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Contribution of local artifacts in assessing spatial experiences
What you keep, what you throw

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ABSTRACT

When we try to utilize a machine, find our way around, or use a service, we look for artifacts which provide us with hints on how to do so. In our paper, we focus on a case scenario, namely, the effort of a traveler to find an underground station. We examine this scenario both from the experienced user's and from the newcomer's perspective. We use agent theory to model the traveler's behavior. We claim that there are similarities in the strategies used by agents when utilizing local artifacts in their effort to perform a spatial task. We differentiate between strategies employed by the experienced and the inexperienced users. We elaborate on the fact that when an experienced user is entering into a new task he utilizes a critical piece of knowledge, stored as resource experience. He has acquired this experience through his involvement in a previous task of similar nature. We examine the aspects used by the novice who does not possess one or more pieces of critical knowledge while seeking to reach his goal. We support that there is a hierarchical array of considerations employed by the agent in his effort to implement the gains of his past experience and we propose a model to assess the artifact's significance and the agents resources experience with a specific spatial task

Wenn wir Maschinen benutzen, uns zu Recht finden wollen oder eine Dienstleistung in Anspruch nehmen wollen, suchen wir nach Artefakten, die uns die bennötigten Hinweise dafür geben. In dieser Arbeit werden wir uns auf einen Fall beschränken, wo ein Reisender eine U-Bahnstation sucht. Wir werden dieses Szenario aus der Perpektive eines erfahrenen Benutzers und eines Neulings untersuchen. Wir verwenden Agent Theorie um das jeweilige Verhalten der Reisenden darzustellen. Wir behaupten, dass es Ähnlichkeiten zwischen den Strategien der betreffenden Personen gibt, wenn sie lokale Artefakte verwenden, um eine räumliche Aufgabenstellung zu bewerkstelligen. Wir unterscheiden zwischen Strategien des erfahrenen und unerfahrenen Benutzers. Wir untersuchen die Tatsache, dass ein erfahrener Benutzer der eine neue räumliche Aufgabe hat, auf Wissen zurückgreifen kann, dass ihm als Erfahrungsquelle dient. Er hat diese Erfahrungen bei vorhergehenden, ähnlichen Aufgabenstellungen erworben. Wir untersuchen andererseits die Situation des Neulings der während er sein Ziel erreichen will kein kritisches Wissen besitzt. Die Überlegungen des Agenten sind hierarchisch aufgebaut Wir stellen ein Modell vor, welches die Signifikanz von diversen Artefakten und Erfahungen des Agenten, bezüglich einer bestimmten räumlichen Aufgabe, bewerten kann.

1 KEYWORDS

Spatial cognition, learning model, artifacts, local artifacts, decision strategy, weighted significance, spatial experience

2 INTRODUCTION

Let us consider the following scenario. A businessman from Vienna is in Paris for a one-day visit and he takes advantage of his free late afternoon hours to visit some of the renowned monuments of the city. Coming from Vienna, he is, as most Viennese, an opera fan and he would like to see the world famous Parisian opera house and, naturally, make all necessary comparisons to the one in his own city. He finds himself in front of the opera house in Paris and he feels very proud to be able to have experienced that moment. It is a warm rainy afternoon with still plenty of daylight. The conditions are not ideal for taking pictures due to dampness, but it is still a must. He would much rather be sited inside and enjoy Carmen, or be given a tour, but as the time is inconvenient for any tour or performance, he decides to move on to visit Notre Dame. After looking at his map which he picked up at the tourist office on his arrival, he is certain that there is an underground station in the vicinity. Given his lack of adequate French, he looks carefully for hints which would point to the entranceway of the station. There is no sign which he could perceive, and he is going through a number of mental processes utilizing locally built elements. We propose in this paper that his special experience is built based on the assessment of these local elements. From this point onwards we will call these elements artifacts. In section 4 we elaborate on the properties of artifacts. Figure 5 shows one type of artifact utilized extensively when moving with public transport, namely signs for the subway stations in four different cities.

