Fusion of Perceptions in Architectural Design

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Introduction

Perception is an interdisciplinary concept, and taking important place in many diverse applications. These range from design of objects and spaces, where perceptual qualities are aimed for (Bittermann and Ciftcioglu, 2008), to robotics where a robot moves based on perception (Ciftcioglu et al, 2006a; Bülthoff et al, 2007). In some of the above mentioned works, probability theoretic computations are used to simulate perception of objects from an observer’s viewpoint. That is, the degree to which an object is visually noticeable from the viewpoint is quantified as described in Ciftcioglu et al (2006b), Bittermann and Ciftcioglu (2008). This degree is given by a probability. Considering a basic geometric situation as shown in figure 1, for a visual scope \(-\pi/4 \leq \theta \leq \pi/4\) the probability density characterizing perception of a plane is shown in figure 1b for \(l_o=2\) and given by (1) Bittermann and Ciftcioglu (2008)

\[ f_\theta(x) = \frac{2}{\pi} \frac{l_o}{(l_o^2 + x^2)} \quad (-l_o \leq x \leq +l_o) \]  

(1)

where the probability density with respect to \(\theta\) is given by \(f_\theta(\theta)=1/\theta_S\) and \(\theta_S=\pi/2\) in (1). The one-dimensional perception of an object spanning from arbitrary object boundaries \(a\) and \(b\) on the x-axis is obtained by

\[ P_x = \int_a^b f_\theta(x) \, dx \]  

(2)
Perception is an event subject to probability. For the case of perception of an object by a single human observer the computation is accomplished by (2) when the object is considered as one-dimensional. The same computation can be valid for three-dimensional objects, provided we consider the projection of the object on a plane. In this case, the same formulation can be used twice for each respective orthogonal dimension of the plane in the form of product of the two probability densities integrated over the projected area on the plane.

**Perception from multiple viewpoints**

In this research the union of different perceptions of a single common object is investigated. Namely, as the perception is expressed as a probability, the union of different events is subject to consideration. In this respect two case studies are presented, showing a resulting equivalent single perception from multiple viewpoints. That is, perceptions from different viewpoints are fused. This type of perception requirements can occur in many practical applications. To demonstrate the perception from several viewpoints we restrict the study to two basic examples. It is noted that they may not be important depending on the particular design problem, however the example are simple in order to clearly explain the method. The same method can be applied in more complex tasks, such as courtroom design (Bhatt et al, 2011), auditorium design, office design, as well as urban design. In the first case study we consider an exhibition gallery environment, where there are several entrances to a gallery space, and we are wondering what the best position to place an object is, so that perception the object ‘receives’ is maximized. In the second application we are considering an urban environment, where a building will be erected that will be seen from a number of viewpoints. We are interested to obtain the degree of perception of the different parts of the future building from the different viewpoints. In this case study this is to identify which part of the building is most conspicuous, in order to determine for instance where the building the entrance should preferably be positioned, so that it will be easily noticed.

The scene subject to investigation in the first case is shown in figure 2a, with the three perception events $\theta_1$, $\theta_2$, and $\theta_3$. The figure shows a plan view of the space and the location of the object subject to perception assessment and optimal positioning.

The functional space is object is subject to perception from the three viewpoints VP1, VP2, and VP3, where the object respectively subtends the angle domains $\theta_1$, $\theta_2$, and $\theta_3$ as seen in the figure. The dashed lines in the figure indicate the boundaries of the observer's fields of view at the respective viewpoint, which are taken to be the same in this example. Figure 2a shows the intersections among the visual scopes $\theta_{S1}$, $\theta_{S2}$, and $\theta_{S3}$, and also the intersections among the angle domains $\theta_1$, $\theta_2$, and $\theta_3$ that are

![Figure 2](attachment:figure2.png)

*Figure 2 Plan view of perception of an object from three viewpoints VP1, VP2, VP3 (a); Venn diagram showing the union of the three perception events $\theta_1$, $\theta_2$, and $\theta_3$ (b)*
subtended by the object. Figure 2b shows a Venn diagram corresponding to the perception situation in figure 2a. In the case of perceiving an object from several viewpoints this corresponds to the probabilistic union of the perceptions, which is obtained by

\[ \Pr(\theta_1 \cup \theta_2 \cup \theta_3) = \Pr(\theta_1) + \Pr(\theta_2) + \Pr(\theta_3) - \Pr(\theta_1 \cap \theta_2) - \Pr(\theta_1 \cap \theta_3) - \Pr(\theta_2 \cap \theta_3), \]

as this is seen from figure 2b. It is noted that the events \( \Pr(\theta_1), \Pr(\theta_2), \text{ and } \Pr(\theta_3) \) are not independent, as they refer to the perception of the same object.

The probabilities \( \Pr(\theta_1), \Pr(\theta_2), \text{ and } \Pr(\theta_3) \) are obtained by similar computations as given by (2) but for two-dimensional space in the plan view or for three-dimensional space, where \( \theta \) becomes solid angle \( \Omega \). That is, in the two-dimensional case \( \Pr(\theta) = \frac{\theta}{\theta_S} \), where \( \theta_S \) is the solid angle of the scope.

A computer experiment is carried out, where \( \Pr(\theta_1), \Pr(\theta_2), \text{ and } \Pr(\theta_3) \) are obtained by probabilistic ray tracing, so that a three-dimensional object is subject to perception measurement without need for projection to a plane. Namely, vision rays are sent in random directions within a three-dimensional vision scope, where the probability density with respect to vision angle within the scope is uniform. The ray tracing for a particular object position is shown in figure 3. Figure 3a, 3b, and 3c show the rays sent to model the vision within the scope. These rays are termed vision rays. Among these rays, some are intersecting the object. These rays are termed perception rays, and they are shown in figure 3d, 3e, and 3f. In the first case study, optimal placement of the object in the gallery space will be identified by means of evolutionary search, maximizing the union of perceptions of the object.

Figure 3  Rays having uniform probability density w.r.t. the vision angle modeling visual scope of a human entering the space from three viewpoints VP1, VP2, and VP 3 (a, b, c); Those rays within the scope that hit the object subject to optimal positioning (d, e, f)

In the second case a building in an urban context is subject to perception analysis from three viewpoints. This is seen in figure 4, which schematically shows the floorplan of the urban situation, as well as the perception cones and vision scopes belonging to the viewpoints. Figure 4b shows a 3D rendering of the scene to clarify the geometric relation, where it is noted that 6 different portions of the building’s façade are respectively subject to analysis from the three viewpoints. Figure 4c shows random vision rays with uniform pdf w.r.t. the vision angle modeling visual scopes.
for three viewing positions VP1, VP2, and VP3. Figure 4d shows those rays among the vision rays that hit the building subject to perception, for perception computation. The results from the analysis for the respective building façade portions will be presented.

References

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