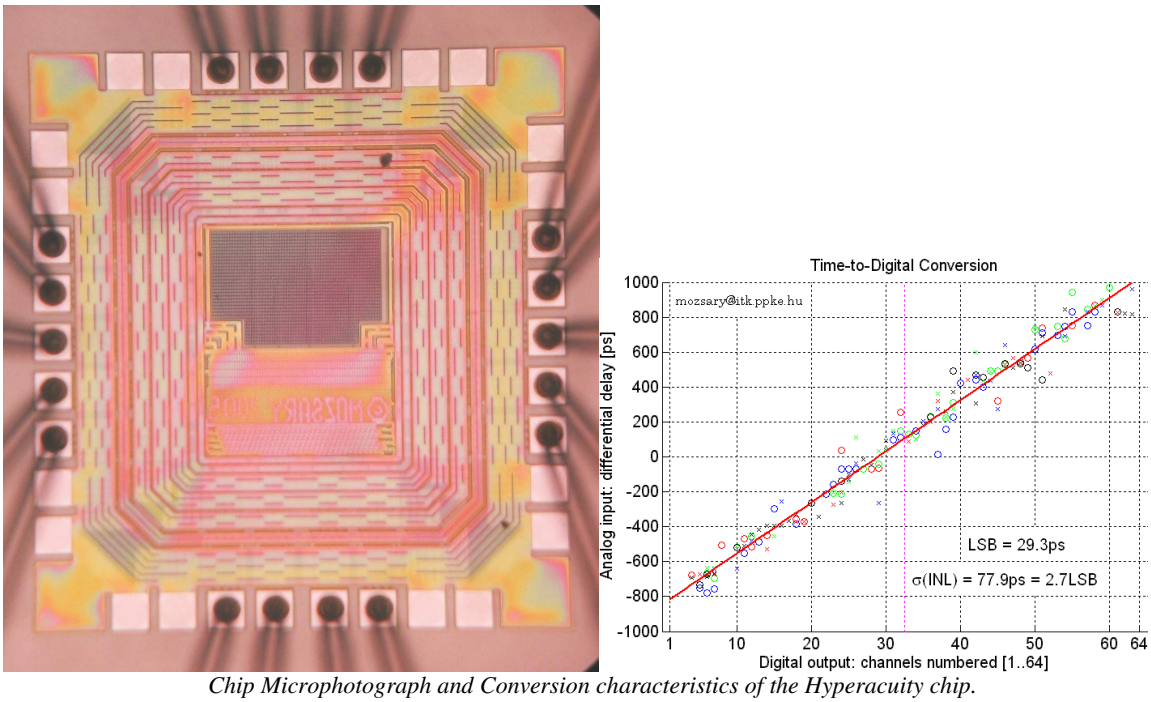
Papers

"Hyperacuity" time measurement chip: 30 picosecond = 1 cm at speed of light

András Mozsáry
(Supervisors Jen-Feng Chung and Professor Tamás Roska)

One of the best animals in auditory sensing is the Barn Owl. This champion species of hearing is able to catch its prey in total darkness, relying on acoustic signals only. The Barn owl has a sound direction sensitivity, so that it is said to hear the mouse making noise in the grass for 10cm resolution from a 3m distance. The mechanism of sound localization is based on measuring Inter-aural Time Differences (ITD). There is time difference between the sound reaching the two ears on the head of the owl. Consider the sound source is on the right side of the owl, than right ear is closer while left ear is more far away from the sound source. Conclusively, the path of the sound waves travelling to the left ear is longer distance, and the path to the right ear is shorter. One can calculate the delay between two ears, based on the geometry of 10cm resolution and the finite propagation speed of sound 340 m/s. The result is on the order of 10 microseconds. The direction-sensitive neurons in the Owl's brain compose a simple and regular anatomy. This grid structure found in the Nucleus Laminaris and the Inferior Colliculus has been translated to Cellular Neural Network – Wave Computer , and implemented on a 0.35µm CMOS technology integrated circuit chip. Like the two identical ears, there are two identical chip input pins 'IN1' and 'IN2'. Input signals are two rising edge step pulses, and the circuit measures delay between them. The output is a digital 6-bit binary number. The circuit has a symmetric input range from –950ps to +950ps. The time resolution of 29.3ps was measured. For illustration, we may calculate flight of a light beam, that takes 29.3ps · $3 \cdot 10^8$m/s ≈ 1cm distance.

