Virtual Learning and Object Reconstruction

This installment of Computer's series highlighting the work published in IEEE Computer Society journals comes from IEEE Transactions on Learning Technologies *and* IEEE Transactions on Pattern Analysis and Machine Intelligence.

VIRTUAL ENVIRONMENTS, REAL LEARNING

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In his familiar deadpan style, comedian Steven Wright once said, "In school they told me 'practice makes perfect,' and then they told me 'nobody's perfect.' So I stopped practicing." Although we certainly hope learners reach a different conclusion, his observation highlights the central role of practice during knowledge and skill acquisition. Studies on human learning have demonstrated that providing learners with opportunities to practice improves their performance over time, reveals gaps in their knowledge, uncovers their misconceptions, and leads them to correct their errors. In so many words, practice is learning.

Enter virtual learning environments (VLEs). With virtual practice of a target skill, educators and researchers can design realistic scenarios that address specific needs, provide levels of difficulty and fidelity that match developmental aspects of learning, and allow learners to practice as long as required or desired. Multiuser VLEs connected online essentially remove any physical barriers to collaboration, teaching, and learning.

These benefits are exemplified in Stephanie August and her colleagues' work at Loyola Marymount University, as described in "Virtual Engineering Sciences Learning Lab: Giving STEM Education a Second Life" (*IEEE Trans. Learning Technologies*, vol. 9, no. 1, 2016, pp. 18–30).

In their paper, the authors introduce the Virtual Engineering Sciences Learning Lab (VESLL), a VLE developed for use in Second Life, a widely used free online virtual environment. They extol the flexibility of open and free virtual worlds, explaining how they enable both traditional, lecture-style presentations and highly interactive, collaborative, and self-directed work. In stark contrast to massive open online courses and other less immersive platforms, learners move freely within the virtual space, using chat, action, and movement to accomplish their learning goals.

VESLL focuses on key engineering education topics, including number systems, circuit design, and differential equations. These tasks are embedded "in-world," allowing learners to design, share, and interact. The authors also report on a user evaluation of the system, breaking down the appeal of the approach from a learner's perspective. Further, preliminary knowledge assessments from use of VESLL suggest that the system is at least as effective as classroom learning—an important result considering that learners work entirely virtually.

This is an exciting period for educational technology research. Nonstop innovation in human–computer interaction, including computer graphics, virtual reality, and user-sensing technologies, has made new and powerful pedagogical approaches possible. Schools, museums, and workplace learning environments are some of the most important beneficiaries of computer science's broad advances, and should serve as critical contexts for future investigations.

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RECONSTRUCTING OBJECTS FROM A SINGLE PICTURE

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How should computer programs reconstruct objects from a single picture? The objects we see in pictures are 3D, but the picture itself is a projection of the object to two dimensions. The geometry of projection isn't that complicated—for most cases, as long as we have at least two pictures of an object, there are programs that can produce excellent, detailed, and useful reconstructions.

However, a single picture is very different because many important phenomena are conflated to produce that picture. For example, a pixel might be dark because it has dark paint on it, there isn't much light, or the surface is tilted away from the light. In their paper "Shape, Illumination and Reflectance from Shading," Jon Barron and Jitendra Malik of the University of California, Berkeley, describe a novel and effective approach to untangling these various physical effects to produce—from a single picture—a reconstruction that contains the shape of an object, the patterns of reflectance on the object, and the illumination field in which the object sits (*IEEE Trans. Pattern Analysis and Machine Intelligence*, vol. 37, no. 8, 2015, pp. 1670–1687). Recovering any of these is a classical problem in computer vision.

Surprisingly, inferring all of these properties together yields superior results. An image pixel's color is determined by the light arriving at that location in the camera—light that was reflected through the lens and to the camera from some surface in the world. The surface will reflect different fractions of the incident light at different wavelengths (the reflectance of the surface), changing the reflected light's color. The illumination field in which the object sits might vary with direction (think of a flashlight beam in a dark room) and might be colored. The surface will collect more light from directions that point directly toward it, and less light from directions that are nearly tangent. Each of these effects is quite difficult to model accurately in ways that admit useful inference; for example, light doesn't just arrive at a surface patch from a light source but rather is reflected from patch to patch, and most surfaces reflect light unevenly across the outgoing directions.

Reconstruction pixel by pixel won't work. There has been some success with approximate physical models, but there's been rather more disappointment caused by ill-behaved mathematics. Instead, Barron and Malik show that strong prior constraints apply to the spatial structure of surface reflectance and geometry, to the choice of colors that appear on the surface, and to the illumination field. The trick is to produce a reconstruction that exactly reproduces the image while having the best value of cost functions that score compatibility with these constraints. By doing so, the authors are leading research in this area away from arcane mathematical questions and toward considerations of the kinds of reconstructions that are more likely. As a lagniappe, there's a rant on one author's website detailing problems with the current processes of reviewing and publication in computer vision. **C**

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