הפקולטה להנדסה ביו-רפואית בטכניון
Department of Biomedical Engineering - Technion, Israel
מדע והנדסה לקידום הרפואה

הנדסה ביו רפואית הטכניון

פרויקט גמר

תשע"ג

בשיתוף:

GE Healthcare
Pneumedicare Ltd.
PHILIPS Medical Systems
Medoc advanced medical systems
Allium Medical
MST Medical Surgery Technologies

שלום רב,

אנו שמחים להציג בפניכם את תקצירי הפרויקטים של הסטודנטים המסיימים לימודיהם בשנה זו, שנת תשע"ג.

הפרויקט המבוצע ע"י סטודנטים בשנה"ל האחרונה מהווה את גולת הכותרת במסגרת לימודיהם לתואר בהנדסה ביו - רפואית .

במסגרת הפרויקט מביאים הסטודנטים לידי ביטוי את הידע שרכשו במהלך השנים תוך גילוי יוזמה ועניין בתחום הספציפי בו נעשה הפרויקט.
מטרת הפרויקטים לתת מענה לצרכי פיתוח ומחקר של חברות העוסקות בתחום ההנדסה הביו-רפואית תוך עמידה בסטנדרטים המקובלים. חלקם של הפרויקטים מובילים ליזמת כגון הקמת חברות הזנק ורישום פטנטים.

בברכה,

ד"ר אלכס וילנסקי , אחראי קורס פרויקטים
פרופ"ח אמיר לנדסברג, דיקן הפקולטה

3D estimation in laparoscopic surgery

Ortal Senouf;

Supervisor: Udi Pfeffer, MST-Sys Ltd

A trend in minimally invasive surgery is the transition from a procedure being fully carried out by the medical staff to semi-automatic and even fully-automatic surgeries. As a result, the need for developing computer vision algorithms for a 3D perception of the surgical scene arises. In automatic systems based on computer vision, 3D estimation is useful both for objects recognition, as well as fast and smooth convergence of object tracking algorithms. In this project we try to apply general 3D estimation and reconstruction methods on recorded data of laparoscopic scenes. Specifically, we have chosen to implement the Structure-From-Motion (SFM) method in which the 3D structure and location of objects can be evaluated from two views (or more) of the same scene (Figure). The principle behind this method is to extract corresponding features and their locations from different views and calculate the transformation between the image's 2D coordinates and the world's 3D coordinates (Figure). The current challenges are the elimination of geometric distortions (Affine,Projective) and the reconstruction of a depth map or 3D shapes from point clouds.

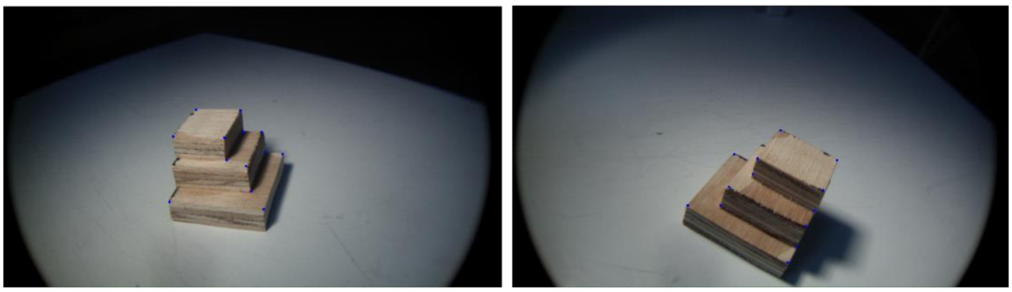


Figure 1: two views taken with a laparoscope

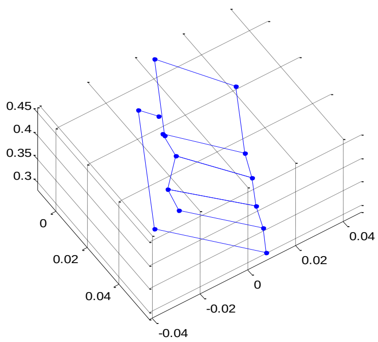


Figure 2: Phantom's 3D reconstruction

3-D Adaptive Filter for Mediastinum and Lung Parenchyma in Spiral CT

Mey Gelbart, Itai Friman;

Supervisor: Andrei Feldman, Philips Medical Systems

Lungs CT contain two main types of tissue – mediastinum (including blood vessels, fig. 1, left and right) and parenchyma (Fig. 1, middle). The mediastinum is a group of structures in the thorax surrounded by loose connective tissue containing mostly the heart and its great vessels. The parenchyma is the functional area of the lungs. The two types of tissue are characterized by different features and, therefore, require different image processing; the mediastinum has a low SNR in contrast to the parenchyma, which has a high one. Currently, the lungs CT image processing is separately done for the two types of tissue and a physician receives two separate images, one for each.

