Course outline

Section 1: Introduction (45 mins)

- Introduction to Gradients in Images/Surfaces
  - Gradients as Vector fields, Curl, Divergence, Integrability

- Non-integrable Vector Fields in Vision and Graphics
  - Example Application: High Dynamic Range Tone Mapping, Shape from Shading
  - Importance of Integrability
  - Reconstruction from Non-integrable Fields
    - Space of All Possible Reconstructions
    - What Solution does Poisson Equation give?
    - Boundary Conditions: Dirichlet vs. Neumann

- Traditional Applications: Reconstruction from Measured Gradients
  - Photometric Stereo
  - Shape from Shading

- Modern Applications: Manipulation & Reconstruction of Image Gradients
  - Single Image Manipulation: Example, Cartooning via texture de-emphasis

Section 2: Gradient-domain Manipulation of Images (60 mins)

- Per Pixel Operations
  - High Dynamic Range Compression
  - Poisson Image Matting
  - Shadow removal

- Corresponding gradients in two images
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  - Vector operations (gradient projection)
    - Combining flash/no-flash images, Reflection removal
  - Projection Tensors
    - Reflection removal, Shadow removal
  - Max operator
    - Day/Night fusion, Visible/IR fusion
  - Binary, choose from first or second, copying
    - Image editing, seamless cloning

- Corresponding gradients in multiple images
  - Median operator
    - Specularity reduction
    - Intrinsic images
  - Max operation
    - Extended DOF

- Combining gradients along seams
  - Weighted averaging
  - Optimal seam using graph cut
  - Image stitching, Mosaics, Panoramas, Image fusion
  - A usual pipeline: Graph cut to find seams + gradient domain fusion

Break (10 mins)

Section 3: Techniques to Reconstruct from Gradients (60 mins)

- Numerical Solutions
  - Direct Solvers using Sine and Cosine Transforms
    Multi-grid solution (2D and 3D)
    Reconstruction using Projection on Basis Functions
      Frankot-Chellappa Algorithm
      Shaplets
      Wavelets
    Preconditioning
      Hierarchical Basis Preconditiong
      Locally Adapted Hierarchical Basis Preconditiong

- Robust Reconstruction Techniques
  Poisson equation is based on least squares
  RANSAC, M-estimators and Anisotropic Techniques
  Graph based Approaches

Section 4: Advanced Gradient-based Operations (45 mins)

Video Synthesis
  Spatio-Temporal Editing
  Video operations in Gradient Domain

Meshes and Surface Descriptors
  Mesh Editing with Poisson-Based Gradient Field Manipulation
  Poisson Surface Reconstruction

Others
  Gradient Camera
  Color to Gray conversion

Relevant publications of the proposers with respect to the topic

- **A. Agrawal**, "Scene Analysis under Variable Illumination using Gradient Domain Methods", PhD Thesis, Dept. of Electrical and Computer Engineering, University of Maryland, College Park, 2006

- **A. Agrawal**, **R. Raskar**, S.K. Nayar & Y. Li, "Removing Photography Artifacts using Gradient Projection and Flash-Exposure Sampling", ACM Transactions on Graphics (Proceedings of SIGGRAPH) 2005

- **A. Agrawal**, **R. Raskar** and R. Chellappa, "Edge Suppression by Gradient Field Transformation Using Cross-Projection Tensors", IEEE Conference on Computer Vision and Pattern Recognition (CVPR) 2006

- **A. Agrawal**, **R. Raskar** and R. Chellappa, "What is the Range of Surface Reconstructions from a Gradient Field?", European Conference on Computer Vision (ECCV), 2006

- **A. Agrawal**, R. Chellappa & **R. Raskar**, "An Algebraic Approach to Surface Reconstruction from Gradient Fields", IEEE International Conference on Computer Vision (ICCV), 2005

- J. Tumblin, **A. Agrawal** & **R. Raskar**, "Why I Want A Gradient Camera", IEEE Conference on Computer Vision and Pattern Recognition (CVPR) 2005

- **R. Raskar**, Kar-Han Tan, R. Feris, J. Yu, M. Turk. Non-photorealistic camera: depth edge detection and stylized rendering using multi-flash imaging, ACM Transactions on Graphics. 23(3), pp. 679-688, 2004.

- H. Wang, N. Xu, **R. Raskar** and N. Ahuja, "Videoshop: A new framework for spatio-temporal video editing in gradient domain", Graphical Models Volume 69, Issue 1, Pages 1-88 (January 2007)

- **R. Raskar**, A Ilie, J. Yu, "Image Fusion for Enhancing Context in Images and Video" ACM Nonphotorealistic Animation and Rendering (NPAR) 2004

- R. Feris, M. Turk, **R. Raskar** and K. Tan, "Specular Reflection Reduction with Multi-Flash Photography", International Journal of the Brazilian Computer Society, 2005.

- H. Wang, **R Raskar**, N Ahuja , "Seamless Video Editing", ICPR 2004

- H. Wang, **R. Raskar** and N. Ahuja, "High Dynamic Range Video Using Split Aperture Camera", IEEE 6th Workshop on Omnidirectional Vision, Camera Networks and Non-classical Cameras (OMNIVIS, in conjunction with ICCV'05), Beijing, China, Oct. 2005

- R. S. Feris, **R. Raskar**, L. Chen, K. Tan and M. Turk. Discontinuity Preserving Stereo with Small Baseline Multi-Flash Illumination. IEEE Internation Conference on Computer Vision (ICCV'05)

Bio:

Amit Agrawal received the B.Tech degree in Electrical Engineering from Indian Institute of Technology (IIT), Kanpur, in 2000 and M.S. and PhD degrees in EECS from University of Maryland, College Park, in 2003 and 2006 respectively. Prior to his graduate studies, he worked as a DSP engineer at Hughes Software Systems, India, for one year. He is currently a visiting research scientist at MERL. His research interests are in computer vision, image processing and computational photography. Current projects include motion photography, flash photography, surface reconstruction from gradient fields, high dynamic range (HDR) imaging and gradient domain imaging. His papers have appeared in several vision and graphics conferences including SIGGRAPH, CVPR, ICCV and ECCV. He is a member of IEEE and ACM.

Ramesh Raskar is a Senior Research Scientist at MERL. His research interests include projector-based graphics, computational photography and non-photorealistic rendering. He has published several articles on imaging and photography including multi-flash photography for depth edge detection, image fusion, gradient-domain imaging and projector-camera systems. His papers have appeared in SIGGRAPH, EuroGraphics, IEEE Visualization, CVPR and many other graphics and vision conferences. He was a course organizer at Siggraph 2002 through 2006. He was the panel organizer at the Symposium on Computational Photography and Video in Cambridge, MA in May 2005 and taught a graduate level class on Computational Photography at Northeastern University, Fall 2005. He is a member of the ACM and IEEE.