Computer Vision

Katsushi Ikeuchi
Editor

Computer Vision

A Reference Guide

With 433 Figures and 16 Tables

Springer Reference

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Preface

Computer vision is a field of computer science and engineering; its goal is to make a computer that can see its outer world and understand what is happening. As David Marr defined, computer vision is "an information processing task that constructs efficient symbolic descriptions of the world from images." Computer vision aims to create an alternative for human visual systems on computers.

Takeo Kanade says, "computer vision looks easy, but is difficult. But, it is fun." Computer vision looks easy because each human uses vision in daily life without any effort. Even a new-born baby uses its vision capability to recognize the mother. It is computationally difficult, however, because the original outer world is made up of three dimensional objects, while those projected on the retina or an image plane, are of only two dimensional images. This dimensional reduction from 3D to 2D occurs along the projection from the outer world to images. "Common sense" needs to be used to augment the descriptions of the original 3D world from the 2D images. Computer vision is fun, because we have to discover this common sense. This search for common sense attracts the interest of vision researchers.

The origin of computer vision can be traced back to Lawrence Roberts' research, "Machine Perception of Three-Dimensional Solids." Later, this line of research has been extended through Project MAC of MIT. Professor Marvin Minski, the then director of Project MAC, initially believed that computer vision could be solved as a summer project of an MIT graduate student. His original estimation was wrong, and for more than 40 years we have been investigating various aspects of computer vision.

This 40-year effort proved that computer vision is one of the fundamental sciences, and the field is rich enough for researchers to devote their entire research lives to it. This period also reveals that the field contains a wide variety of topics from low-level optics to high-level recognition problems. This richness and diversity were an important motivation for us to decide to compile a reference book on computer vision.

Lawrence Roberts' research contains all of the essential components of the computer vision paradigm, which modern computer vision still follows: homogeneous coordinate system to define the coordinates, cross operator for edge detection, and object models represented as a combination of edges. David Marr defines his paradigm of computer vision: shape-from-x low-level vision, interpolation and fusion of such fragmental representations, 2-1/2D viewer-centered representation as the result of interpolation and fusion, and 3D object-centered representation. Roughly, this reference guide follows these paradigms, and defines the sections accordingly.

The online version of the reference guide is intended to be developed continuously, both by the updates of existing entries and by the addition of new entries. In this way, it will provide the resources to help both vision researchers and newcomers to the field be on the same page with the continuing and exciting developments in computer vision.

This reference guide has been completed through a team effort. We are most grateful for all the contributors and section editors who have made this project possible. Our special thanks go to Ms. Neha Thapa and other Springer colleagues for their assistance in the development and editing of this reference guide.

March 2014

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Editor's Biography

Katsushi Ikeuchi is a professor at the University of Tokyo. He received his B.E. degree in mechanical engineering from Kyoto University in 1973 and Ph.D. in information engineering from the University of Tokyo in 1978. After working at the MIT Artificial Intelligence Laboratory as a postdoctoral fellow for 3 years, the MITI Electro-Technical Laboratory as a research fellow for 5 years, and the CMU Robotics Institute as a faculty member for 10 years, he joined the Institute of Industrial Science, University of Tokyo, as a professor in 1996.

His research activities span computer vision, computer graphics, robotics, and intelligent transportation systems.

In the computer vision area, he is considered as one of the founders of physics-based vision: modeling image forming processes, using physics and optics laws, and applying the inverse models in recovering shape and reflectance from observed brightness in a rigorous manner. He developed the "smoothness constraint," a constraint to force neighboring points to have similar surface orientations. The constraint optimization method based on the smoothness constraint, later referred to as the regularization method, has evolved into one of the fundamental paradigms, commonly employed in various low-level vision algorithms. In 1992, his paper with Prof. B.K.P. Horn, "Numerical Shape from Shading with Occluding Boundaries," was the original paper to describe the constraint-minimization algorithm with the smoothness constraint, [Ikeuchi K, Horn BKP (1981) Numerical shape from shading and occluding boundaries. Artif Intell 17(1–3):141–184] and was selected as one of the most influential papers to have appeared in the Artificial Intelligence Journal within the past 10 years.

Dr. Ikeuchi and his students developed a technique to automatically generate a virtual reality model by observing actual objects along the line of the physics-based vision paradigm [Sato Y, Wheeler MD, Ikeuchi K (1997) Object shape and reflectance modeling from observation. Computer graphics proceedings, SIGGRAPH97, Los Angeles, pp 379–387]. This early work, which appeared in SIGGRAPH1997, is considered one of the starting points of the area later referred to as "image-based modeling." After returning to Japan, he and his team began to apply the image-based modeling technique to model various cultural heritage sites. This project has become to be known as the e-Heritage project. They succeeded in modeling all of the three big Buddha statues in Japan as well as the complicated stone temple, Bayon, in Angkor Ruin, to name a few [Ikeuchi K, Miyazaki D (2008) Digitally archiving cultural objects. Springer, New York]. Through these efforts, Dr. Ikeuchi received the IEICE Distinguished Achievement Award in 2012.

Dr. Ikeuchi has also been working on robot vision. In this area, he has been concentrating research on how to reduce the cost of production by using robot vision technologies. This includes how to make efficient production lines and, more importantly, how to reduce the cost of making robot programs to be used in such production lines. In the early 1980s and even today, one of the obstacles to introduce robot technologies to production lines is the so-called bin-picking problem: how to pick up one part from a stack of similar parts. Using shape-from-shading techniques, he was successful in making a robot system that could pick up a mechanical part from a stack [Horn BKP, Ikeuchi K (1984) The mechanical manipulation of randomly oriented parts. Sci Am 251(2):100–111].