The objective is to acquire an optimal image of both types of tissue, in which the parenchyma is in good resolution fulfilling the clinical needs and the mediastinum is clear of noise. The processing is simultaneously executed to both types of tissue and the physician receives only one image. This serves as an all-in-one alternative, which is less time consuming and more convenient to the physician evaluating the CT image for clinical diagnosis.

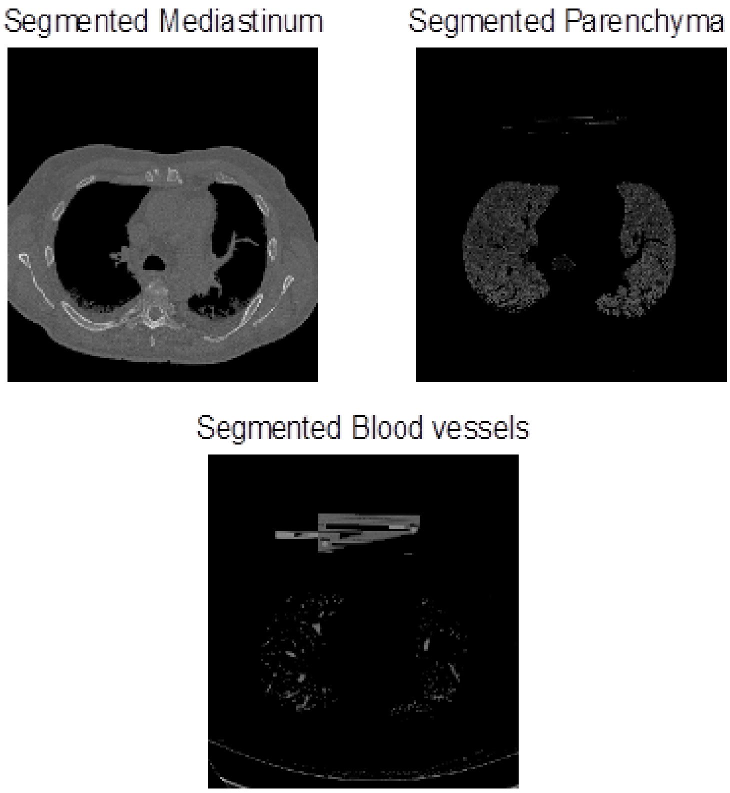


Figure 1: The three data layers resulting from segmentation of the input image. From left to right: mediastinum, parenchyma and blood vessels.

3D scatter correction algorithm for 3D CT systems

Samer Toume & Suzan Baransi;

Supervisor: Boaz Rosenan, GE Healthcare

Developing an effective scatter correction method is still a major challenge in the field of three dimensional computed tomography (3D CT), since 3D CT systems typically suffer from severe scatter distortions, artifacts and contrast loss in reconstructed images due to the large object volume exposed for each projection.

In our assignment we implemented and tested a new 3D scatter correction MATLAB algorithm (Figure 1). This venture is part of GE Healthcare Iungo project that aims to build a new frame work allowing algorithm developers, who use mainly MATLAB, to embed their algorithms in the regular reconstruction flow written in C^{++}, so they can experiment, research and evaluate the parameters of the algorithms more easily.

Our project consisted of two stages: first, we implemented all sub-functions and combined them in the right order to obtain the complete algorithm using MATLAB. Then we compared our results with the ones obtained from an existing implementation of the algorithm written in C^{++}. We adjusted our MATLAB implementation to achieve the same results.

Secondly, we embedded the algorithm into the regular reconstruction flow of the system, using GE's Iungo platform to test and evaluate the parameters to achieve the optimal performance of this 3D scatter correction algorithm.

