Dynamic Visual Computing

A Research Statement
by
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My first encounter with visual computing was to design and implement a robust function/routine/method for hidden element removal for 3D modeling of machine elements. This was part of my Masters dissertation and the work was supervised by Prof. G. Ramaiyan, Dean, College of Engineering, Guindy, Chennai. This project taught me the importance of the design of reusable libraries for graphics programming. A possible area of future research is to design a ***reusable library*** for physics based deformable objects.

At the Supercomputer Education and Research Centre at IISc, I had the twin challenge of designing algorithms for visual supercomputing to exploit the most powerful supercomputer. An added dimension here was to run programs in a production environment for top class scientific applications developed by scientists at IISc. The challenge was to handle enormous amounts of data that were transferred between the supercomputer and the Onyx super-graphics workstations. I closely interacted with Prof. Rajaraman and Prof. N. Balakrishnan at the Supercomputer Centre, which gave me an opportunity to design multi-million dollar ***research infrastructure*** which included several compute servers and 45 SGI machines to carry out cutting edge research in aerodynamics, bioinformatics and superconductivity.

Prof. Swami Manohar (inventor of the Simputer) at the Department of Computer Science and Automation at IISc supervised me on my PhD thesis on 'Parallel Algorithms for Volume Visualization of Unstructured Grids'. This research transformed the way visualization was done. Instead of using traditional triangles and tetrahedra for unstructured grid visualization, a novel scheme was proposed to exploit the emerging Volume Graphics algorithms to seamlessly visualize unstructured grids by transforming cells in an unstructured grid into voxels. The contribution of this research thesis lies in the reduced complexity that was possible due the development of a ***linear voxelization algorithm***. The work was granted an award for the Best PhD thesis of IISc. We also extended the research to exploit parallelism in all three spaces, namely, shared memory, distributed memory as well as in the massively parallel SGI reality engine hardware. In addition to visualization, we also demonstrated that linear voxelization can be used efficiently as a kernel for Rapid Prototyping in the GWorp architecture, a research project funded by the Government of India. With faster computers and larger memory, larger grids are generated rapidly and automatically, and hence this problem continues to be a hot bed of visualization research.

A major breakthough in my research career was due to an United Nations fellowship to pursue research at the National Center for Supercomputing Applications at UIUC-Urbana Champaign at USA. My stay at NCSA was hosted by Prof. Donna Cox who is a leading visualization expert and a key note speaker at SIGGRAPH and the Supercomputing conference. With more than 300 researchers and scientists at NCSA who use visualization on a production basis, there was no dearth of data. I had an opportunity to develop ***3D time-varying visualization*** algorithms for complex atmospheric data, CFD simulations as well as MRI data. My research contribution was to extend the features of Nicer-Slicer-Dicer in two tangential directions: first on comparative visualization of multiple time varying datasets

using volume visualization techniques, and second to speedup visualization algorithms using parallel machines (CM5 and the SGI 360 systems). This remains a challenge even today in the medical imaging field to register pre- and post operative data as well as to classify and segment multimodal data (CT, MRI, PET, etc.).

At the Eurographics Hardware Workshop at Maastricht, I met Prof. Arie Kaufman who invited me as a visiting faculty to the Center for Visual Computing at the State University of New York at Stony Brook, USA. My main task was to work on the US Navy project to develop a volumetric terrain rendering system that can deliver 30 frames/second. The concept we developed was similar to the 30 frames/second frame buffer, but instead of pixels, we use voxels for the volume buffer. ***Ever wondered why the US Navy was interested in terrain rendering?*** This project gave an opportunity to interact with several researchers at SUNY-SB including Prof. Amitabh Varshney, Dr. Bouquan Chen, Dr. Lichan Hong, Dr. Nilo Stolte, Dr. Suya Yao, Dr. Yong Zhou and the late Dr. Shigeru Muraki.

Dr. Andrew Abrahams from JP Morgan had a challenging project for me. Given a basket of portfolios, how do we efficiently do a pricing of the portfolio. This computation normally takes 6 hours on the production machines. When I met Dr. Andrew Abrahams at Wall Street, the research challenge he posed me was to ***take the program that takes 6 hours and run it in 6 minutes***. This will help JP Morgan to run the program several times a day and predict an accurate price for the portfolio. This enormous computational challenge can be handled only by using distributed supercomputing. I made some tangible research contributions on the JP Morgan project, but the results were never published as it was a business secret. With global bourses, realtime transactions and large mutual funds, 'computational' financial engineering is a real challenge for research.

