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# Planning Human and Robot Placements for Shared Visual Perspective

Jules Waldhart<sup>1</sup>, Aurélie Clodic<sup>1</sup> and Rachid Alami<sup>1</sup>

**Abstract**—While *so-called* robotic guides have been studied thoroughly, the focus of these robots was more to open the road or accompany a person or a group until they reach their destination. Interaction was essentially limited to the initiation and ending of the task and implemented using a screen or speech. Providing route directions is a specific task that such robot is meant to realize. We claim that this task can be studied and tackled as a joint task where not only the robot as route direction provider but also the human as listener must be modeled and taken into account for planning. Interestingly, the pertinent way a speaker and a listener share their space, move and point accordingly to enable the understanding and completion of way-finding direction has not been very much studied in the spatial cognition literature and has not been yet tackled as such in the human-robot interaction community. We propose the SVP (Shared Visual Perspective) planner that searches for the right placements both for the robot and the human to enable efficient visual perspective sharing needed for providing route direction and enables to choose the best landmark when several are available. The shared perspective is chosen taking into account not only the visibility of the landmarks, but most importantly the whole guiding task.

## I. INTRODUCTION

When one asks a direction to an employee in charge of providing information to visitors of a public place, said employee will most likely point a direction and give some instructions to reach your destination (“This way, take the first street on your left,...”). In trivial cases, she/he will point directly at the destination (“It is just here”). In some other interesting cases however, the employee may move and take you to a position where she/he can show you some (previously hidden) landmark (“It is just behind this corner”), thus simplifying the directions and easing your task, like our robot does in the example shown in Fig. 1. These scenarios could be summarized as follow for a robotic guide:

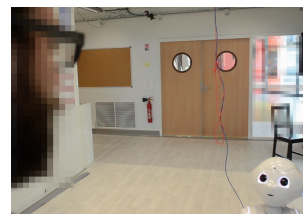
- an interactive robot, placed near an information desk in a public space, is available to provide information and route directions
- it can move a little (say several meters around its base) in order to place itself and ask its human addressee to move with it in order for both of them to reach a configuration where it can point to one (or several) landmark(s) and utter route direction information
- the robot is not intended to accompany the persons to their destination but to help way-finding.

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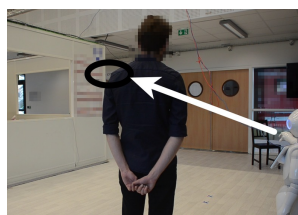
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(a) Initial situation, the visitor asks for a shop.



(b) Visitor's perspective at his initial position: he cannot see the sign (in the corridor).



(c) Robot asked the human to move a little and also placed itself such as the sign is visible to both and it can point at it.



(d) Visitor's perspective from the planned position. He can see the sign now.

Fig. 1: In-lab demonstration of the SVP planner. The robot has to show the circled landmark to the human; the SVP planner has found nearby positions for the human and the robot (c) from where it can be seen and pointed at.

This scenario is similar to the one proposed in [1], but with a major difference: the robot is able to navigate with people to reach a perspective that is more pertinent to provide route direction. The scenario is in-line with what people expect from an information robot in a shopping mall[2].

A number of contributions have been proposed and systems have been built for robot guides, from the first museum guides [3], [4], [5] to more recent robot guides in large areas [6], [7], [8]. However, the focus of these robots was more to open the road or accompany a person or a group until they reach a final destination. Here the problem is different, the robot can move not too far from its base and provide route information using gesture and speech.

While a number of issues have been studied and proposed to build and evaluate direction-giving robot behaviors, very little has been done when the robot and the human are placed in a way where they cannot see the landmark. Indeed most of the existing work assume that they are already placed in a favorable position and, if the human is not correctly placed, they assume that she/he will adjust.

The problem we want to tackle can be formulated as a planning problem, where the robot computes a position for both of them. This can be quite tricky since a number of constraints and selection criteria can and must be taken into account.

In this task, not only the robot action needs to be taken into account but also an action to be achieved by the human since they will create a mental model of the route, interpret the information, search for it in the environment, etc...[9]. This is why, we can consider that it is typically a human-robot joint task [10], [11], [12] where the robot needs to have the abilities to estimate the perspective of the human, and to elaborate a shared plan involving the human and the robot that will allow to place both of them in a desired perspective.

We focus here one particular component, the SVP Planner, but this work is part of an overall project that aims to implement and evaluate a complete system. This involves the development of a number of components such as human perception system [13], human-aware reactive motion planner [14], Human-Robot joint action supervision [15] and dialogue [16].