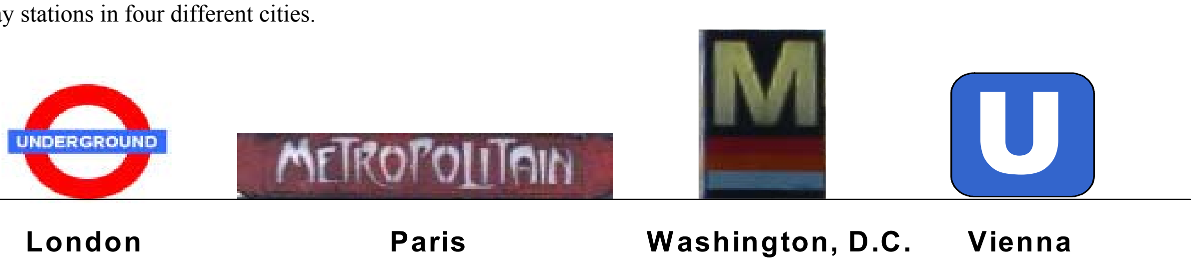

Figure 5. Signs for subway stations in different cities

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Whether looking for a subway station in a foreign place or trying to find a postal box in an unfamiliar area, we employ very similar strategies based on past experiences and on the affordances embedded into natural and manmade objects which are relevant to our task. Building the new spatial experience is always a composition of both. We use agent theory to model the traveler's behavior when locating the entrance of the subway station. The notion of experience as introduced by Russell (Russel 1921) provides us with a foundation for developing the experience evaluation scheme.

The next section summarizes the agent's properties. Section 5 elaborates on the notion of experiencing the space. In addition, the section provides a distinction between landmarks and artifacts. Section 6 provides a three-class classification scheme for local artifacts based on their components. Section 7 presents the linkage between the importance of the local artifacts and the evaluation of an agent's experience with the spatial task. Finally, Section 8 summarizes the conclusions of this paper and proposes future directions to further this research.

3 THE PARTICIPANT AGENT

We model the participant of the spatial experience as a cognitive agent, namely an agent who cognizes about himself and about his surrounding. The *"agent's architecture characterizes its internal structure, that is the principle of organization which subtends the arrangement of its various components"* (Ferber 1998). Table 2 provides a summary list of features which are possessed by an agent as listed in Ferber.

1. He can act upon the environment.
2. He can communicate with other agents.
3. He is driven by objectives.
4. He possesses resources on his own.
5. He can perceive the environment.
6. He has a partial representation of his environment.
7. He possesses skills and can offer services.
8. He may be able to reproduce himself.
9. He tends to satisfy his objectives using his skills, resources, percepts, representations and output of his communication.

Table 2. Capabilities of the physical or virtual agent –based on (Ferber 1998, pp9)

Our participant in the spatial experience is a goal driven agent. In our scenario, his goal is to locate the entranceway of the subway station. We model his resources based on his level of experience in reference to the local artifacts. We elaborate on the notion of the local artifacts in the following sections of this paper.

4 SPATIAL CONNECTIONS

Talking about space has never been straight forward. From Aristotle to contemporary scientists and philosophers "place" and "space" slides/lingers within a large range of definitions and points of view. For Aristotle "place" holds a large list of quantitative and qualitative properties such as, the replacement, dimensions, enclosure, inclusion, occupation by a separable physical object, characterized by two universal directions namely up and down, forces resulting in motion or rest and as such connected to time, void etc (Aristotle). Couclelis and Gale suggest that an algebraic structure of space can assist in transcending the disarray dominating the scientific community when facing the issue of space. They schematize space looked from six different perspectives namely the Euclidean, physical, sensorimotor, perceptual, cognitive and symbolic and they provide the algebraic axioms and operations that govern each of the above types of space (Couclelis and Gale 1986). Frank proposes algebras as a means for describing spatial features (Frank 1999). The equivocal notion of space is transduced to all its semantically related derivatives, "spatial" being one of them. "Spatial" is defined as pertaining to or involving and having the nature of space (Merriam-Webster 2003).