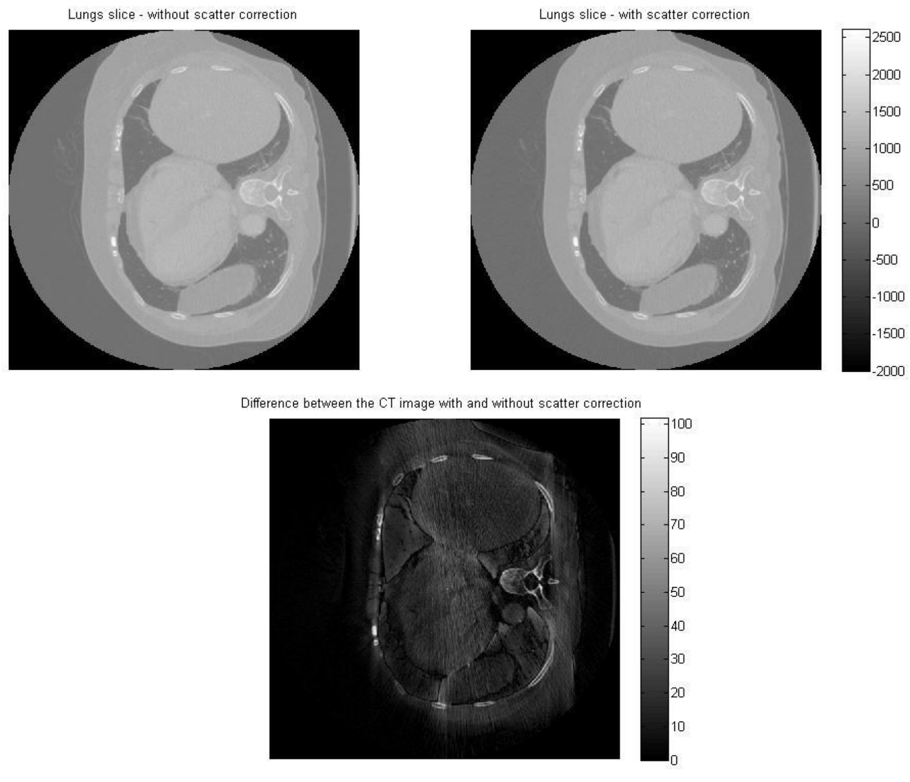


Figure 1: A demonstration of the scatter correction algorithm performance on an image of the lungs

Measuring membrane capacitance under fast pressure descent

Eti Atias & Savyon Mazgaoker;

Supervisors: Michael Plaksin , Prof. Eitan Kimmel, BME Faculty, Technion

The Bilayer Sonophore (BLS) Model predicts that the cell's membrane, composed of phospholipid bilayer, performs expansions and contractions of the intramembrane space due to changes in the surrounding pressure (Figure 1). These specific distance variations may lead to change in the bilayer membrane capacitance.

In order to confirm this theory, a specially designed voltage clamp conjugated pressure chamber was built for measuring the epithelial cells monolayer capacitance during fast pressure descent (Figure 2). Theoretical simulations provided us a forecast of the results.

A voltage clamp was used on dummy electrical circuit for simulating the epithelial cell monolayer response. The parameters revaluation was achieved using *Least Mean Square* (LMS) algorithm. The final experiment on living monolayer was not carried out due to lack of time.

In addition, an alternative approach of measuring the dependent bilayer membrane expansion capacitive current ($V_m \frac{dC}{dt}$) of charged planar black bilayer membrane was implemented during membrane potential fixation.

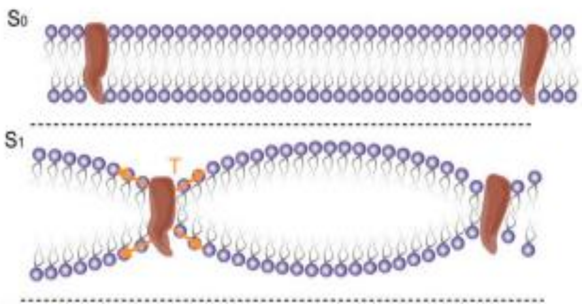


Figure 1: Interaction of BLS and a pressure field induces bioeffects on the cell membrane: protein ring defines membrane cavitation (S_1) compared with the reference stage (S_0).

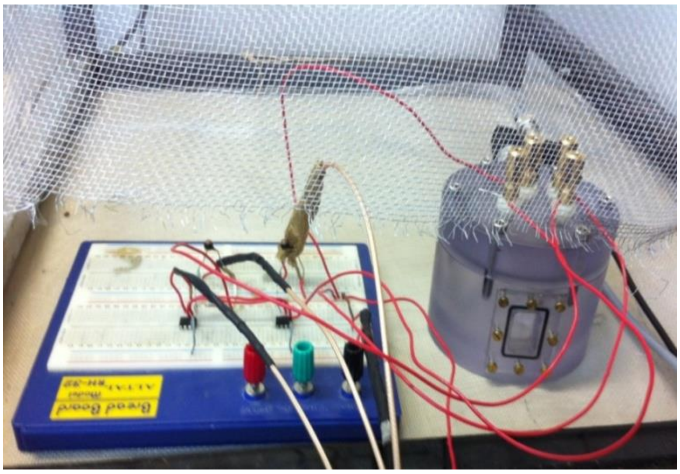


Figure 2: Our experiment system includs voltage clamp and pressure chamber, connected via electrodes. Current, voltage and pressure signals are acquired, displayed and processed using MALAB.

Auto Filter

Moran Tauber, Ohad Silbiger;
Supervisor: Andrei Feldman, Philips Medical Systems

The Window Width (WW) of a CT image is a key factor to the physician and assumed to relate to optimal image noise standard deviation (STD) and optimal reconstruction cutoff frequency.

Under these assumptions, the goal of our project is to automatically generate a reconstruction filter, based on WW and scanning Field Of View (FOV).

