Image Systems Engineering at Stanford

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Abstract

A new Image Systems Engineering Program (ISEP) has recently been launched at Stanford University. The program includes more than a dozen faculty participants drawn from four departments. The planned stages of growth of the Program are described, with emphasis on the anticipated respective roles of the university and industry.

1 Introduction

An Image Systems Engineering Program has been launched at Stanford University. The program embraces a wide variety of image-related subjects, including medical imaging, image rendering, image compression, image processing, image scanning and printing, the optics of imaging, and the role of the human observer in imaging systems.

There are several reasons for creating an academic program with a special focus on imaging systems. First, in many modern systems the sheer amount of data needed to represent images is often the driving force behind computational and hardware design. Hence, it is important for engineers to understand the mathematics of image coding and compression as well as the requirements images pose on system design. Second, because of the significance of human vision within the imaging pipeline, the end-to-end design of an image system also requires an unusual interdisciplinarity, and thus a special program is needed to serve as a vehicle to integrate the training and research from faculty in different disciplines. Finally, there exists a large and still-growing collection of companies whose products are mainly concerned with the creation, manipulation, and delivery of images. This industry is international in character, but a substantial computer-related segment resides in Silicon Valley, physically near Stanford University. For all of these reasons, a grass-roots initiative from the faculty involved has led to the formation of the Image Systems Engineering Program (**ISEP**) at Stanford.

2 ISEP Faculty

The initial group of ISEP faculty have come together from four academic departments: Statistics and Psychology from the School of Humanities and Sciences, and Electrical Engineering and Computer Science from the School of Engineering. There are already more than a dozen faculty involved in the program in various ways. A list of Stanford faculty currently engaged with ISEP and a brief description of their interests relevant to image systems engineering, follows:

- Ronald Bracewell (EE) – Image mathematics

- Tom Cover (EE) – Image representations, processing, and information
- Joseph Goodman (EE) – Analysis and processing of images.
- Robert Gray (EE) – Image compression, with applications to medical images.
- Anoop Gupta (CS/EE) – Computer architecture, image compression for distance learning (e.g., internet) applications.
- Patrick Hanrahan (CS/EE) – Image rendering, graphics.
- David Heeger (Psych/CS) – Human vision, motion, and computer graphics
- Marc Levoy (CS/EE) – Image rendering, graphics.
- Al Macovski (EE) – Medical imaging and image processing.
- Teresa Meng (EE) – Algorithm and chip design for low power video compression.
- Dwight Nishimura (EE) – MRI imaging and image processing.
- Richard Olshen (Biostat) – Biostatistics applied to medical images.
- Carlo Tomasi (CS) – Computer vision, motion, image mathematics.
- Brian Wandell (Psych) – Human vision and color imaging technology.

Because of the depth and breadth of expertise represented by this group of faculty, we hope that their participation in the program will lead to a synthesis of ideas and new research directions that would be impossible without the central focus for interaction provided by the Program.

3 Industrial Participants

The Program is in an early stage of its evolution, with many of its eventual industrial partners not even aware of its existence. Even so, we have had a very substantial contribution already from one industrial partner: Hewlett-Packard generously donated $1M of image systems equipment for an Image Engineering Systems Laboratory to be used in our teaching program. In addition individuals from Xerox, Apple, and AT&T have both provided their help and expertise in the formative stages. We envision eventually a group of perhaps 20 industrial partners for the Program, structured in an organization described in the next section. Our goal will be a mixture of both US and international companies, with perhaps 50% from the US, 25% from Europe and 25% from Asia.

4 Program Model

We have experience with many different types of university/industry centers at Stanford University. Our model for ISEP is based on the very successful *Center for Telecommunications* we developed over the last ten years. From our experience in building that partnership, we know that building a structure like ISEP must pass through several different stages:

- After the initial agreement amongst faculty that there is a need to build strength in a certain area, there is a stage where the goal is to build trust between the various faculty members involved. An excellent vehicle is to hold monthly seminars for the faculty involved, with a different faculty member describing his or her research in the relevant area.
- At Stanford, we find that a considerable level of strength in the image systems engineering area already exists in our insti-

tution. Therefore, an early stage is to introduce new coherence into the program, particularly in the area of course offerings, and to give the program greater visibility to the outside world.

- Also at the beginning, we believe that a meeting involving industrial scientists and engineers can be extremely helpful in making the existence of the Program known to some of the companies that are hoped to be partners in the future, as well as to gather specific advice and suggestions about future faculty appointments, promising areas of research, and needed additions to the curriculum.

- There is no stronger indication of commitment to a subject by a research university than one or more new faculty appointments in that area. We anticipate at least one faculty appointment in the next year or two, with the specific area being chosen based on our internal perceptions of need and the advice received from our industrial advisors.