Experience is linked to gaining knowledge through direct observation or participation (Merriam-Webster 2003). For Russell, experience is an occurrence which could affect the participant's subsequent behavior (Russel 1921). The generation of spatial experience is linked to hierarchical reasoning which occurs in more than one level. Newcombe and Huttenlocher propose a comprehensive scheme of spatial coding colligated to external landmarks and to one's self. In the first category, they differentiate between "cue learning" and "place learning". "Cue learning" provides an association between the physical object which is to be located and an external landmark often linked to habitual placing, such as coding the resting location of someone's car keys at his home. "Place learning" renders coding of distances and directions in relation to external landmarks such as the coding required to search for one's key thought to be dropped in the park at a certain distance from a tree and at a certain direction compared to the zero angle direction between the tree and the playground door for example. In the category of one's self referenced spatial coding Newcombe and Huttenlocher distinguish between "response learning" and "dead reckoning". "Response learning" often mentioned as sensorimotor coding is the codification of a location or of a path through an assemblage of body movements such as the spatial coding required to walk around a familiar place in the dark. Lastly, they propose that "dead reckoning" is the coding which takes place when a location is linked to distance and direction relevant to someone's current position and to subsequent movement. They attribute this spatial coding to animals when foraging in a apparently unvarying terrain (Newcombe and Huttenlocher 2000).

In this paper, we propose that the coding of a spatial experience is also attributed to stationary, moving, and dynamic local artifacts. We suggest that the level of the user's experience influences the utilization strategies of the local artifacts which are pertinent to a task. We propose a simple evaluation model for measuring a user's experience for a certain task linked to the user's ease with local artifacts.