Our work focused on large matrix images (1024x1024), on which we have shown the possibility of achieving a desired STD through the use of a proper filter, at a given cutoff frequency. I.e. through the optimal relationship between WW and STD, an automatically created filter will reconstruct an optimal image.

The filter mentioned is based on a mathematical model using q-function [$Q(x) = 1 - \Phi(x)$], where $\Phi(x)$ is the cumulative distribution function of the normal Gaussian distribution, and was constructed using regression between desired STD and empiric filtering results. The figure below shows images reconstructed using a set of such filters, while leaving the cutoff frequency unchanged, thus minimally affecting resolution.

Future work would be to determine cutoff frequency and to correlate the model with other scan parameters, such as differentiating reconstruction matrix and noise spectrum.

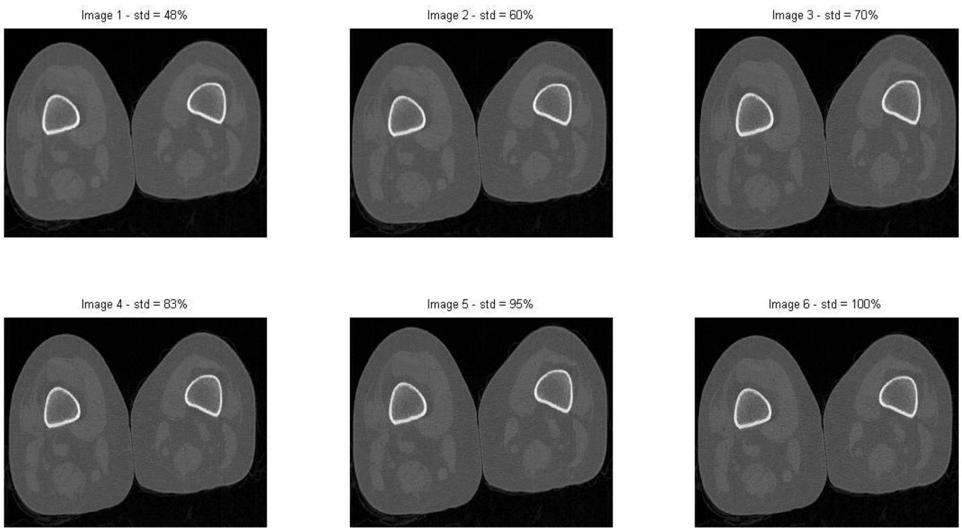


Figure 1: Images reconstructed using q-function model, ranging between 48%-100% of std. Model showed better results for std > 50% (up to 10% error).

Verification of the ability to detect and classify apneic episodes by monitoring the chest wall motion

Galit Hirshberg and Edna Friedman;
Supervisors: Sarah Kohn and Anna Faingersh, PneumedicareLtd.

Apnea is airflow cessation, which often occurs in premature infants due to their under-developed respiratory system. Apnea is one of the suspected causes for SIDS (sudden infant death syndrome) in healthy infants. In an obstructive apnea, respiratory effort increases and frequency decreases. Alternatively, lack of respiratory drive will result in central apnea, where the respiratory effort is absent. Existing respiratory monitors use parameters, such as heart rate and blood oxygen saturation levels, or detect lack of motion. Pneumedicare uses a novel technology where acceleration measurement provides an indication of effort, as well as motion.

Our project goal was to identify apneic episodes before the existing monitoring systems do as well as to classify these as central or obstructive. We acquired data during experiments in rabbits using the Pneumonitor and other traditional measurements, while simulating obstructive and central apnea. We developed an algorithm which detects change in respiratory effort and the respiratory wave forms, implemented in Matlab.

We succeeded in identifying breaths with amplitudes higher than the baseline. Additionally, we verified obstruction events analyzing the cross-correlation between the signal and a cosine wave. Our algorithm detects obstructions 20 seconds on average before saturation drops (Fig. 1).