We first give the main definitions in §II. Then, we provide a brief overview of related work in §III. Information required about the task, then environment and the involved agents (Human and Robot) are presented in §IV-A. In §IV-B we discuss the evaluation criteria for the task. Then, we formulate more precisely the problem and present our implementation of the planner in §V, with results in §VI. Finally, we conclude and consider future improvements in §VII.

## II. DEFINITIONS

We propose here below the set of definitions that will used:

**Visitor** the person asking for help,

**Guide** the (robot) agent providing information,

**Destination** the place the human visitor wants to reach,  
**Landmarks** indications, either verbal or physical, are based on landmarks, they include signposts, billboards, recognizable furniture or building elements [17]. A destination can hold a landmark (like a shop front).

**Guiding** we will use this term in the meaning of physically going with the guided persons to some place (not necessarily the destination),

**Pointing** the action of extending one arm in the direction of an object in order to indicate its position to the visitor; a successful pointing task results in the visitor seeing and unambiguously identifying the object,

**Route direction** refers to the information one gives to the visitors in order to have them find their way toward a destination. They can be a mix of verbal indications, pointing in the physical environment or on a map given to describe paths or locations.

**Visibility** the visibility of an object from a perspective is quantified by the size of the visible part of the object in the field of view, *i.e.* a solid angle.

## III. RELATED WORK

We review here some contributions related to the tasks of guiding, providing route directions and pointing. Both human cognition studies and robotic or system implementations are briefly discussed.

### *Landmarks selection*

Landmarks are used to support route description, and it is not enough to use them, one must choose them accordingly [17], [18], [19]. The criteria for choosing landmarks are related to semantic properties, perception salience and the appeal to context [18]. Also studies show the importance and relevance of propositions connecting landmarks and the actions to take (like “at the parking lot, turn right”) [19]. [9] proposes “best practices” for the choice of route direction based first on a temporospatial ordering of the statements and then on the use of shared knowledge to convey common ground during the interaction.

### *Pointing*

In situated dialog, physical signals intended to direct the addressee attention to an element of the environment can be sorted into two classes: “directing-to” and “placing-for” [20]. In [21] a study is conducted to highlight the rich design space for deictic gestures and the necessity to adapt them to physical, environmental, and task contexts. Another key aspect for the synthesis of the robot pointing gestures is their legibility [22]. Interesting studies have been done in the analysis of gestures accompanying verbal route directions [23].

Pointing can also be seen as a joint-action where the guide has to verify that the visitor has successfully looked at the pointed direction or object, through gaze analysis and dialogue.

### *Placements to share visual perspective*

Beyond extending one’s arm, pointing at an object may require repositioning the agents to facilitate the perspective sharing and communication between the visitor and the guide [24], [25], [26].

[27] provides a pertinent analysis of the stages to a successful pointing gesture. They mention the need for the viewer to be able to see both the gesture and the referent as well as the necessity of holding the gesture until coming to mutual agreement with the observer about what is being pointed at.

The consideration of the point of view of the observer by the speaker is discussed in [24] and in [25]. In [26] the importance and role of the “Shared visual space” is stressed.

Concerning issues linked to placement planning, there are substantial results on planning sensor placement (e.g. [28]) as well as planning the robot position to let it share the human visual perspective [29] but we have found no contribution on planning shared perspective for both the human *and* the robot *i.e.* searching for a reachable placement of both partners.

[30] study the way a guide and a visitor place themselves and possibly move during the explanation of a route in the context of a large mall.

#### Route direction

In this activity, the guide gives indications on how to reach the desired destination, mostly through dialogue, but this can be improved by some gestures. Once the route directions have been successfully communicated to the visitors, they can navigate to their destination.

The synthesis of a combination of speech and gesture in order to achieve deictic reference has been discussed in [31]. [32] proposes a model for a robot that generates route directions by integrating three crucial elements: utterances, gestures, and timing.

### IV. THE SVP PLANNER

The problem addressed here is related to several modalities: speech, gestures (including deictic) and navigation. These modalities are deeply connected, in the sense that they support each other: speech describes a navigation path; gestures improve speech by anchoring it to landmarks or describing actions; navigating closer to the destination simplifies the speech and may allow different (better) deictic gestures. Altogether, route directions are improved by pointing at pertinent landmarks. The guide can take the visitors to a location where said landmarks are “sufficiently” visible from their (shared) perspective.

All in all, there is a continuity of solutions between providing route directions from the starting point to guiding the visitor to his destination, including guiding only to a good perspective where to provide route directions.