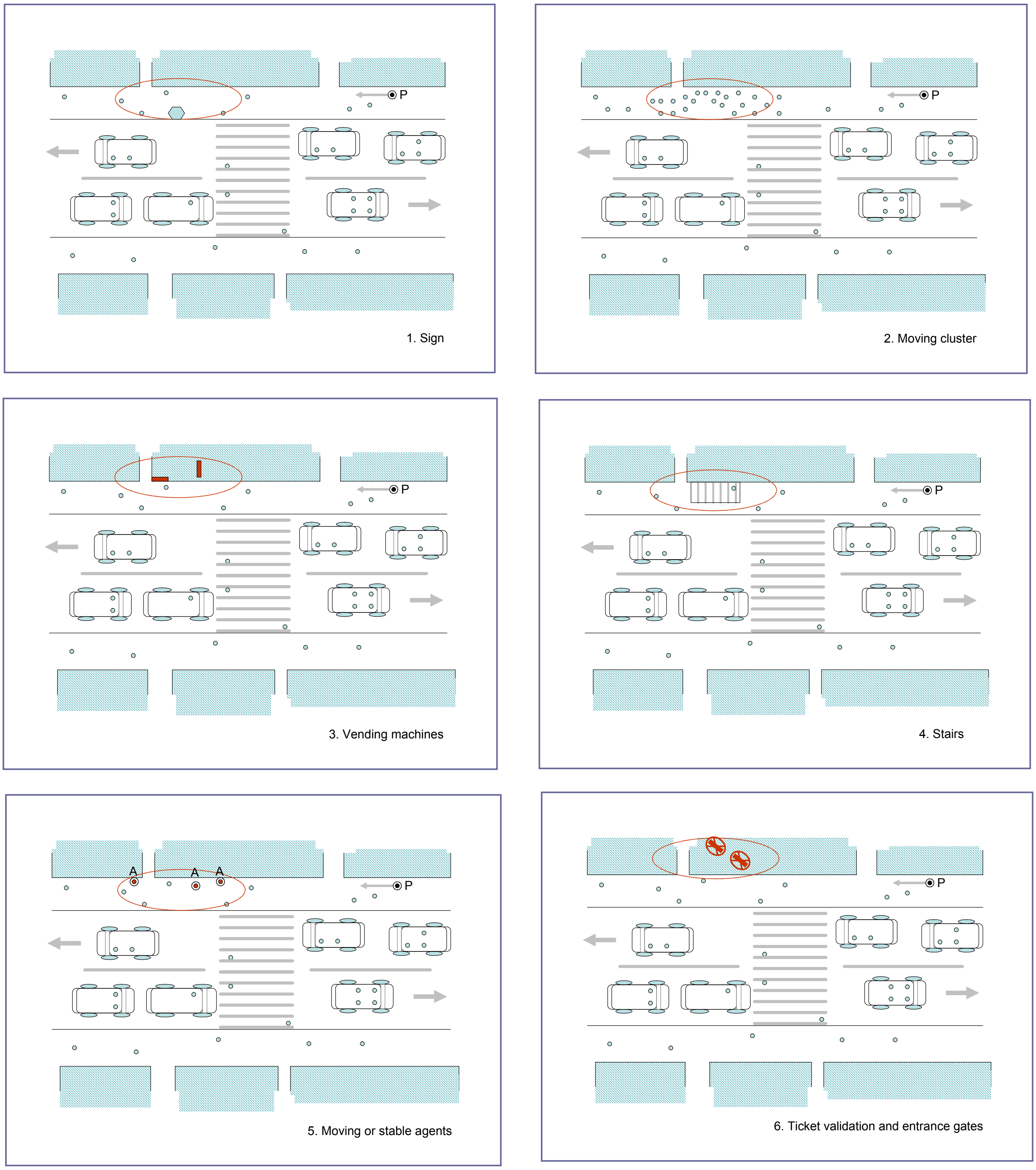

Figure 6. Artifacts used when searching for the entrance of an underground station

4.1 Spatial landmarks and local artifacts

Landmarks or better *spatial landmarks* –as opposed to temporal landmarks referring to certain point of time in the past or a potential time in the future—are defined as fixed markers or prominent and identifying features of a landscape (Morris 1973) and as a point of structure used for referencing (Merriam-Webster 2003). In addition, Lynch ascribes the property of singularity to a landmark bound to stand out from its surroundings (Lynch 1960). We observe here an analogy to the property of distraction of attention which Dewey attributes to natural signs (Dewey 1938). Furthermore, Sorrows and Hirtle distinguish three types of landmarks based on their predominant quality, namely visual, structural, and cognitive landmarks (Sorrows and Hirtle 1999). Nothegger et al. proceed to utilize this categorization in calculating a feature's salience (Nothegger, Winter et al. 2004). We remark, based on the literature, that the two most prominent properties of a landmark is that it is fixed feature, therefore not moving, and that it has the capacity to be used for spatial referencing.

Artifacts are defined as manmade or artificial objects as opposed to natural objects – a distinction for objects provided by Aristotle in his Physics (Aristotle)—which are bound by intentionality (Hilpinen 2004). As a product of a human action, artifacts have a maker or author, author in a generalized sense. Local artifacts are those which carry a significance pertinent to a location thus, their intentionality employs a spatial aspect. Hilpinen proposes an evaluation scheme based on the intended character of an artifact, its actual character and a predefined purpose. He calculates three measures for identifying intensions and purposes namely a) the degree of fit between intended and actual character of an object, b) the degree of fit between intended character of the object and the purpose and c) the degree of fit between the actual character and the purpose.

5 COMPONENTS OF LOCAL ARTIFACTS

We expand the above qualities of an artifact to include movement and changes. We consider that the author of an artifact can be more than a human maker as we will present subsequently. We consider that artifacts carry by default the property of affordance in the same sense as Gibson describes it in the case of a chair which affords sitting and of a handle which affords turning (Gibson 1986) and, as we are expanding, of a coin slot which affords to have a coin dropped in. Concluding here we see that the notion of affordance is embedded into the very definition of artifacts.

Figure 6 demonstrates six different cases of artifacts used by the participant P in his effort to yield the spatial experience of locating the entrance of an underground station in a city setting. The first tile demonstrates a perceivable sign of the subway station. The subway station sign constitutes a *stationary artifact* made by the designer to convey the location of the station to the potential passengers. It is the most commonly used artifact by passengers who can perceive and decipher it. It adheres to semiotic theory as introduced by Pierce and encompasses the elements of a sign's triad (Pierce 1992). The sign-triad consists of the a) likeness which represents the mapping of icons, sounds, gestures of pictures, b) indication which connects to the portion of experience and differentiates between experience and inexperience and c) symbol which connects the idea to the world (Pierce 1992). The formation of the spatial experience is based on referencing in relation to an external landmark as described in Section 4 of this paper.

The second tile of Figure 6 depicts the situation of a participant perceiving a dynamic cluster of people exiting and entering a building. We consider this cluster of people as a *dynamic artifact*. The author in this case is the design of the station. Its characteristic dynamic form, due to the bottleneck phenomenon caused at the door of the building, indicates this cluster's intentionality, namely to exit or enter the station. A spatial experience is codified in this case based on a dynamic artifact. Similar experiences are formed by observing ants moving towards a grain of food on the ground or by connecting a flooded area to a location.

