Center for Subsurface Sensing & Imaging Systems

Advanced Optical Sensing and Imaging Technologies

Badri Roysam (RPI)  Lance Ladic (Siemens)
Charles DiMarzio (NU)  Christoph Hergersberg (GE)
Irving Bigio (BU)  Richard Levenson (CRI)

CenSSIS Research & Industrial Collaboration Conference 2006
Oct 4, 2007
Session Agenda

- Brief Introductory Speeches by Panelists
  - Badri Roysam (RPI)
  - Lance Ladic (Siemens)
  - Charles DiMarzio (NU)
  - Christoph Hergersberg (GE)
  - Irving Bigio (BU)
  - Richard Levenson (CRI)

- Panel Discussion
- Q & A
- Closing comments and panel summary
Trends in Contemporary Biology

- Reductionist → integrative
- High-throughput methodologies
- Leveraging bioinformatics
- **Complex Systems**
  - Composed of several components that interact
  - Key properties **“emerge”** from interactions among system components
- **Dynamic Systems**
  - Processes of interest evolve over **time and space**
  - Driven by interactions and **relationships** among system components

Knowledge Infrastructure, Capable Instrumentation

Modern Biology

High Throughput

High Content
Modern Optical Microscopy: A Multi-dimensional Measurement Tool

- The only way to acquire 3-D location and spatial structure
  - Intact, un-fragmented tissue

- Fluorescence multiplexing allows multiple structures and functional markers to be recorded in context
  - Structure-structure relationships
  - Molecular gradients and signaling

- Time-lapse allows dynamic processes to be recorded
  - Structural dynamics
  - Migration and Transport

- Combining dimensions allows us to record processes in their spatial & temporal context:
  - Structure-function relationships
  - Networks and Connectivity
  - System-level analysis
Current Excitement and Challenge

- Ever increasing numbers of structural and functional endpoints can be observed simultaneously in 3-D
  - Growing libraries of organic fluorophores & quantum dots
  - Multi- and hyper-spectral microscopes
  - Spectral unmixing tools
  - Support for complex fluorescence phenomena

- Easier to work with live cells
  - Sensitive, high-resolution, 3-D imaging
  - Minimally-damaging (MP, SHG), time-resolved imaging
  - Better instrumentation + better understanding of biology
  - Fusion of multiple microscopy modalities

- High-extent + high-resolution + high-throughput imaging
  - High-throughput tissue prep & imaging hardware

Continuing Challenges
- Fewer markers at a time
- Complex data analysis
Roysam Lab Activities

- **Retinal Image Analysis**
  - Registration, mosaicing, spatial referencing, multi-modality fusion (color, FA, OCT)

- **General-purpose automated change interpretation systems**
  - Structural and functional changes in retinas, developing embryos, tumors, stem-cells, neurons,..

- **5-D Microscopy Image Analysis**
  - Recent Applications:
    - Mapping Brain Tissue
    - Stem-Cell Niches
    - Mapping embryo development
    - Mitochondrial organization and dynamics
    - High-throughput approaches to Tissue Engineering
    - Tumor Biology
    - Cancer Pathology w/ Hyperspectral Data
    - Mapping gene transcription and regulation
  - Rapid prototyping systems for microscopy image analysis

Logos:
- Siemens
- CRI
- GE
- MGH
- mbf Bioscience
- Siemens
Retinal Changes

Diabetic Retinopathy

Vascular Changes

Functional Changes from 2-wavelength

570 nm

600 nm

Geographic Atrophy

J. Biomedical Optics (2005), IEEE-TBME (2005)

Macular Degeneration (FA)
Stem-Cell Microenvironments

Doetsch 2003, Temple 2002

GFAP+, LeX+, GFAP+, GFAP+, LeX+, negative

Distance to blood vessel (µm)
Frequency

R01 NS051531, 2006 → 2011
Mapping Embryo Development

Collaboration: Bill Mohler, University of Connecticut

H1-GFP C. elegans worm

Cell Tracking

4-D Spinning Disk Confocal Sequence, every 2 mins
Discussion Points

- **Emerging and continuing trends in the optical sensing and imaging industry**
  - Are there important new directions for academic research centers to consider?
  - Are there synergistic areas of opportunity between industry and academic research centers?

- **Mechanisms and models for effective collaboration between industry and academia**
  - What has worked, and what has not?
  - Are there new ones to consider?

- **Training future leaders**
  - What can we learn from corporate in-house leadership training programs?
  - What skills are critical for engineering leadership?
  - How can industry foster and leverage the Gordon Fellows program?
  - Are there “Challenge projects” in the optical sensing and imaging area that can effectively engage industrial and academic researchers?