The description of the task could be:

- 1) guiding –physically accompanying– the visitor to some place;
- 2) pointing at a landmark;
- 3) providing route directions –based on the pointed landmark;
- 4) reaching the destination (visitor only);

in that order, but with each step being optional. The SVP planner solves the problem of finding a position for visitor and the guide where a pointing of some landmark(s) can be performed. The landmarks to point at is dependent on the task. It is important to notice that all of these steps are taken into account by the SVP planner to evaluate the task solution as a whole.

In this context, our Shared Visual Perspective planner proposes a solution to:

- compute both placements for a robot guide and a visitor that enable shared visual perspective regarding a landmark and allow effective pointing of the robot,
- if several landmarks are provided, choose the best landmark to point at.

To do so, the SVP planner takes into account a number of parameters in the evaluation qualifying the whole task.

#### A. Model

Our approach relies on a variety of information about the environment and the agents, either symbolic, physical, or on mental states. Provided with these data, the SVP planner can be potentially adapted to any situation where a robot has to provide route directions and to point at landmarks, like streets, museums, malls, offices, university campuses...

1) *Physical Environment Model*: The environment needs to be represented in three dimensions, its accuracy influences the pertinence of the visibility computations and navigation planning. All the obstacles to navigation or sight (occlusion) must be represented. The model must discriminate potential landmarks from each other and from other objects or obstacles to allow the computation of a specific landmark visibility. In our implementation, we represent the environment using 3D meshes, visibility of objects is computed with OpenGL (similar to what is used by [29]). Each 3D object could be associated to a name and considered as a landmark when needed.

2) *Symbolic Environment Model*: The SVP planner needs information at symbolic level, mostly about landmarks. The SVP planner takes as input a list of landmarks that could suit the destination, the choice regarding this set of landmarks is not in the scope of this paper. Each landmark is associated to a scalar representing the duration of the utterance of the route direction if this landmark is used. This duration also influences the difficulty for the human to remember the indications. In the version presented in this paper, this value is provided as an input, however [33] presents an environment model built for providing route directions that can be suitable to our approach. A similar system is being developed within our team to be integrated with the SVP planner.

3) *Human Model (visitor)*: We want the guide to adapt to different human visitor capabilities, so the system is accessible and do not discriminate certain persons by ignoring their specificities, and also adapt to a range of use cases. Our system can make use of the following information to adapt the solutions:

- height of the subject eyes, to compute its perspective accordingly;
- visual acuity to enforce the use of more visible and salient landmarks;
- navigation speed, to compute plan duration and give more important penalties to long routes;
- urgency to reach the place (to balance the importance of plan duration over other criteria).

These attributes are taken as input here but we believe they can be acquired and/or inferred through dialogue and perception (e.g. persons with a stroller or loaded shopping cart, persons in a wheelchair or with crutches are usually slower than average; a person in a hurry may express it verbally or through body attitude).

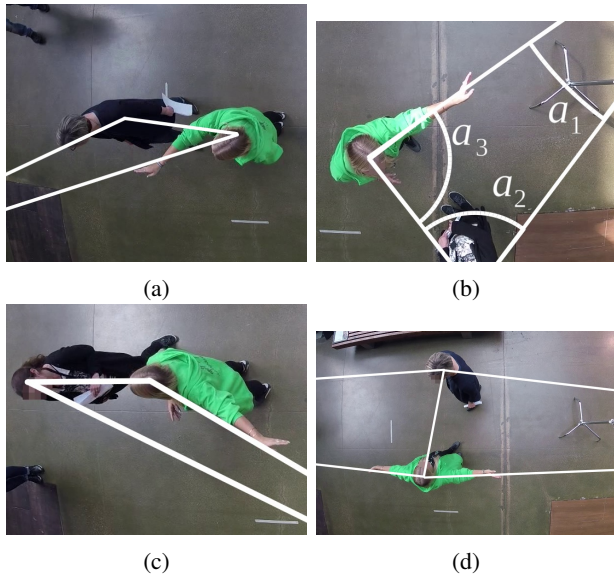


Fig. 2: Four examples of real pointing scenarios. The person wearing a green (light) sweatshirt is the guide pointing at a landmark (two in (d)); in white are represented the triangle formed by the landmark, visitor and guide.

4) *Robot Model (guide)*: The robotic guide may be able to navigate, in which case the planner can take as input a maximal distance the robot can run from its initial position. We use a speed estimation to compute plan duration (that is probably not the maximal speed, but rather an average measured speed in the same situation – environment, crowd...). Our approach can indirectly take into consideration capacities of the robot by tuning some related parameters: accuracy of the pointing gesture and gaze estimation, dialogue capacities (inducing a higher cost of dialogue-based tasks).