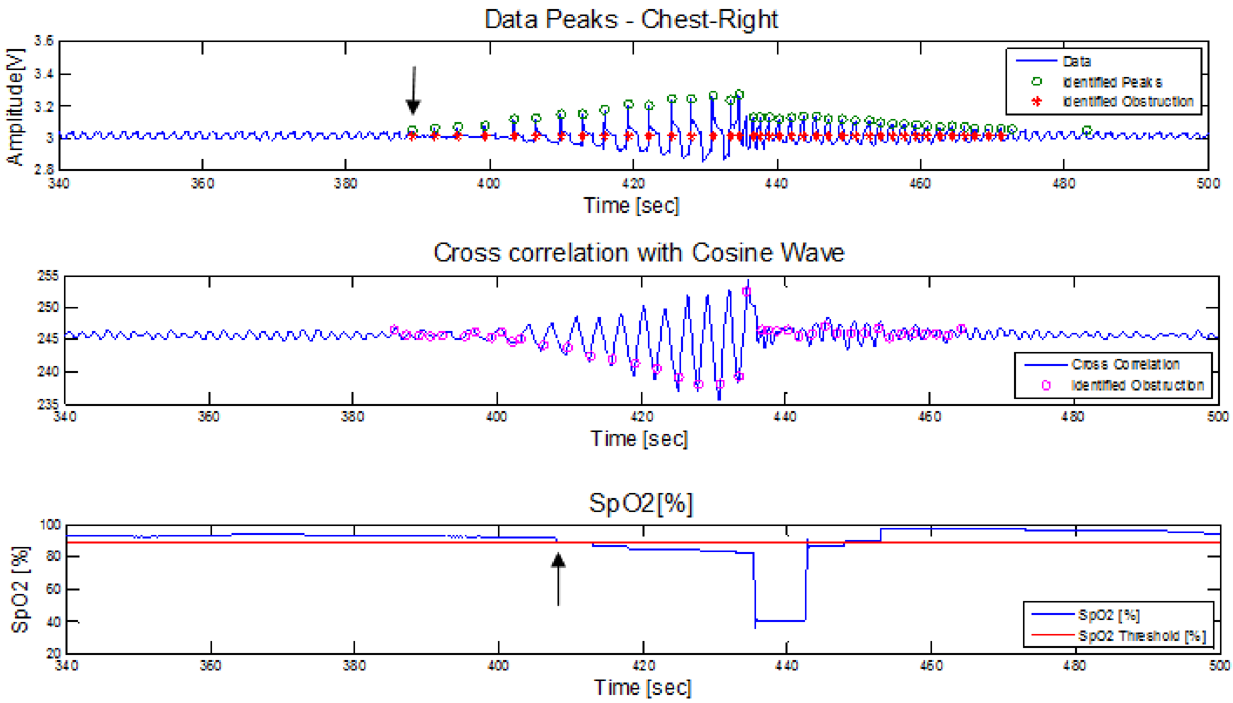


Figure 1: Algorithm identification of total obstruction: Top- find peaks method, middle-cross correlation method, bottom- saturation drop (pulse oximeter).

Endofast resorb system performance test

Lior Noyovitch;

Supervisor: Matan Gedulter, I.B.I Company

The EndoFast Resorb system is indicated for surgical mesh fixation to tissues during minimally invasive procedures of organ prolaps repair,

The System is similar to EndoFast Reliant System (FDA Approved) in design, manufacturing processes and intended use. The only difference between both products is the fastener parts material, which is metal in the EndoFast Reliant system and bioresorbable polymer in the EndoFast Resorb System. Here we can see, a fastener, anchored to a synthetic tissue.

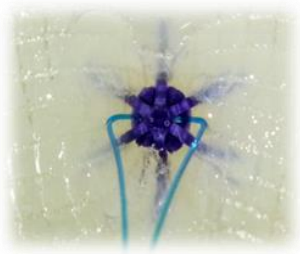


Figure 1: the EndoFast resorb Fastener

Distinguishing between the two systems requires characterization, specific and designated, for the polymer based system. Varies tests were performed, derives from the need to assure the system is capable of successfully serving the indication it is made for. Tests methods were based on: retracing and adjusting the tests being performed for the metal system (EndoFast reliant), interfacing a tensile machine through designing adaptors and fixtures and exploring the mechanical behavior of the polymer based fastener (*in vitro* tests).

Tests were designed to examine the mechanism of devices used for fixating and extracting the fastener and of mechanical behavior of the fastener (taking into consideration its degradation). The results demonstrated that fastener mechanical properties were found reliable and met all predetermined acceptance criteria.

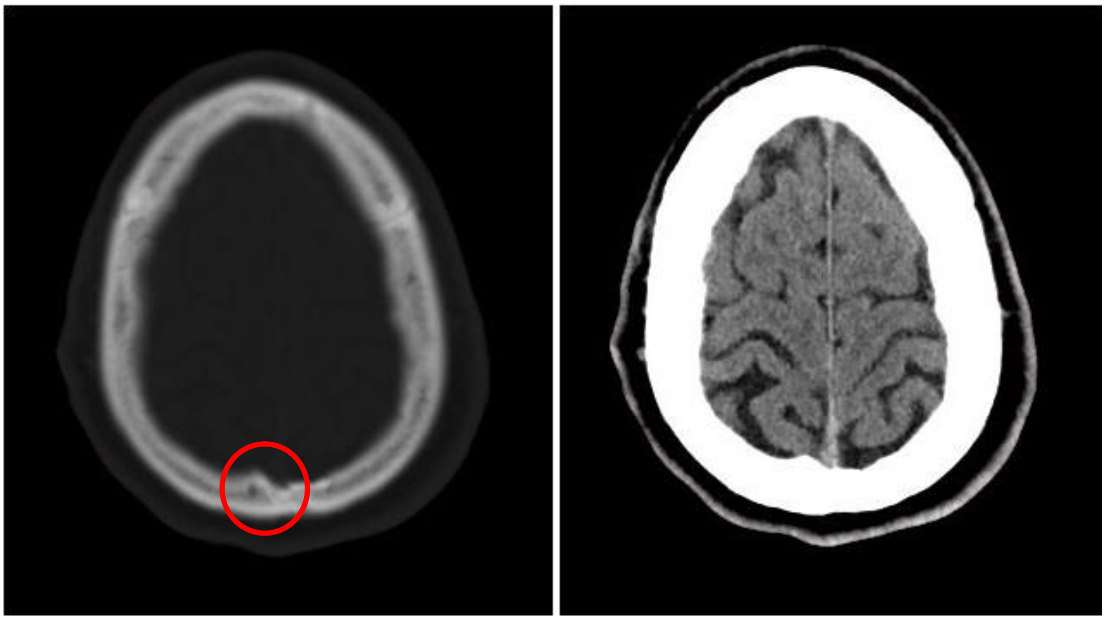
The EndoFast resorb system was founded suitable for its indication of use.

