# VSRC Research Programming and Computational Analysis Core

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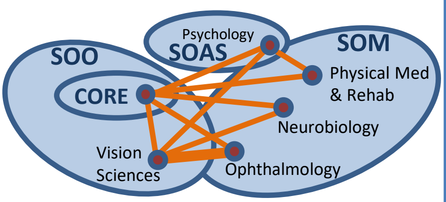
## Services and Equipment

The **Research Programming and Computational Analysis Core** offers researchers development of comprehensive custom programs and software systems for needs the available commercial products cannot meet. The software can be designed for analysis and processing of numerical and image and data. Also, the core specializes in development of instrument control systems that allow custom instrumentation to be interfaced with computers in the laboratory setting for precise control and data collection. The core actively interacts with and supports collaboration of laboratories in 5 departments of UAB SOO, SOM, and SOAS




Besides the features, capabilities, and reliability of the software being developed and provided to the scientists, the core also focuses on system usability, and efficiency. To achieve that, the core concentrates on

- **Automation** of processes and system execution what allows the systems to run autonomously, which frees researchers' time
- **Remote communications and control** of systems over the network allows researchers to attend and monitor systems executing, and to process data that is streamed in real time
- **Parallel and distributing processing** allows systems that involve excessive calculations to execute and complete in reasonable time frame on multiple units
- **Integration and consolidation of code** developed in different programming environments into single systems allows researchers to use software more effectively and efficiently

### Services include

✓ development of custom software including:
- data acquisition systems
- data and image processing
- video tracking
- customized instrument control systems

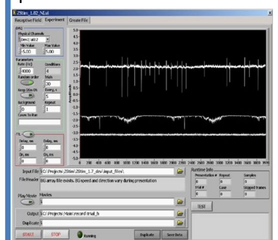
✓ website authoring, hosting and development of web applications

### Equipment

MacPro with Intel Xeon CPU and AMD Fire Pro GPU's, PC Workstations, Linux Based Servers, UAB Cheaha Cluster

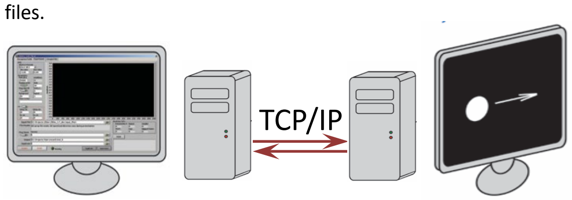
## Instrument Control System Development

**ZStim** is the fully-integrated software system that was developed for whole-cell patch-clamp recordings experiments performed on rabbit retinas in vitro.



The software allows to simultaneously display static or dynamic visual stimuli generated in real time and to acquire cell responses from a microelectrode or a microelectrode array. The system allows precise real time control of external instruments

**Figure**. The GUI allows the investigator to specify parameters of experiment execution, data acquisition and recording. All parameters of the visual stimuli can be preselected using input files.

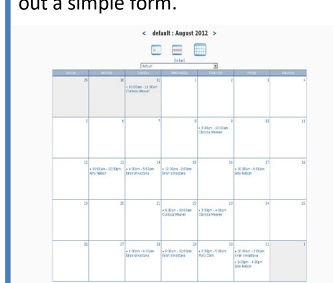



The system consists of 2 computers that communicate using TCP/IP protocol to synchronize tasks and data. The system can run autonomously for extended period of time, and data collected during experiment can be transferred to another computer on the network in real time

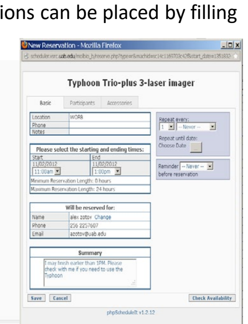
## Web Programming

### Online Equipment Schedulers

The Research Programming and Computational Analysis Core created, hosts and administers multiple online schedulers that allow the affiliates to reserve shared equipment in the VSRC Molecular and Cellular Analysis and Ocular Phenotyping Cores online.
All affiliates can register as users and view equipment reservations immediately. Reservations can be placed by filling out a simple form.



A scheduler calendar that displays all posted reservations and can be viewed online by all registered members at any time.



The available equipment can be reserved online by all registered members by filling a form.

## Parallel and Distributed Computing

### Image Processing

Post-processing of Optical Coherence Tomography (OCT) images for vessel shadow removal, contrast enhancement, and signal recovery. Adaptive amplification with image depth is applied to the image in order to estimate the tissue-intrinsic optical attenuation coefficient of each layer of the ocular tissues

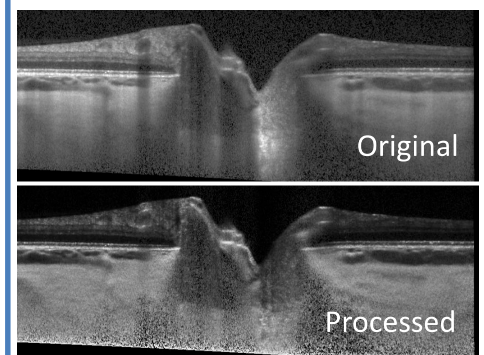
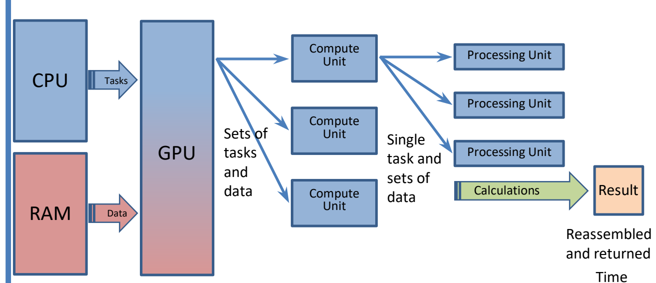



**Figure**. Attenuation of the OCT light intensity can be viewed in original image (top). Interlayer contrast of the image is significantly enhanced after post-processing (bottom), along with the removal of the retinal vessel shadows.