5) *Domain Parameters*: Some parameters may depend on the given domain where the robot is deployed. The guide may be allotted a limited amount of time to serve each visitor, or on the contrary be expected to help each visitor as much as possible, *i.e.* provide the maximum effort to solve a request once it has been asked to the guide.

## B. Evaluating the Solutions

The decision is based on estimation and comparison of the possible solutions to the task. The solution evaluation has to take into account:

- chances of success (the simpler the indications the higher is the probability that the human will remember them and reach the destination);
- optimality for the visitors – in terms of duration and effort;
- optimality for the guide according to its global objectives – serving as much visitors as possible vs. providing the best quality of service for the individuals.

1) *Placements to share visual perspective*: When pointing at an object, the guide objective is that the visitor identifies it unambiguously. To achieve this, it may be helpful to (1) reduce the difference of perspective, by getting the two agents almost aligned with the object. Stress is put on the alignment when the object is difficult to distinguish because it is small in the field of view. A secondary objective for the guide is to (2) relieve the visitor from some physical or mental effort by placing itself between the visitors and the destination, so they don't have to turn their head around to successively look at the pointing arm or gaze and in the pointed direction. A last objective on the pointing position is (3) for the guide to be able to monitor the visitor gaze, and speak to them; but the guide also needs to enforce pointing with gaze, so it should be able to look at the visitor and at the chosen landmark.

These properties are estimated by building a triangle whose vertices are the visitor, guide and pointed object centers, as represented in Fig. 2. The three angles (see Fig. 2b) denote the above mentioned properties of the pointing position. Angle ( $a_1$ ) at the pointed object vertex correspond to the difference between the perspectives of the agents. Angle ( $a_2$ ) at the visitor vertex reflects how much they have to switch from looking at the guide being pointing and the pointed object; it also indicates if the guide sees the visitor's face when they look at the landmark, allowing gaze detection or not. The third angle ( $a_3$ ) is for the guide to look at the object and the visitor. The SVP planner seeks to minimize the two first angles, as doing so would reduce visitor efforts and improve chances of success.

2) *Guiding*: The joint navigation step is evaluated considering the distance run while guiding, and the duration of the guiding step thanks to the speed estimations provided as input. When a guiding step is necessary, the solution evaluation is penalised by a constant value that represents the time needed to ask the visitor to move and explain what she/he should do.

3) *Route Directions*: The utterance of route directions to the visitor, or more ambitiously the construction of a dialogue in which the directions are given to the visitor, is likely to be a time consuming step of the task. Even more importantly, it is a critical part for the success of the task: too complex instructions will be likely to lead the visitor to get lost or simply abandon the task and find another way for reaching her/his objective, making the guide counterproductive. The duration and complexity of the route directions is directly related to the number of steps of the route [19]. The guide will need to find simpler routes, use visible landmarks to simplify them, move to a place where such landmark is visible. This is illustrated in the example of Fig. 8b where the guide uses a landmark next to the door and starts its route directions from that point, hence removing one step in the route to explain (the one to reach the door from the current position). The planner will seek to choose a landmark

associated to simplest possible route description.

### C. A Planning Request

Equipped with the data provided by the models defined section IV-A, a request to SVP planner contains at least:

- initial position of the robot (guide)  $p_{g_0}$  and the human (visitor)  $p_{v_0}$ ,
- visitor's destination position  $p_{v_d}$ ,
- list of landmarks  $L$ .

and outputs:

- placements both for the guide and the visitor,
- list of visible landmarks from those placements.

Some other parameters that are set by default can be parameterized: height of the eyes of the human; height of the eyes of the robot: those that the human consider to be the eyes of the humanoid robot, not the camera actually used for perception; speed estimations for each agent; maximal distance the robot can run from its initial position; minimal visibility score to consider a landmark visible; other parameters to tune the importance of each aspect of the task with respect to each other in the choice of the best solution (like optimizing the duration over the visibility,...).

## V. IMPLEMENTATION

The SVP planner decides where the robot and human should go to reach a good shared perspective from which efficient route directions can be given. This step is a key decision of the overall task, as the position will determine all the other steps. This is why our planner uses an objective function that encompasses all the task, rather than just evaluate the quality of the pointing and perspective. Our solution is designed to match the high coupling of all the steps of the task.

The evaluation criteria presented above are represented as cost and constraints. Constraints are inequalities that represent the validity of a solution, and costs are used to choose the best solution among the valid ones.