What do Edmond, CMU and NTU have in common? At the Center for Financial Engineering, Nanyang Technological University we got a large infrastructure grant under the Academic Research fund to continue research in this area which also evoked keen interest from the Monetary Authority of Singapore. I handled three challenges as the principal investigator for a project on financial visualization. In the first work with Dr. Sampath we produced novel data mining algorithms for financial data. In a graduate thesis by Mr. Tan Toh Fei we demonstrated that volume graphics can be used for visualization of various strategies in Option Pricing. With Mr. Xiong Fei, we produced a multi-layer visualization technique to understand the mutual funds that produce better earning across the globe from a database of over 10,000 mutual funds. After completing his Masters program at NTU, Mr. Xiong Fei pursued his PhD at Dartsmouth college in the USA. As long as trading continues, financial engineering stirs the mind of analysts and computational engineering as well. As the Deputy Director of the Center for Financial Engineering, these projects on Financial Engineering provided me the opportunity to interact with Prof. Ho Kim Wai, Vice Dean, Research at the Nanyang Business School and Prof. Sanjay Srivatsava, associate dean at CMU's Tepper School who teaches economics and finance.

With Prof. Eric Sung from the School of Electrical Engineering and Dr. Zhang Yu., who graduated from the PhD program, we embarked on a novel physics based face modeling and animation. The research statement proposed by Prof. Eric Sung goes like this. ***Given several video clips, how will you efficiently recognize the face of former US president Bill Clinton with a smiling expression?*** Our goal was to develop a personalized physics based face model that will generate a wide range of natural expressions. This research resulted in several top research publications in peer reviewed journals, including the IEEE TVCG. This research was further continued by Mr. Chen Chen as part of his ongoing PhD thesis to rapidly

generate instrumented personalized faces with adaptable and animatable synthetic faces. A by-product of this research was the strong interest that evoked the interest of some skin specialists for face surgery. The potential application was a simulator that can model the skin of the human face with which the surgeon can perform a simulation to treat burns on the human face as well as for plastic surgery. The surgery simulator also helps the surgeon to make appropriate incisions for minimizing the stretch and scars on the skin surface. The challenge continues as more detailed microscopic surgery techniques continue to evolve.

A visit to the Beckman Institute at UIUC hosted by Prof. Yoshisa Shinagawa gave an opportunity to study the ***subtle facial expressions.*** This prompted us to look at image and video based facial expression analysis. Ms. Ramya Sridharan worked on her Masters dissertation to quantify the facial expressions using a dense optical flow model. Mr Evgeny Markin, a PhD student under the Moscow-NTU (MIPT-NTU) program works under my supervision to track and quantify facial movements and posture from a video input. Potential applications range from performance driven face animation to novel face-based user interfaces. Even though the results have been successful at the laboratory environment for capturing facial features, research on subtle facial expressions will remain a challenge as there are several factors such as the modeling of partial occlusion, lighting conditions and skin color that are not easy in a practical system.

Touch lab directed by Prof. Mandayam Srinivasan at MIT has carried out world class research contributions in Haptics Research from the trans-Atlantic touch, surgery simulation, force shading to brain-inspired touch. The question posed to me was: can we graphically render a ***human liver that mimics the appearance of real live liver seen by the surgeons.*** I spent the summer of 2001 at the Touch Lab, MIT to develop novel rendering schemes that can render realistically with a glistening effect. We found out that we could render using cube map a liver with realistic rendering and glistening effect. The result was presented at the MMVR 2002 conference. This work was further continued by Mr. Lu Qiang, a PhD student under my supervision to produce a parametric representation to perform real-time deformation. Further research is required to incorporate physics-based representation on geometric images. The visit to Touch Lab also gave an opportunity to work closely with Prof. Suvranu De, Prof. M. Mani, Prof. Jung Kim, Dr. David Schloerb, Mr. Wee Kee Chia and several other researchers at the Touch Lab.

Undergraduate Research Success: Apart from my collaboration with top leaders in research across the globe and the supervision of Graduate students, I have also focused on undergraduate research. One of the major success in this field of research has been to motivate and nurture young minds to persevere and pursue research. The students who worked on undergraduate research projects went on to pursue research at the graduate level. This includes Gunjan Kathuria, Tiffany Elise, Klarinda Widjanarko, Christopher Tay, Ho Suzanne, Swami Viknash and Stephen Foo. These young individuals are already in the path of becoming successful researchers and they continue to motivate young minds in the future.

Dynamic Visual Computing has gained prominence with the recent explosion of the games industry. As the Research Director of the newly established gameLAB, working closely with Prof. Tony Chan and Mr. Wong Chee Kien, I lead the research efforts in developing new techniques for high-end game shaders, game AI, game animation and techniques for online gaming. This has led to international collaborations with Dr. Mark Price (BBC, UK), Dr Lizbeth Goodman and Prof. Jeffrey Shaw. I co-chaired Cyber Games 2005 and 2006, an International Conference that focused on Games Research and Development.