Geometry of Visual Experience in Large Spaces
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1. ABSTRACT
The space that you experience around yourself always has some structure, even when you are surrounded by darkness or dense fog. The otherwise "empty" space has its up and down, left and right, back and front. And when parts of the environment are visible, the structure of experience becomes more complex, articulated by what you can or cannot see from different locations. Visibility varies across locations because of the occlusion and because human vision is highly selective: sensitive to some optical patterns and blind to others. One way to describe the complex structure of spatial experience is to divide space to solid regions where different experiences are possible. This approach would allow the designer to draw maps of potential experiences for any built environment. The maps would help to predict where certain parts of the environment are perceived concurrently, and also to anticipate sequences of experiences by individuals taking different paths through the environment. I describe first steps towards constructing such a predictive model.

2. EXTENDED ABSTRACT
In the 1970s, the influential theorist of art and film Rudolf Arnheim used some core ideas of Gestalt psychology to investigate what he called "the dynamics of architectural form"[1]. He pointed out that "in perceptual experience, the spaces surrounding buildings ... cannot be considered empty. Instead these spaces are pervaded by visual forces generated by the architectural structures and determined ... by the size and the shape of their generators" (p. 30). Arnheim used a drawing by the architect Paolo Portoghesi (Figure 1) to illustrate the "perceptual fields" created by objects. The concentric circles in the drawing represent "a field of visual forces" that "expands from the center and propagates its wave front as far into the surrounding environment as its strength permits" (emphasis by SG). A metaphor inspired by physics, this view anticipated that visual experiences could be represented as a map or a continuous field.

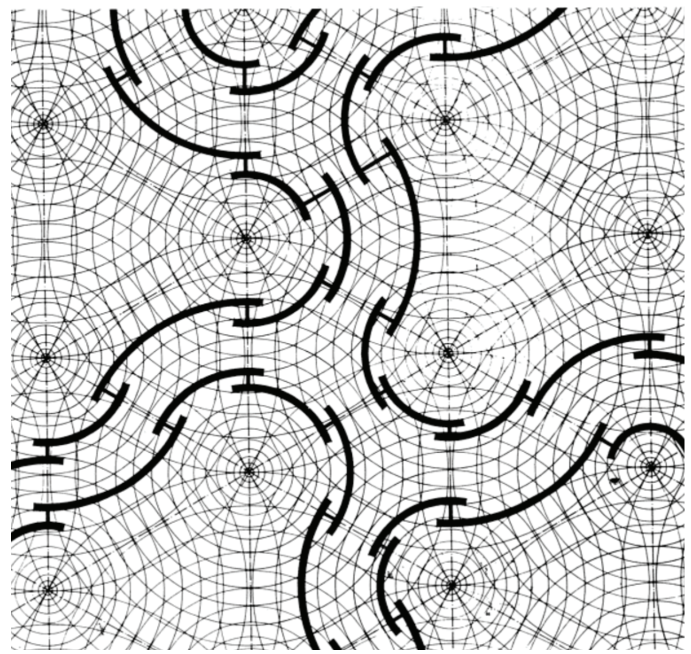

Figure 1: The plan view of a hypothetical "perceptual field" generated by an arrangement of curved walls. The drawing is by Paolo Portoghesi, reproduced from Arnheim [1].

Recipients of the inaugural Harold Hay Research Grant from the Academy of Neuroscience for Architecture, Gepshtein, McDowell & Lynn [2] launched a program of research germane to these ideas. But instead of the metaphorical "strength" of "visual forces," a readily measurable quantity was employed: a metric of pattern visibility adopted from visual psychophysics and systems neuroscience. This metric takes into account the basic fact that the amount of perceptible detail in an optical pattern depends on the distance from the pattern, called the "viewing distance."

Visibility of optical patterns had been studied previously in tightly controlled laboratory conditions. A number of models of pattern visibility were advanced and tested, of which the model of Donald H. Kelly [3, 4] is the most comprehensive. In the laboratory studies, human observers typically report their perception of patterns presented on flat screens at fixed viewing distances in small dark rooms. Gepshtein et al. [2] called this format the "cinematic mode" of perception. For this project, the model of Kelly was generalized so the researchers could derive maps of experience in large built environments, across a wide range of viewing distances. Gepshtein et al. called the latter format the "immersive mode" of perception. The goal was to establish a proof of concept for the generalized model, by testing it in the immersive mode at the UCLA Architectural Robotic Laboratory [5].

Using two industrial robots that carried a projector and a large screen (Figure 2), visibility of periodic optical patterns was measured on the scale of architectural design. Large images propelled through space were used to map the solid regions in which specific visual features could or could not be seen.

Figure 2: The apparatus used by Gepshtein, McDowell & Lynn. Large industrial robots, carrying a projector and a screen, were deployed to map solid regions of visibility for static and dynamic visual patterns on the scale of architectural design [2, 5].

For the proof of concept, the model was first validated in several paradoxical cases. In one case, visibility of patterns predictably diminished as they approached the observer. In another case, visibility dropped abruptly because of a slight change of the viewing distance, again as predicted by the model. The latter effect was enhanced when the pattern was moving, which is important when the environment contains moving parts or digital media, or when static pattern are seen in the periphery from a moving vehicle. In sum, the generalized model successfully predicted dynamics of perception in the immersive mode.

Having such a model embedded in the software for computer-aided design, the architect would be able to derive the aforementioned maps of potential experience for specific built environments. The maps would describe the most likely possibilities (or norms) of experience, rather than predict the actual experience, similar to how "competence" is generally different from "performance." To predict the actual experience, the model should also include a metric of pattern salience, and thus account for the likely shifts of attention by the observer moving through the environment.

Further details of this study, and a list of colloquia and publications inspired by this work, are being gathered in [5]. This project triggered a series of events that led to the establishment of the Center for Spatial Perception and Concrete Experience (SPaCE) at the University of Southern California [6].

2. REFERENCES

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[4] Gepshtein S, Lesmes LA, Albright TD (2013). Sensory adaptation as optimal resource allocation. Proceedings of the National Academy of Sciences, USA, 110(11): 4368-4373.

[5] http://vcl.salk.edu/~gepshtein/Hay/

[6] http://wbispace.usc.edu/

3. AUTHOR BIOS
Sergei Gepshtein, Ph.D. is a scientist at the Salk Institute for Biological Studies, trained in neurobiology, psychology, and vision science. Before joining the Salk Institute, where he directs Collaboratory for Adaptive Sensory Technologies, Sergei investigated stereoscopic vision and interaction of vision and haptic sense at the University of California, Berkeley, and then studied computational principles of perceptual organization and pattern visibility at RIKEN Brain Science Institute in Japan. His current research concerns visual norms (whose role in perception is similar to the role of laws in physics) and the question of how humans imagine future and use vision to plan and execute extended, multistep actions. Sergei increasingly collaborates with designers and filmmakers, helping to develop new methods of perceptual continuity in immersive environments: physical, virtual, and mixed.