### A. Search Space

The planner decomposes the area accessible to the guide in a two-dimensional grid, and searches for the best pair of positions

$$X = (p_g, p_v) = ((x_g, y_g), (x_v, y_v))$$

both for the guide and visitor, expanding from the initial positions  $X_0 = (p_{g_0}, p_{v_0})$ . The destination state is  $X_d = (p_{g_0}, p_{v_d})$  (the guide goes back to its initial position and the visitor reaches the destination; if the destination is outside the grid,  $p_{v_d}$  is the position of the visitor where she/he will leave the grid).

### B. Constraints

Constraints are computed for a tuple of : landmark, visitor position and guide position, that is  $(l, p_v, p_g)$  or equivalently  $(l, X)$ . A solution is valid only if all the constraints are respected.

a) *Visibility constraint*:: ensures that the two agents see the landmark (hence that shared perspective and joint attention are possible)

$$v(l, p_g) \geq V_{ming} \text{ and } v(l, p_v) \geq V_{minv}$$

b) *Interaction distance constraint*:: interaction distance within 20% of the desired distance

$$(|p_v \vec{p}_g| - D_I)^2 < (D_I \cdot 0.2)^2$$

where  $|p_v \vec{p}_g|$  = distance between the agents and  $D_I$  = desired distance interaction. The value of  $D_I$  relates to the proxemics theory and is intended to ensure a social interaction distance. (The 20% error is actually a parameter.)

*Guide range constraint*:: keeps the guide within a certain distance from its initial position

$$d_g(X) < D_{max}$$

*Guide time constraint*:: limit the duration of the task for the guide

$$T_{Guide}(X) + T_{Return}(X) + T_{Indic}(l, X) < T_{max}$$

### C. Costs

In addition to these constraints, our implementation takes the following parameters into account:

1) *Navigation Distance and Duration*: To estimate the distances and duration of the navigation phase, we use the same grid as the visibility grid. It allows to compute shortest paths with Dijkstra Algorithm [34]. We compute the distances from three points, giving distances between these points and any point in the grid. We compute distances from  $p_{g_0}$ ,  $p_{v_0}$  and  $p_{v_d}$ , respectively providing the following path lengths for any  $X$  in the grid: distance runs by the guide  $d_g(X) = d(p_{g_0}, p_g)$ ; distance run by the visitor  $d_v(X) = d(p_{v_0}, p_v)$ ; remaining distance to reach the destination for the human  $d_{destination}(X) = d(p_v(X), p_{v_d}(X))$ .

We compute an estimation of the joint navigation (guiding) step duration as

$$T_{Guide}(X) = \max(d_g(X)/s_g, d_v(X)/s_v)$$

where  $s_g$  and  $s_v$  are the respective average speed estimations of the agents and the durations

$$T_{Destination}(X) = d_{Destination}(X)/s_v$$

$$T_{Return}(X) = d_s(X)/s_g$$

respectively for the human to reach the destination and for the robot to return to its base.

2) *Landmarks visibility from visitor and guide placements*: For each landmark  $l$  and position  $X$  we compute the visibilities of  $l$  by the guide and the visitor  $v(l, p_g)$ ,  $v(l, p_v)$ .

To speed up the computation, each visibility score is precomputed, because it is a quite expensive step. The 3D space is sampled with a grid that holds score representing perceived size of the objects in the 360 degrees fields of view from each cell center (the values of  $v(l, p)$  for various sizes



of human). Sample visibility grid (3D) are shown in Figure 3. The visibility computation itself is done by assigning each object a unique color, rendering the 3D scene with OpenGL and counting the number of pixel of each color, from each cell of the grid. To avoid issues related to distortion, the field of view is split in section of a maximum range of 90 degrees in each direction.

3) *Route direction complexity regarding a landmark:* For each landmark  $l$ , providing the route direction based on that landmark has a complexity  $C_{Indic}(l, X)$  and a duration estimation  $T_{Indic}(l, X)$ . These values are given as an input of the request.

4) *Pointing Conformation:* We use the three angles  $a_i(l, X), i = [1, 2, 3]$  representing the pointing conformation, computed from a triangle whose vertices are robot and human eyes and the center of the landmark (cf figure 2).

5) *Cost Function:* The cost function combining the parameters presented above is:

$$c(l, X) = \left( (T_{Guide}(X) + T_{Indic}(l, X))(K_v + K_g) + T_{Destination}(X) \cdot K_v + T_{Return} \cdot K_g + K_v \cdot V(l, X) + 1 \right) \times \left( \sum_{i=1}^3 a_i(l, X) K_{ai} \right) \quad (1)$$

Where  $V(l, X) = \max(0, V_{min} - v(l, X))$  and the  $K_x$  are inputs of the algorithm reflecting the properties presented in IV-A.