Dual Filter Reconstruction Process for Head CT Scans

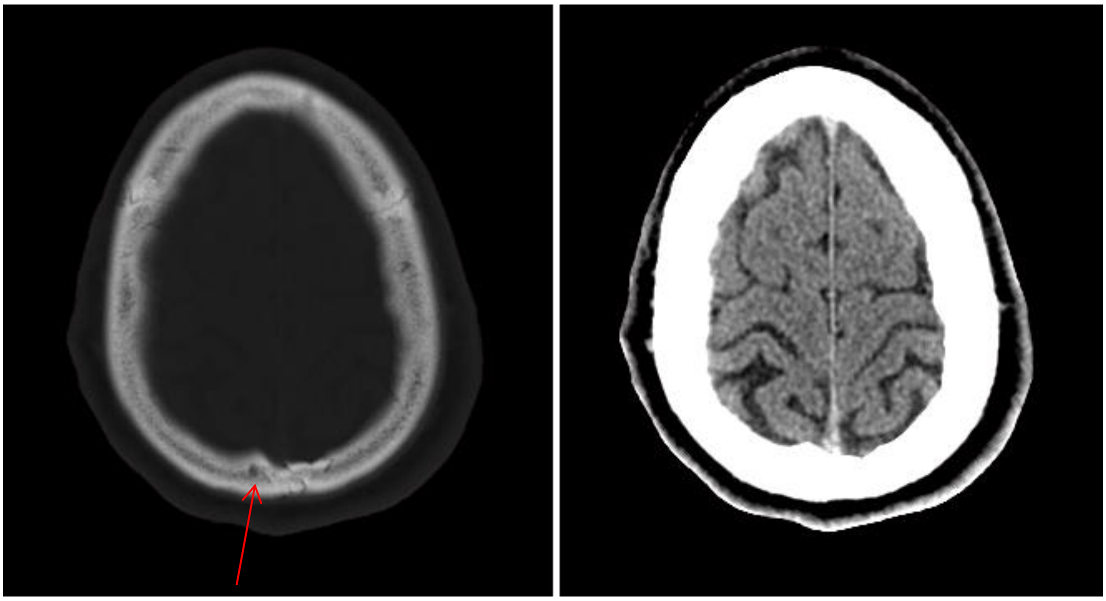
Maya Levital & Hadas Moriah;

Supervisor: Andrei Feldman, Philips Healthcare LTD.

Our project focuses on head CT reconstruction algorithms.
Currently, full assessment of head CT scans relies on two different images. These images are produced by separate and different reconstruction processes.
The reason for that lies in the nature of the head's anatomical slices, composed of two types of tissue: soft tissue (gray and white matter), and bone tissue. Bone areas present many details of pathologic importance; hence a physician wishing to evaluate bone tissue pathology must apply a high pass filter during the reconstruction process. However, in order to also detect brain tissue pathologies, he must look for low frequency patterns, such as brain hemorrhage or tumor tissue.
Moreover, both gray and white matters have almost similar X-Ray attenuation coefficients, which makes them hardly indiscernible from one another. In order to improve their visual separation, an edge enhancement filter is applied.
We have established a method to create a single image that displays both soft tissue and bone areas, satisfying the required characteristics of each. Our method comprises automatic segmentation, separate processing of different segments of the image in radon space and fusion of these segments in a smooth manner. Other issues we have successfully dealt with are beam hardening and ringing artifacts.
Results: Due to the high variance of image intensity values in bone vs. brain parts, visualization of each is simply achieved by `stretching' the range of intensity values the image contains to span a desired range of values (an operation called contrast stretching or windowing).



