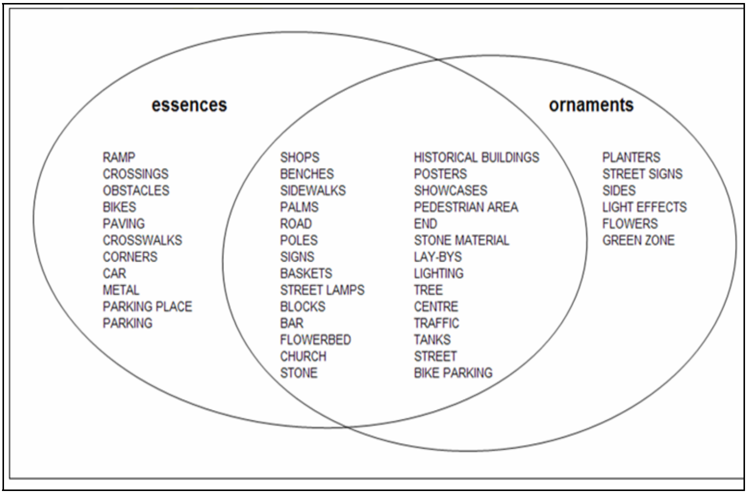

Figure 2 – Essences and ornaments occurring in protocols (high rank excerpts)

Comparing with the indoor corridor, the outdoor streetscape shows increasing complexity (fig. 2). From the one side, some elements are basically common to the two feature groups, similarly to the indoor experimentation. Sensorial perceptions seem to be important when describing both essences and ornaments during the navigation task. Yet, the representation of ornaments is significantly integrated by non-sensorial perceptions, such as the emotional ones. This occurrence was not evident in the indoor experimentation: it is common in urban environment spaces.

Factor analysis on keywords showed that 5 variables explained about 80% of the total variance:

1. Structural features
   Buildings and service areas
   Elements of position and directions
   Shopping-related elements
   Moving aids and supports
   Elements of parking & vehicular mobility

2. Ornamental features
   Physical elements at urban scale
   Phys. elements at architectural scale
   Elements of shopping and leisure
   Elements of street furnishing
   Tourist-oriented elements

It resulted that 5 the two lists show areas of logical overlapping, as expected. Yet, among the most statistically significant features (top of the lists), there are some exclusive clusters, i.e., position/direction elements (in structures), and architectural elements (in ornaments). Non-intersecting areas are more evident than in previous indoor experimentation. Goodman's skepticism seems somehow confirmed: yet, a fuzzy distinction still remains, emphasizing two clusters. Results were confirmed after further cross-analysis with other significant features (e.g., 'landmark' and 'beacon').

Brief conclusions and follow-up

The paper investigates some ways of conceptualization and imaging of the space by human agents. The specific aim is to understand what are the features that make a perceived and navigated environment a well structured space, particularly looking at the distinction between 'fundamental' and 'ornamental' features (Goodman, 1951). The contextual investigation approach is the finding out of a way to reach a spatial objective in simple spatial environments. The space considered is simple, in that it is highly structured (in robotics terms, e.g., Wooldridge and Veloso, 1999) and inducing neither disorientation, nor difficult decisions to each navigating agent. In this condition, it is possible to draw out indications on some attributes of the space, and check if spatial features play significant roles in helping/hindering the navigation.
In order to enhance the simplicity of the context for experimentations, a monodimensional space was chosen, i.e., an indoor university corridor and an outdoor city street. The study

seems to show that the conceptualization of a corridor space is highly tributary to the existence of some categories, namely 'substances' and 'ornaments', whose presence, scarcity of lack is able to make the navigation task harder or easier. In this sense, it seems to confirm some basic assumptions of our work. However, 'substances' do not seem to be sufficient to represent a fully structured space, because many 'ornaments' work as structural features themselves. This seems to be in line with Goodman's original skepticism.

What's more, when looking at the urban street case, space features as not even enough to categorize the environment as a mono-dimensional corridor. The fact that environment is crossed by agents with various directions, times and distractions seems to be determinant in inducing a lower structuring degree than the university space. Yet interestingly, there is a structuring degree in the urban case, that emerges from the students' arguments in protocols. A possible explanation for that is that the structuring degree is induced by the intentional action of navigating agents and confirmed by the path facilitation and features of a pedestrian street.

This is an intriguing point. In fact, if agents' intentionality is a critical element for space structuring (i.e., for making the environment intelligible and navigable), then the agent's ability to single out and associate space features becomes critical itself. This makes the creative attitudes of agents decisive for effective space imaging and navigation tasks. Also, it is interesting to note that association abilities were even boosted when the navigation processes were carried out by students strolling around in groups. In those cases response protocols can be considered as a multi-agent, rather than single-agent, knowledge base, and therefore creative attitudes may emerge as actually enhanced in cases of cooperative multi-agent tasks -even if creativity is not always separable and recognizable as a single-agent feature.

In general, the research provides intriguing insights on the way how agents acting in simple environments may perceive and structure spacescapes, according to inherent space features but also to their behaviours and organization abilities –a bulk of their creativity. This is interesting for spatial planning, particularly when trying to grasp and represent more effectively the characters of the environment, for the development and management of human spaces. On the other hand, the quest for creativity-supporting agent-based models of navigating the environment can be a reasonable research target for future research.

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