This is the cost for a landmark and position. As we want to choose the best landmark to point at, the cost  $c(X)$  at a position  $X$  is the best of the  $c(l, X)$ , that is

$$c(X) = \min_{l \in L} (c(l, X))$$

where  $L$  is the set of landmarks provided in the request.

#### D. Search Algorithm

Our implementation performs a search by propagation from the cell containing  $X_0$ . The propagation is based on a set of *open* cells, where neighbors of previously closed cell are added, except when the closed cell break some evaluation constraint. This prevents the algorithm to explore all the possibilities.

Table I exhibits planning times in the environment presented in Fig. 5. We can clearly see that our approach is not meant to be used for the robot to navigate long distances. Our objective here is not to present an efficient solving algorithm, but rather to investigate the modeling and evaluation of the task such a planner should use.

We can also consider that we are not actually looking for the global optimum, rather a *good* solution. Experience shows that cost function often inaccurately fathom the task, hence searching for the exact optimum of the objective function is excessive; when they are functions expensive to evaluate or with many local optima, it becomes unreasonable.

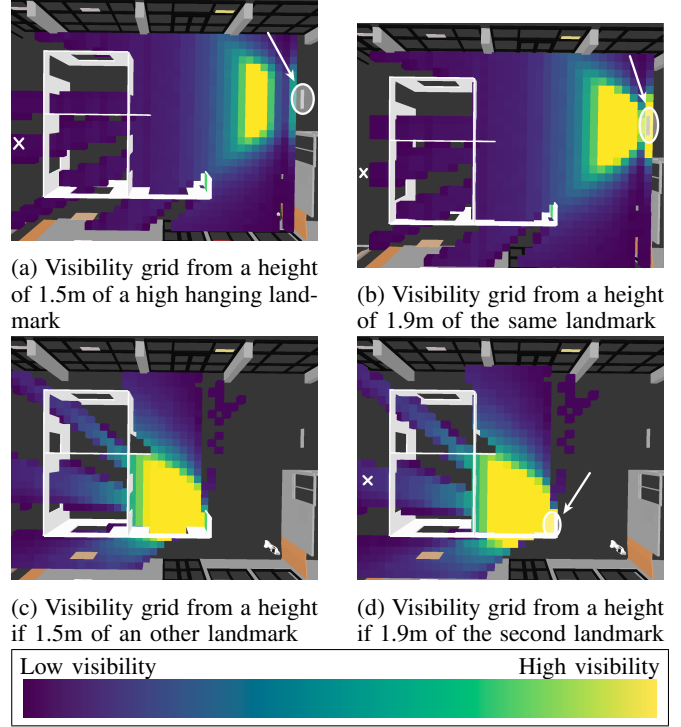


Fig. 3: Grids representing the visibility of two landmarks in our lab building environment, at two different viewpoints height. The grids are actually three dimensional, we represent here two 2D slices of two visibility grids. Cells are cubes of 40cm sides. Lighter/yellow cells are those from where the visibility of the object is the best, while from dark/purple ones the object is hardly visible. Transparent cells correspond to the object being not visible at all. We see how the visibility measure is determined by distance and obstacles. The landmark for which the visibility is shown is highlighted by a white ellipse and arrow, the cross on the far left is the position from where the perspectives of Figure 4 are taken.

#### E. Choose the Best Route

One step further, the planner could be provided multiple alternative routes, and choose the best one based on the already existing cost. Indeed, we try to capture the whole task in this cost. So this would be achieved by simply running the planner for each route, and picking the one which provides the solution with the best cost.

## VI. EXAMPLES

We present examples in two environments. The first one is a virtual mall (Fig. 5) with a central hall where the robot can navigate, and two corridors leading to a number of shops. The shops in the central row are accessible from the two corridors. The available landmarks are either signboards indicating the shops placed in their corridor, and shop fronts.

In the examples of Fig. 5, we forbid the guide to move more than 1.8 meter away from its initial position. We see

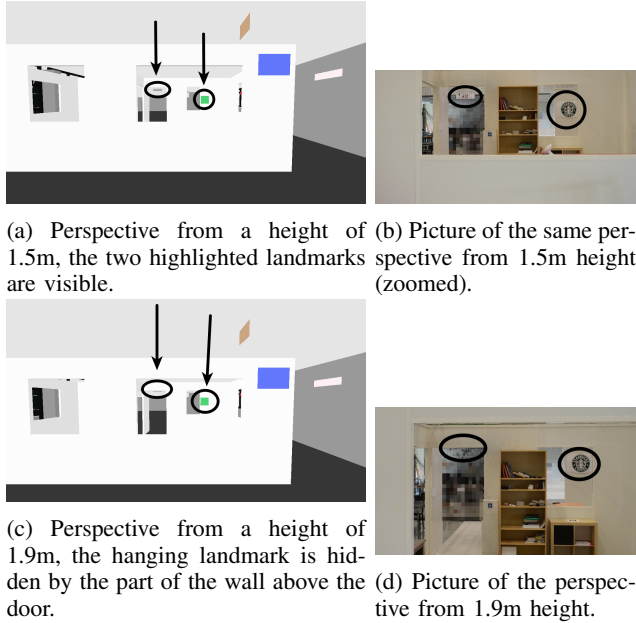


Fig. 4: Two perspective taken from the position marked in Figure 3, with the same landmarks indicated by a black ellipse and arrow.