It was evident that the next obstacle was the cost of programming after completing the bin-picking system. In the early 1990s, he began a project to make a robot program which learns motions from observing human operators' movements [Ikeuchi K, Suehiro T (1994) Toward an assembly plan from observation, Part I: Task recognition with polyhedral objects. IEEE Trans Robot Autom 10(3):368–385]. He and his team demonstrated that this method, programming-by-demonstration, can be applied to handle not only assembling block-world objects, but also machine parts as well as flexible objects, such as rope knotting tasks [Takamatsu J et al (2006) Representation for knot-tying tasks. IEEE Trans Robot 22(1):65–78]. Along with his students, he further extended the method in the domain of whole-body motions by a humanoid robot [Nakaoka S et al (2007) Learning from observation paradigm: leg task models for enabling a biped humanoid robot to imitate human dance. Int J Robot Res 26(8):829–844]. They succeeded in making a dancing robot, which was capable of learning and mimicking Japanese folk dance from observation. He received several best paper awards in this line of work, including IEEE KS Fu memorial best transaction paper award and RSJ best transaction paper award.

Besides these research activities, he has also devoted his time to community service. He chaired a dozen major conferences, including 1995 IEEE-IROS (General), 1996 IEEE-CVPR (Program), 1999 IEEE-ITSC (General), 2001 IEEE-IV (General), 2003 IEEE-ICCV (Program), 2009 IEEE-ICRA (program), and 2010 IAPR-ICPR (program). His community service also includes IEEE RAS Adcom (98-04, 06-08), IEEE ITSS BOG, IEEE Fellow Committee (2010–2012), and 2nd VP of IAPR. He is an editor in chief of the *International Journal of Computer Vision*, and a fellow of IEEE, IEICE, IPSJ, and RSJ.

Through these research activities and community services, Dr. Ikeuchi received the IEEE PAMI-TC Distinguished Researcher Award (2011) and the Shiju Hou Sho (Medal of Honor with purple ribbon) from the Japanese Emperor (2012).

Yasuyuki Matsushita received his B.S., M.S., and Ph.D. in Electrical Engineering and Computer Science (EECS) from the University of Tokyo in 1998, 2000, and 2003, respectively. He joined Microsoft Research Asia in April 2003, where he is a senior researcher in the Visual Computing Group. His interests are in physics-based computer vision (photometric techniques, such as radiometric calibration, photometric stereo, shape-from-shading), computational photography, and general 3D reconstruction methodologies. He is on the editorial board of *International Journal of Computer Vision* (IJCV), *IEEE Transactions on Pattern Analysis and Machine Intelligence* (TPAMI), *The Visual Computer*, and associate editor in chief of the IPSJ Transactions on Computer Vision and Applications *Journal of Computer Vision and Applications* (CVA). He served/is serving as a program co-chair of Pacific-Rim Symposium on Image and Video Technology (PSIVT) 2010, The first joint 3DIM/3DPVT conference (3DIMPVT, now called 3DV) 2011, Asian Conference on Computer Vision (ACCV) 2012, International Conference on Computer Vision (ICCV) 2017, and a general co-chair of ACCV 2014. He has been serving as a guest associate professor at Osaka University (April 2010–), visiting associate professor at National Institute of Informatics (April 2011–) and Tohoku University (April 2012–), Japan.

Rei Kawakami is an assistant professor at The University of Tokyo, Tokyo, Japan. She received her B.S., M.S., and Ph.D. degrees in information science and technology from the University of Tokyo in 2003, 2005, and 2008, respectively. After working as a researcher at the Institute of Industrial Science, The University of Tokyo, for 3 years, at the University of California, Berkeley, for 2 years, and at Osaka University for a year, she joined the University of Tokyo as an assistant professor in 2014. Her research interests are in color constancy, spectral analysis, and physics-based computer vision. She has been serving as a program committee member and a reviewer for International Conference on Computer Vision (ICCV), International Conference on Computer Vision and Pattern Recognition (CVPR), European Conference on Computer Vision (ECCV), Asian Conference on Computer Vision (ACCV), and as a reviewer of the *International Journal of Computer Vision* (IJCV) and the *IEEE Transactions on Pattern Analysis and Machine Intelligence* (TPAMI).

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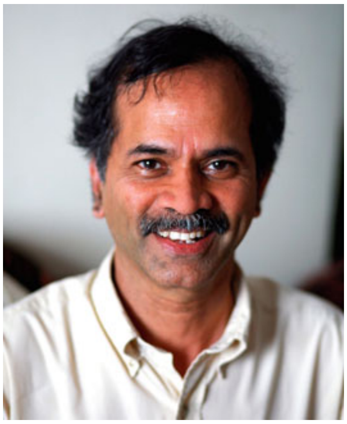

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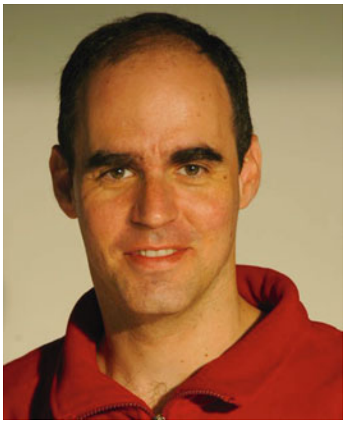

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