The third tile of Figure 6 presents the case of perceivable ticket vending machines which indicate the existence of a station. The vending machines are considered as *stationary artifacts* created by the transport authority in order to facilitate ticket purchasing. The purchasing of the proof of payment for transport, namely the ticket purchasing constitutes one of the four building block of transport (Pontikakis 2004). Ticket vending machines employ affordances indicative to their intended use in the sense which affordances and knowledge in the world are described by (Gibson 1986) and by (Norman 1993). The spatial experience is again built based on external referencing to a fixed feature.

Similarly, the fourth tile of Figure 6 depicts the situation where a stairway is perceived. We regard the staircase or the periodically moving escalator as a *stationary artifact* made by the engineer to enable the access to a lower level of a facility, in our case the subway station. An escalator affords to be used for descending or ascending and constitutes an external area for referencing a spatial experience.

The fifth tile of Figure 6 depicts a typical situation of moving agents in the vicinity of the entrance of a subway station. Vendors of newspapers and beggars constitute representative types of these agents. We regard these agents as *moving artifacts*. Similarly to the case demonstrated in the first tile of Figure 6, we consider that the design of the station is their author and that their intentionality is bound by their role. Here, the spatial experience is coded based on a moving artifact. Similarly, spatial experiences of an accident, a hospital or a burning area are formed based on an ambulance or a fire truck in duty.

Finally, the sixth tile of Figure 6 presents the employment of ticket validation gates as a means for entering the station. When perceivable, the gates represent a strong indication of the entrance to a station. Particularly in case where the subway station is part of a large indoor complex such as in commercial areas, the entrance gates are sometimes the only artifact which can be used. In such cases, the subway signs and escalators blend in with the rest of the signs and escalators of the surroundings. Similarly to the case of an escalator, we regard the gates as a *stationary artifact* produced by the transport authority to screen the legitimating of the passengers. Ticket validation constitutes a component of the business aspect of a trip with public transport (Pontikakis 2004). The gates afford to be used for passing and screening and contribute to the formation of a spatial experience based on referencing in relation to an external fixed feature.

Figure 7. The entrance of the subway station in Paris across the Parisian opera house

Additional artifacts based on cultural elements can be possibly found in the vicinity of an entrance of a subway station. Figure 6 presents six major ones classified in three major categories, namely, stationary, dynamic and moving artifacts. Often, artifacts are present but are not perceivable due to obstructions. Figure 7 presents the entrance of the subway station across the opera house in Paris. The signs are only perceivable after someone has reached point A or has descended a few steps. The artifacts of the moving clusters and stairways are utilized here to construct the spatial experience. In other cases, artifacts are perceivable but are not decipherable. Figure 8 presents a street car stop in Vienna. Ordinarily, the frame of such a stop is blue, however the one shown here is red. Very few Viennese can tell you what it means to wait at a red framed stop. These type of stops indicate that the transportation vehicle always makes a mandatory stop, independent of the demand of passengers in or out of the vehicle. These stops are named “safety stops”. Naturally, this information is of no use to those who are not familiar with this concept.

Figure 8. Street car stop in Vienna

In this section, we discussed three types of artifacts which are utilized when trying to locate the entrance of a subway station, namely *stationary*, *dynamic* and *moving* artifacts. We indicated that the construction of a spatial experience is connected not only to external fixed features, but also to dynamic and moving artifacts.

6 LEVELS OF EXPERIENCE WITH LOCAL ARTIFACTS

In the previous section, we pointed out that not all artifacts which are placed in the vicinity of the entrance of a subway station can be utilized by a participant to build a spatial experience. Some of these artifacts are either not visible because of obstractions or are not perceivable because they blend in with the rest of the environment. There are cases, however, where an artifact is perceivable but is not decipherable such, as the artifact depicted in Figure 8. In this section, we discuss the evaluation of local artifacts for a certain task and we relate this evaluation to the participant’s experience.