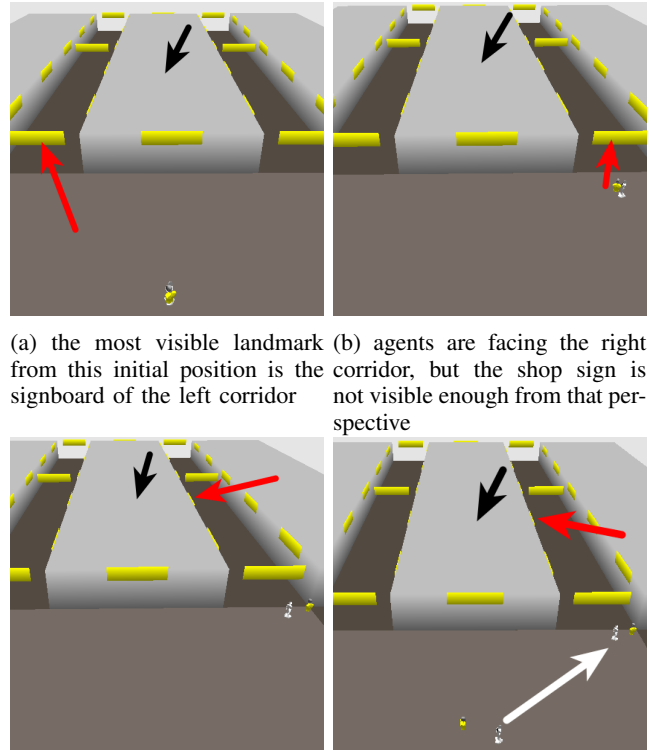
TABLE I: Planning times in the mall (resolution= 0.8m). The radius is the distance the robot must not exceed from its initial position. Times are averaged over 5 run, variance is minor due the deterministic nature of the algorithm. State numbers are the counts of states ( $X$ ) explored by the propagation algorithm.

Area radius (m)	State number	average time (s)
20	12,775	3.39
10	8,029	2.33
5	1,615	0.47

how the robotic guide is showing different landmarks depending on its position. The three solutions are obtained with the same settings and only a different initial state. Fig. 5b and 5c illustrate how a small change in the perspective can lead to significantly simpler route directions: here from “the second shop on the left side of this corridor” to directly pointing at the desired destination. When allowing the robot to guide the visitor on longer distances while inciting to find solutions with simple route directions, the robot guides the visitor to a location where the shop is visible (Fig. 5d).

The second example (Fig. 6) is the ground floor of a building of our lab, featuring an entry hall, offices and meeting room, and a large hall with an experimenting apartment. The main hall is around 12 by 20 meters the central apartment occupies a 9x9 meters square.

In Fig. 8 we show how the robot can make use of landmarks situated on the path to the destination and balance between guiding and providing route directions. In Fig. 8a the robot is guiding the visitor to a place where the destina-

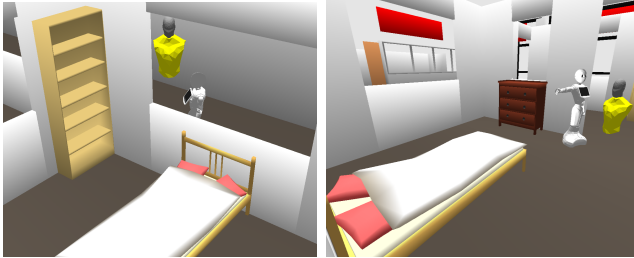


(a) the most visible landmark from this initial position is the corridor, but the shop sign is not visible enough from that perspective  
 (b) agents are facing the right from this initial position is the corridor, but the shop sign is not visible enough from that perspective  
 (c) changing the initial position of agents, the shop sign becomes visible enough to be pointed at directly  
 (d) with the same initial position of agents, the robot is allowed to move 1.8m around initial position, which is not enough to significantly change the perspective. Red arrow indicates pointed landmark, black arrow (center) is the destination location (second shop of the central row, accessible via the two corridors); on the contrary, in (d) the guide is incited to guide (white arrow) to simplify the route directions.