Left image: Bone window in reconstructed image, using current available technology. Due to time constraints, physicians normally asses both brain and bone regions relying on an image reconstructed using a filter designed for better visualization of brain parts. This is why bone areas seem blurred.
Right image: Brain window in reconstructed image, using current available technology. Brain region appears contrast-enhanced as expected.



Left image: bone window in reconstructed image created in the proposed method. The bone is significantly more detailed than in the image above. The arrow points to a tiny blood vessel inside the bone that is seen less clearly with regular reconstruction filter (compare to the circled area, top image). Right image: brain window in reconstructed image created in the proposed method. Brain region appears contrast-enhanced, as expected.

Standalone Thermal Quantitative Sensory Testing device for Diabetic Peripheral Neuropathy

Tal Aharoni & Eyal Biran;
Supervisor: Yael Frankel, Medoc Ltd.

Diabetic Peripheral Neuropathy (DPN) is a disease characterized by the impairment of A_δ and C fibers. Early diagnosis of DPN is critical for establishing the appropriate treatment.
Thermal Quantitative Sensory Testing (tQST) is a common method for detection of DPN. In this method the amount of physical stimuli required for sensory perception to occur in a patient is measured and quantified. Current tQST devices are unsuitable for clinical use.
The main objective of our project was to examine the feasibility of a standalone tQST device for DPN detection. In the first part we studied QST current technologies and determined the optimal QST device protocol and specifications for DPN detection based on previously published studies regarding QST and DPN. In the second part of the project we built a prototype based on those specifications. The prototype is based on the Arduino Nano microcontroller, and consists of several electric circuits, a response unit and a probe. Our algorithm was written in Matlab and includes features, such as temperature stabilization, temperature change in predefined rates, safety features and device response to patient feedback.

Power consumption and performance feasibility tests were conducted and confirmed our prototype requirements for a standalone QST device.

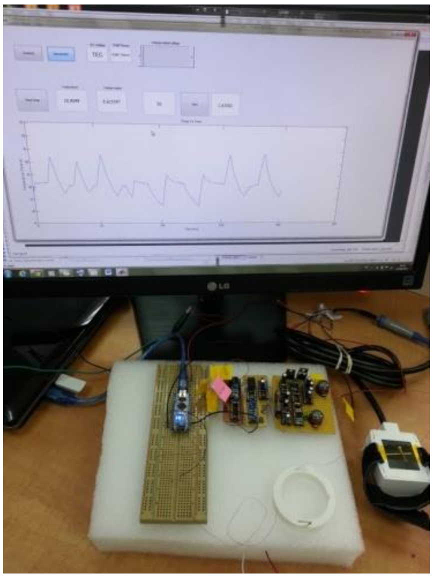


Figure 1: Standalone tQST device prototype

NEAT, a comprehensive Neural-activity Analysis Toolbox

Tom Mayblum & Tzachi Luz;

Supervisors: Omer Naor, Prof. Shy Shoham, Technion BME Faculty.

Many modern neuro-engineering applications, such as brain-computer interface and neuroprosthesis, require recording and stimulation of populations with a single neuron resolution. With large datasets, manual analysis of the recorded data becomes impossible, thus creating a need for automated, generic and user-friendly elaborate analysis tools. Using MATLAB GUI platform, we have developed a toolbox for display and analysis of recorded multi-channel neural activity (Fig. 1), enabling monitoring and pattern detection, during and after an experiment. The toolbox provides the user with multiple analysis features, including raw data presentation and basic methods, such as PSTH, Raster and local field potentials display (Fig. 2). Furthermore, advanced spike sorting algorithms are implemented to allow classification of single unit activity within electrode recording (Fig. 3). Receptive field mapping can be used to learn about the respective portion of sensory space that can elicit neuronal responses when stimulated. Semi-automated noise removal process allows focusing on relevant activity. Our open-source toolbox complies with a standard neuroscience community file format, Neuroshare, enabling its general use with various experimental and recording setups, potentially making this tool publicly available for researchers worldwide.

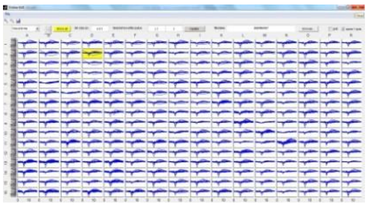


Figure 1: 256-channel display of waveform data

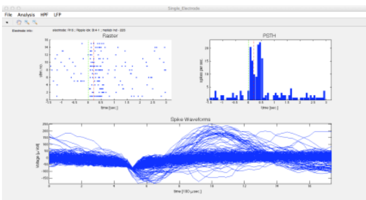


Figure 2 – single-channel view showing raster, PSTH and waveforms for a specific channel

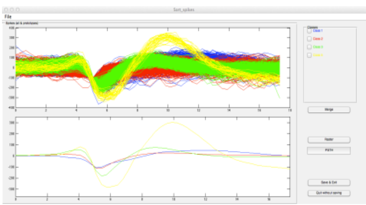


Figure 3 – single channel data after spike sorting. Each class is presented by a different color

Applying force using magnets on cells in 3D scaffolds

Noa Raindel
Supervisors: Dekel Dado-Rosenfeld, Prof. Shulamit Levenberg, Technion, BME Faculty.