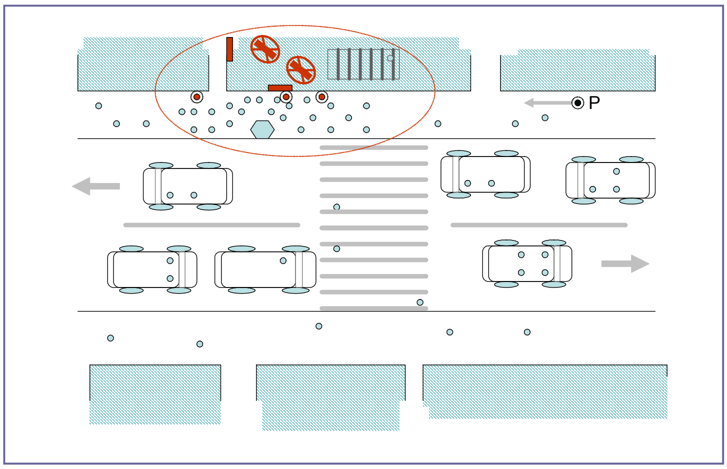

Figure 9. Assemblage of artifacts

Our passenger arrives at the vicinity of the subway either by consulting a map or by asking someone else. We consider this as the base level of the participant's experience. From this level onwards, every artifact which he utilizes is added to his resource experience. We refer to Russell's notion of experience as occurrences which can affect subsequent behavior (Russel 1921). We discriminate here between the resource experience already possessed by the participant and the experience gained through his involvement with the current spatial task. In this paper, we evaluate the relevant experience he already possesses when entering the task.

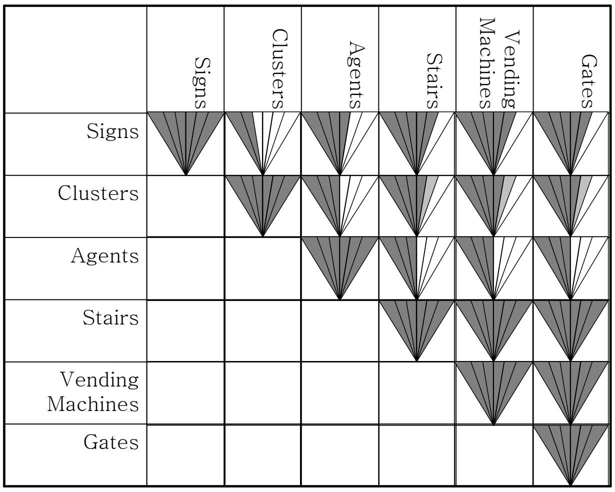

Figure 10. Evaluation mosaic of local artifacts

6.1 Artifact evaluation scheme

We grade each artifact based on a weighting scheme with integers ranging from 1 through 6. The weighting is based on the artifact's *presence* and *visibility*, and it can vary from station to station. The artifact's presence is a boolean value while the artifact's visibility is an enumerated list of integers ranging between 0 and 2, where 0 indicates non visible, 1 indicates partially obstructed, and 2 indicates fully visible. The construction of such schemes is case specific and they can be used by system designers to evaluate different scenaria of the intended use of space based on built-in artifacts. The development of algorithms which can yield case specific results for assisting the evaluation of space by its intended functionality is the subject of subsequent research.

	Presence (*p*)	Visibility (*v*)	Weight (*w*)
Signs	True	2	6
Clusters	True	2	4
Agents	True	2	2
Stairs	True	1	1

Vending Machines	True	1	1
Gates	True	1	1

Table 3. Example of artifact evaluation scheme

Table 3 presents one example of an evaluation scheme where all artifacts are present but they vary in visibility. We can apply this scheme to evaluate the artifacts shown in Figure 9. In this case, all artifacts discussed in section 5 are present, but the ticket vending machines, validation gates, and escalator are located in partially obstructed areas. According to this evaluation scheme, the sign of the subway station employs a higher significance than the moving cluster of passengers, the moving newspaper vendors and other commonly found moving agents.

The "input-output" chart presented in Figure 10 provides a graphical representation of the relevant weights between two artifacts under the current weighting scheme. The larger the shaded area of the triangle, the heavier the weight of the artifact in the corresponding row. This graph assists in quickly visualizing the relative importance of the considered artifacts. Naturally, a change in presence or visibility yields a different weighting scheme for each of the local artifacts.