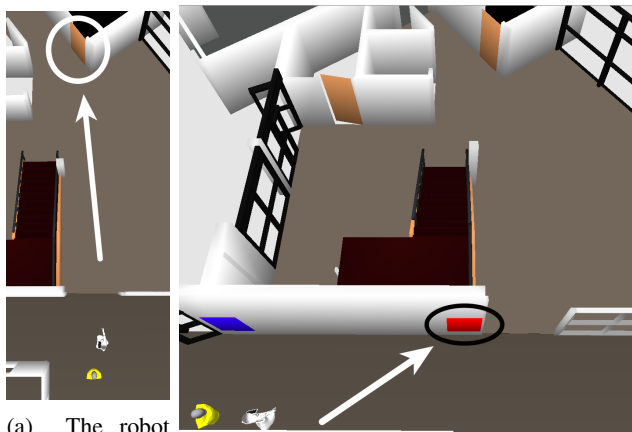
Fig. 6: Overview of our lab building 3D model, with virtual signs added to serve as landmarks.





(a) In this solution, the robot shows the bed to the human through a "window", limiting the joint navigation length. (b) With the same initial situation but with a small person (child) who cannot see the bed through the window, the robotic guide guides to get in the bed room.

Fig. 7: Two distinct solutions to the same problem caused only by a different morphology of the visitor.

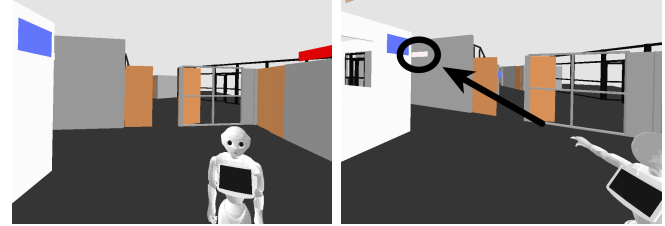


(a) The robot indicates the restroom door (top of the picture) to the human. (b) The robot points at a sign to indicate where the human should go to approach and see the restroom door (both come from the left side of the picture).

Fig. 8

tion is visible, leading to simple route directions; whereas in Fig. 8b, we set a low speed to the robot, so the planners prefers not to guide the human, and use a landmark to indicate a waypoint for human navigation (while the robot is still able to guide the human, the planner prefers no to).

The SVP planner has been integrated to a system allowing its execution on a real robot, we have been running in-lab demonstrations, and we plan to bring it to real life situations for testing. Fig. 1 shows pictures taken during an in-lab test, and Fig. 9 shows the human initial and planned perspectives in the 3D model. The request in this case was made of only one landmark, the shop front, and the robot asks the human to move a bit to reach a perspective where he can see the destination landmark. The robot too is moving to have a similar perspective. While the robot do not need to see the object, it is important that both agents share a visual perspective for an effective pointing.



(a) Initial human perspective in our 3D model. (b) Planned perspective in the 3D model.

Fig. 9: Perspectives in the 3D model for the example of Fig. 1

In this same environment, Fig. 7 illustrates the ability to take into account different human morphologies and adapt to their perspective when pointing at an object that can be hidden by obstacles, leading to very different solutions, in this case with a small child unable to look over a window edge.

## VII. CONCLUSIONS

We have presented the Shared Visual Perspective planner which is part of an original decisional framework for a robot to provide route directions to users of a public space. We have discussed the task model and its evaluation criteria and finally presented example solutions output from the implemented planner.

This framework is a preliminary work for a larger project, presenting a possible component for a complete robotic guide able to provide human visitors both route directions by pointing to the relevant landmarks.

In this framework, other components are required to provide data used for evaluating the options, along with components that will embody and execute the task. Our planner needs information about the route to indicate to the visitor: the path(s) it can take, and landmarks that could improve the route directions if they can be pointed at; [33] presents such a tool. Knowledge about the visitor goal, mental state and capacities presented in IV-A.3 can be provided by dedicated tools based on dialogue and visual perception.

The execution of the navigation (guiding) step is widely addressed in the literature [8], [5]. The pointing gesture by itself is also addressed [27], [22], along with the association of gestures with verbal route directions [23], [21], [31]. These elements would work with objectives provided by the planner presented in this paper: guiding destination, landmarks to point and route to indicate.

We are currently improving the SVP planner in order to refine the geometric reasoning and improve the overall performance: a relevant improvement would be to allow the planner to consider landmark salience and to select not one but several landmarks depending on the route description needs.

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