Tissue engineering focuses on creating 3D engineered tissue aiming to treat or replace damaged tissue, by implanting 3D polymeric scaffolds embedded with cells. The aim of this project was creating engineered 3D blood vessels network *in-vitro* (using a co-culture of Human Umbilical Vein Endothelial Cells (HUVECs) and Human Neonatal Dermal Fibroblasts (HNDF)) as a result of the inadequate blood and oxygen supply to an injured tissue. Previous studies have shown that applying different forces on the cells (i.e. shear force or tensile strain) results in different network morphology. Using novel alginate scaffolds containing iron-oxide particles, named Ferrogels, we applied contraction forces on the cells from a distance (Fig. 1). We succeeded creating network structures for the first time on this scaffold (Fig. 2).

Our main goal was to study the effect of static and harmonic magnetic forces on engineered vessel network morphology. We designed a system for applying harmonic magnetic field on cells embedded within 3D scaffolds. The force applied on the Ferrogel and the cells was evaluated using COMSOL model. Furthermore, the organization of actin fibers was examined. Vessel-networks were imaged using confocal microscopy. Image processing algorithms were applied to compare the different parameters of networks created with and without magnetic field.

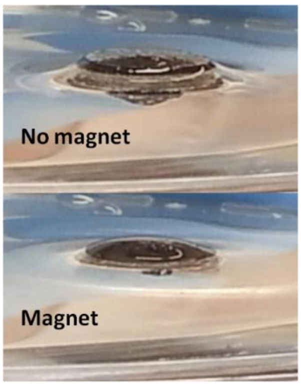


Figure 1

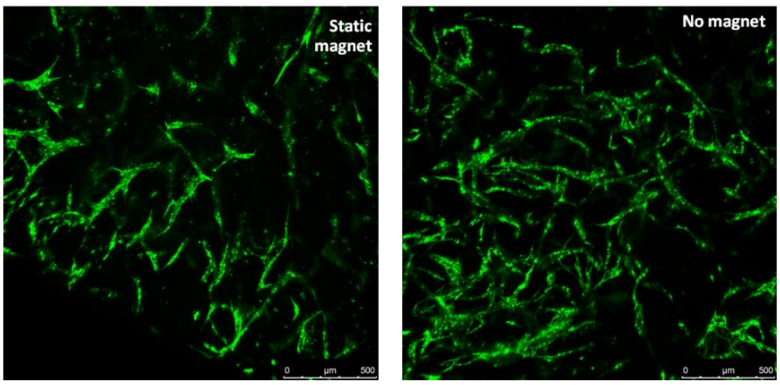


Figure 2

Cycling leg's Simulator for motion Analysis

Gotfrid Limor & Massalha Sonbula;
Supervisor: Dr. Oscar Lichtenstein, BME Faculty.

Understanding the human limbs' motion mechanism is necessary to improve prostheses and implants design. Our project includes the stages of design, building and verification of a mechanical simulator of the lower limb. Our focus is leg's motion during pedaling.

The simulator consists of three connected rods that constitute the leg's elements: thigh, shin and ankle (Figure 1). The challenge was to find a solution that simulates the anatomy, physiology and mechanics of the lower limb.

The equipment needed for the signal acquisition was defined in addition to the motion analysis method. A digital camera was characterized and purchased and Custom-made MATLAB Based Software was developed for the processing and analysis of the data enabling to track (off line) the position of each joint.

Finally, we checked the validity of the simulation by comparing the generated data with measurements recorded from actual human leg movements (Figure 2).

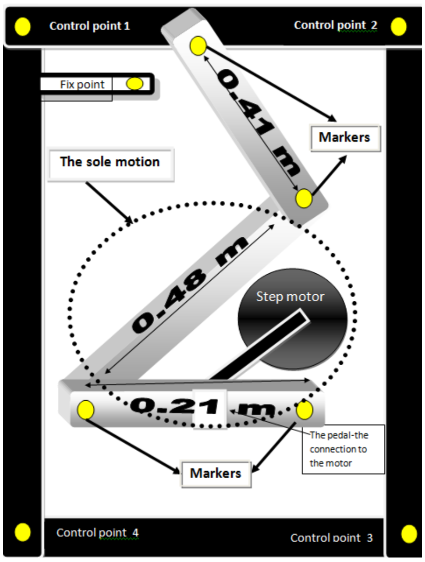


Figure 1: simulator sketch; leg's elements connected together via bearings, the foot is connected to a step motor permitting a circular motion as in pedaling.

Figure 2: Human leg simulation for comparison, the joints are marked and tracked at every frame.