- Eventually the Program will reach a level of strength from which it can enlist more substantial help from industry. Following the model of our other centers, a center membership fee can be introduced, in return for which an industrial partner officially gains a seat on the Advisory Board, as well as receiving the benefits of one or more technical meetings a year and an advisory voice in selection of "seed research projects" initiated with funding from the Program itself. Such projects are expected to be self-sufficient after one or two years, hopefully gaining support from other external sources. In this way the funds contributed by the industrial partners are leveraged from other sources of support.

- An issue that will inevitably arise when the Program starts to fund seed projects is the status of intellectual property that may be generated from that funding. In our case, contributions to a Program are regarded as gift funds and therefore bear no overhead. In effect the University provides the overhead, and therefore retains ownership of all intellectual property. An industrial partner that wishes to license an invention made using Center funds deals with the university Office of Technology and Licensing, which has a long experience in negotiating such arrangements.

- Finally, there are two additional ways that the Program can facilitate interactions between the universityand industry. Member companies can place visitors in residence at the Program for periods of time; such visitors participate directly in the ongoing research in the Program. An alternative arrangement, very successfully used in other centers at Stanford, is the Fellow/Mentor/Advisor (FMA) program, under which a Ph.D. student (the"Fellow") chooses a research project of interest to both his/her faculty advisor (the "Advisor") and also of interest to a scientist or engineer in th member company (the "Mentor"). The advisor and the mentor both provide help and guidance to the student. In some cases, the student may be granted access to special equipment available only in the mentor's company. With a careful choice of mentor, this arrangement can greatly enhance the Ph.D. experience of the student and improve their job prospects when they receive their degree.

5 ISEP Courses

The initial curriculum of ISEP is designed for students in the MS degree program in Electrical Engineering (EE). The EE program at Stanford is large, with more than 200 MSEE degrees granted each year. While there is no thesis requirement for this degree, as part of their academic program, MS candidates must choose a "depth area" in which they take a series of at least three courses. We have established three different paths through an *Imaging Systems* depth area, each of which satisfies the depth requirement and qualifies as part of the initial Program. The three paths areas follows.

Medical Imaging Path – any three of the following courses:

- The Fourier Transform and Its Applications – the Fourier transform and its diverse applications in engineering, including the analysis of linear systems.
- Fourier Optics – Fundamentals of diffraction, imaging with coherent and incoherent light, holography.
- Medical Imaging Systems l – Imaging internal structures within the body using high-energy radiation, studied from a systems perspective.
- Medical Imaging Systems II – Imaging internal structures of the body using non-ionizing radiation, studied from a systems perspective.

Image Processing Path – any three of the following courses:

- Introduction to Computer Graphics – 2D and 3D geometric transformations, scene modeling and simulation, local and global shading models, color and photorealistic image synthesis.
- Introduction to Computer Vision – Image formation, edge detection, image segmentation, shading, texture, stereo, motion, and shape representation.
- Digital Image Processing – Mathematics of image processing operations, including sampling, quantization, linear and nonlinear filtering, compression, enhancement, and restoration.
- Applied Vision and Image Systems – Design and control of color imaging devices. Aspects of human vision relevant to software and hardware design.
- Vision and Image Processing Laboratory – Hands-on exploration of image processing, human and computer vision, and computer graphics.

Fourier and Statistical Optics Path – any three of the following courses:

- Introduction to Modern Optics – geometrical optics, Gaussian beams, wave nature of light, propagation and interferometry, –or
- Introduction to Fourier Optics (see above)
- Optical methods in Engineering Science – The design and understanding of modern optical systems.
- Two-dimensional Imaging – Mathematical analysis of two-dimensional imaging systems.
- Statistical Optics – Application of statistical tools to a variety of problems in modern optics, including imaging with partially coherent light, photodetection statistics, effects of the atmosphere on imaging systems.

ISEP will begin operation in 1996-97. In preparation, courses taught in the separate departments have already begun to integrate their offerings. For example, there has been significant cross-fertilization between the Electrical Engineering course Digital Image Processing and the Psychology course Applied Vision and Image Systems, with exchanges of lectures and cooperative design of the syllabi. With the future hiring of a new faculty member in this field in the Department of Electrical Engineering, we expect this group of course offerings to expand further.

ISEP is a grass-roots, faculty-initiated program. The program has begun by focusing on curriculum; over the next few years the educational program will be quite significant. Inevitably, from teaching collaborations and student interest, interdisciplinary research programs in imaging systems will develop. Eventually, it is possible that the Image Systems Engineering program may become an independent interdisciplinary program, offering its own Ph.D. degree and emphasizing research. Developing a program with the scope of ISEP takes time, and it must be based on a strong conviction that there is added value to both the program and its students from a base that crosses departmental boundaries.

6 Conclusions

A new Image Systems Engineering Program has begun at Stanford University. The Program comprises both an outreach to local industry and revisions of the curriculum. The new curriculum is designed to emphasize, unify and expand the coverage of this important area of science and technology. We anticipate strong growth in curriculum and inter-disciplinary research to be based within the program over the next ten years.