6.2 Resource experience evaluation scheme

In the case of a passenger who has previously used a subway system and tries to locate the entrance of a subway station perceiving and deciphering the appropriate signs is most likely the first thing he does. At first, we evaluate the participant's experience with an artifact without reckoning the artifact's weight. This is referred to as the participant's *pre-weighted experience* (pre_wE_i), and it ranges between 0 and 1. We attribute the value of "0" pre-weighted experience to the novice and the value of "1" to the experienced participant with the specific artifact. If the sign is present and visible but the passenger can not perceive it, then his pre-weighted experience with this artifact is considered zero. Similarly, if the sign is present and visible and the participant perceives it, but he is unable to interpret it, his pre-weighted experience with the sign is again zero. In the cases where the artifact is present, but it is partially obstructed, if it is perceived and deciphered, then the participant's pre-weighted experience is considered "1". If it is not deciphered, it is the result of a probabilistic calculation, which is a topic of subsequent research. If, however, the sign is present, but it is not visible or if the sign is not present at all, then his pre-weighted experience is independent of the sign, namely non applicable (N/A) for inclusion into the evaluation of a participant's overall experience with the spatial task.

Table 4 provides a summary of the above reasoning.

Presence	Visibility	Perceived	Deciphered	Pre-Weight Experience
True	2	True	True	1
True	2	True	False	0
True	2	False		0
True	1	True	True	1
True	1	True	False	Probabilistic Algorithm
True	0			N/A
False				N/A

Table 4. Artifact's pre-weighted experience evaluation scheme

Although this binary scheme for evaluating the pre-weighted experience may seem coarse, it reduces the complexity which a more refined scheme would cause. We can assign for example a higher pre-weighted experience for a partially obstructed artifact based on the level of obstruction. The evaluation of the effects of such schemes requires further research. We expand the above reasoning to include all of the local artifacts which are pertinent to the spatial task.

We calculate the participant's *weighted experience* with each artifact (wE_i) as a function of his pre-weighted experience with the artifact (pre_wE_i) and the artifact's weight (w_i), $wE_i = f(pre\_wE_i, w_i)$.

His overall experience with the task, namely his overall *spatial experience* (sE) is the sum of his weighted experiences with all pertinent artifacts, $sE = \sum_i wE_i$.

In this section, we discussed the artifact weighted evaluation scheme linked to presence and visibility of each artifact. We proposed a model for calculating the resource spatial experience based on the pre-weighted experience with each artifact related to the spatial task. We utilized the task of locating the entrance of the subway station as an example of building a spatial experience. We observe that there is a hierarchical strategy followed by the participant when he builds a spatial experience. This strategy is connected to his resource experience and to the available artifacts. Similar strategies are employed by a participant in building other spatial experiences.

As shown, the model presented here can be utilized by space designers to evaluate artifacts for their intended use. It can also be used by human resource managers to evaluate a participant's experience with a task. Finally, physiologists and sociologists can utilize the model when studying social behaviors.

7 CONCLUSIONS AND FUTURE WORK

In this paper, we introduce the notion of spatial referencing in relation to three types of local artifacts pertinent to a spatial task, namely stationary, dynamic and moving artifacts in addition to the categories of spatial referencing proposed by others (Newcombe and Huttenlocher 2000). We indicate that the construction of a spatial experience is connected not only to external fixed features, but also to dynamic and moving artifacts.

We propose a scheme to assess the significance of local artifacts which are embedded in the environment and are relevant to a specific spatial task. We propose a model to evaluate the resource experience of a participant who is engaged in solving the task in relation to the assessment of the local artifacts. We introduce an artifact weighting scheme which we relate to the participant's weighted spatial experience. The concrete case of a tourist who is locating the entrance of a subway station is used to formulate our proposed scheme. Our participant in the spatial experience is a goal driven agent rendering a resource experience. We differentiate between a novice and an experienced participant in reference to a specific local artifact.

This paper provides the foundation for further research in the area of local artifacts and a participant's resource experience pertinent to the use of space. The following points will provide an enriched insight into these issues and they are the subjects of subsequent research:

1. A higher pre-weighted experience for a partially obstructed artifact which is perceived and deciphered based on the level of obstruction may yield a more fair evaluation of a participant's resource experience.
2. A probabilistic algorithm can be utilized to produce a more sensitive pre-weighted experience in the case of a partially obstructed artifact, which is not perceived by the participant.
3. The concept of the artifact weighting scheme can be extended beyond the realm of subway stations and transportation.
4. An algorithm can be developed to yield case specific results for assisting the evaluation of space by its intended functionality.

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