### Processing with Graphical Processing Unit

Some computationally intensive tasks cannot be carried out by single processors in allowed time. If a task can be separated into a set of smaller independent tasks, they can be carried out by multiple units simultaneously what drastically reduces processing time.
One approach of parallel processing is distributing computations among multiple compute units of Graphical Processing Units




An AMD FirePro D700 GPU has **2048 processing cores** running at 850 MHz what ideally delivers staggering **3.5 trillion of operations per second** (3.5 * $10^{12}$ op/s) what is about 21 times faster than a fairly solid 6-core Intel Xeon CPU running at 3.5 GHz can deliver 168 billion of operations per second (168 *$10^9$ op/s)

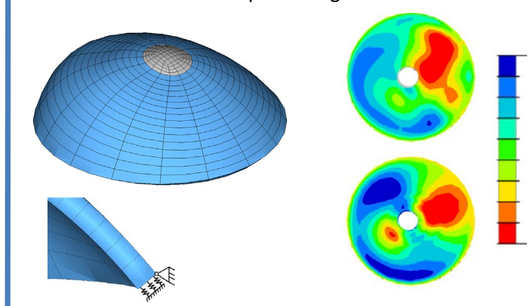
For the image processing task described above, the Research Programming Core developed an algorithm that runs on a single AMD FirePro (GPU) which allows running algorithm instructions implicitly in parallel while keeping the CPU available for other tasks. Usage of GPUs, that are constructed for massive parallelism in computationally intensive tasks, gives the advantage of processing hundreds of simultaneous tasks and provides a significant increase in the computation rate. In the case described above, computation on GPU decreased processing time 17 fold over a 6-core Xeon CPU.

### Computational Modeling

Although GPU's give great advantage over CPU's in calculations, capabilities of GPU's are limited. GPU system of a single computer cannot be extended infinitely.

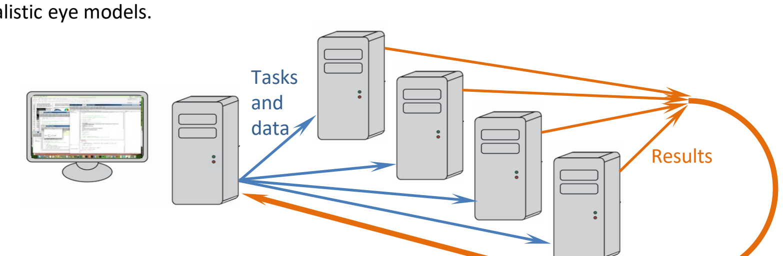
- Memory to core ratio is very low (3Mb per core in case of AMD FirePro700)
- Data transfer can be executed at the fastest rate to or from 2 GPU's at a time
- Operations GPU's can perform are limited to mathematical calculations

For tasks that require computations that exceeds capabilities of GPU's, computer clusters can be used for more efficient processing.



Finite element model of human sclera (from Rafael Grytz, Massimo A. Fazio, Michael J. A. Girard, Vincent Libertiaux, Luigi Bruno, Stuart Gardiner, Christopher A. Girkin, J. Crawford Downs, Material properties of the posterior human sclera, J MECH BEHAV BIOMED 29 (2014) 602-617

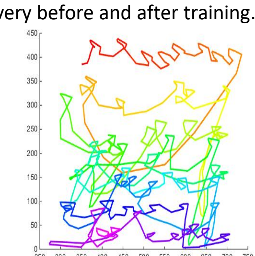
A computational inverse model of the human sclera has been developed by Grytz et al., 2014 that identifies the material properties of the tissues using a global optimization algorithm. The broad application of this method to realistic models is limited based on its computationally demanding algorithms. The computational core translates computational methods like the one of Dr. Grytz into a new cluster-based formulation using the high performance computing resources at UAB. This will allow the Grytz-lab to investigate the biomechanical changes of the eye tissues during aging and pathologic conditions using more realistic eye models.




### Video Tracking and Processing

The subject searches and marks with a pen specific shapes in a large field of objects. The software analyzes the recorded video, tracks pen movements, and records its position and time in each frame for further analysis of speed and directions of movements. The research aims to analyze and compare visual search organization in various clinical populations, in particular in patients after stroke who are undergoing inpatient rehabilitation. Preliminary findings indicate that the method can be used even for patients with the most severely impaired language comprehension due to aphasia, and therefore can provide insight to the general self-organization capabilities of brain impaired individuals, even those who have lost language skills. The method is unobtrusive and simple for patients of various kinds and can be used to evaluate others with cognitive disorders during their recovery before and after training.

The system finds the location of the pen in each frame and records the coordinates into a file for further analysis



Direction of pen movements plotted for analysis of visual search organization

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