Electronic equipment that can measure time of such fine resolution are called Time-to-Digital Converter (TDC). TDCs are required in many nuclear physics experiments like elementary particle tracking and lifetime measurements. (drift chambers, etc.) Another popular application for TDCs is 3D ranging and laser distance measurement. The developed CNN based Bio-inspired TDC employs a new architecture, and it is a good alternative of existing solutions in terms of resolution and conversion speed.



Chip Microphotograph and Conversion characteristics of the Hyperacuity chip.

Nanoantenna Design for THz-band Rectification

Gábor Matyi
(Professor Árpád I. Csurgay)

This paper deals with high-speed THz-band rectifiers composed of nanoantennas and metal-oxide-metal (MOM) tunneling diodes [1,2]. These rectifiers do not require cryogenic temperatures and can be fabricated using CMOS compatible technology, thus they can be integrated with CMOS circuits. We proposes a new design method for nanoantenna-MOM-rectifiers operating at a given frequency-band (f_0) with maximum achievable sensitivity. We have developed a design procedure for single- and double-band, CMOS-compatible, room temperature THz rectifiers for maximal sensitivity.

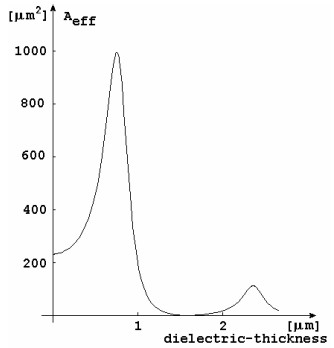


Figure 1. *The effective area of a nanoscale patch-antenna versus dielectric-layer t hickness (The other parameters are constant)*

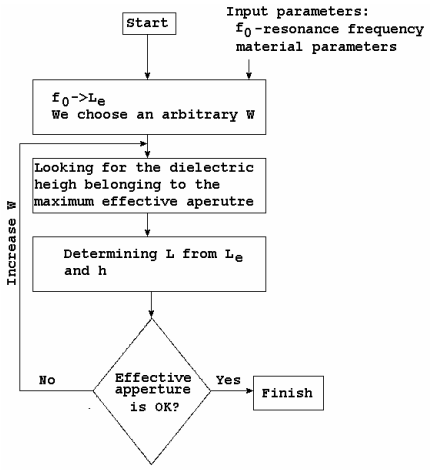


Figure 2. *The design algorithm for single band THz rectifier*

The sensitivity of a rectifier depends on the effective aperture of the antenna (A_{eff}). However, A_{eff} strongly depends on the thickness of the dielectric-layer and the width of the antenna. At small dielectric-layer thicknesses the A_{eff} is small. By increasing the thickness of the dielectric layer the A_{eff} increases until it reaches its optimal value. When we further increase the thickness the A_{eff} will decrease because more and more surface waves are generating on the border of the dielectric layer and it degrades A_{eff}. By increasing the width of the antenna we can further increase the value of A_{eff}.

The Configurable Digital Neural Network with Emulated Digital Cellular Neural Network Cores

Tamás Zeffer

(Professors Ferenc Kovács and Timót Hídvégi)

***Abstract* – A configurable Artificial Neuron Network that is capable of establishing both the emulated digital Cellular Neural Network (CNN) and the static Multilayered Feedforward Neural Network (MFNN) is described. The configurable neural network is designed with the method of modularity where each module is a three weighted input neuron. The network can be optionally large limited only by the gate number available on a chip.**

I INTRODUCTION

Artificial neural networks consist of many interconnected signal processing elements called neurons. In our VLSI solution, we clearly define the function and the interface of these elements for two reasons: in order to utilize the tenet of modularity in IC design and to achieve configurability of size and type of a configurable artificial neural network. In this paper, we present this structural design that makes both types of neural networks configurable, the Cellular Neural Network (CNN) with optionally large neighborhood and the Multilayered Feedforward Neural Network (MFNN) with arbitrary large layers. Besides these features, we also merged these two architectures into one where only a few control signals change the arrangement of the neurons into CNN (CASTLE) [1] performing in parallel or into MFNN.

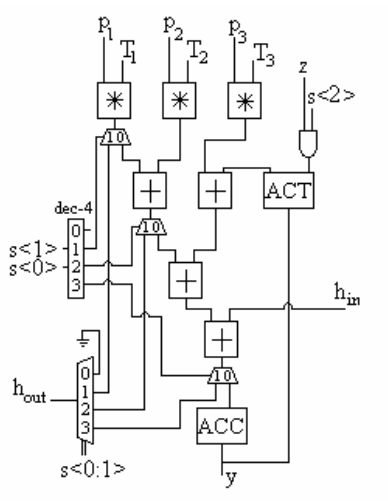
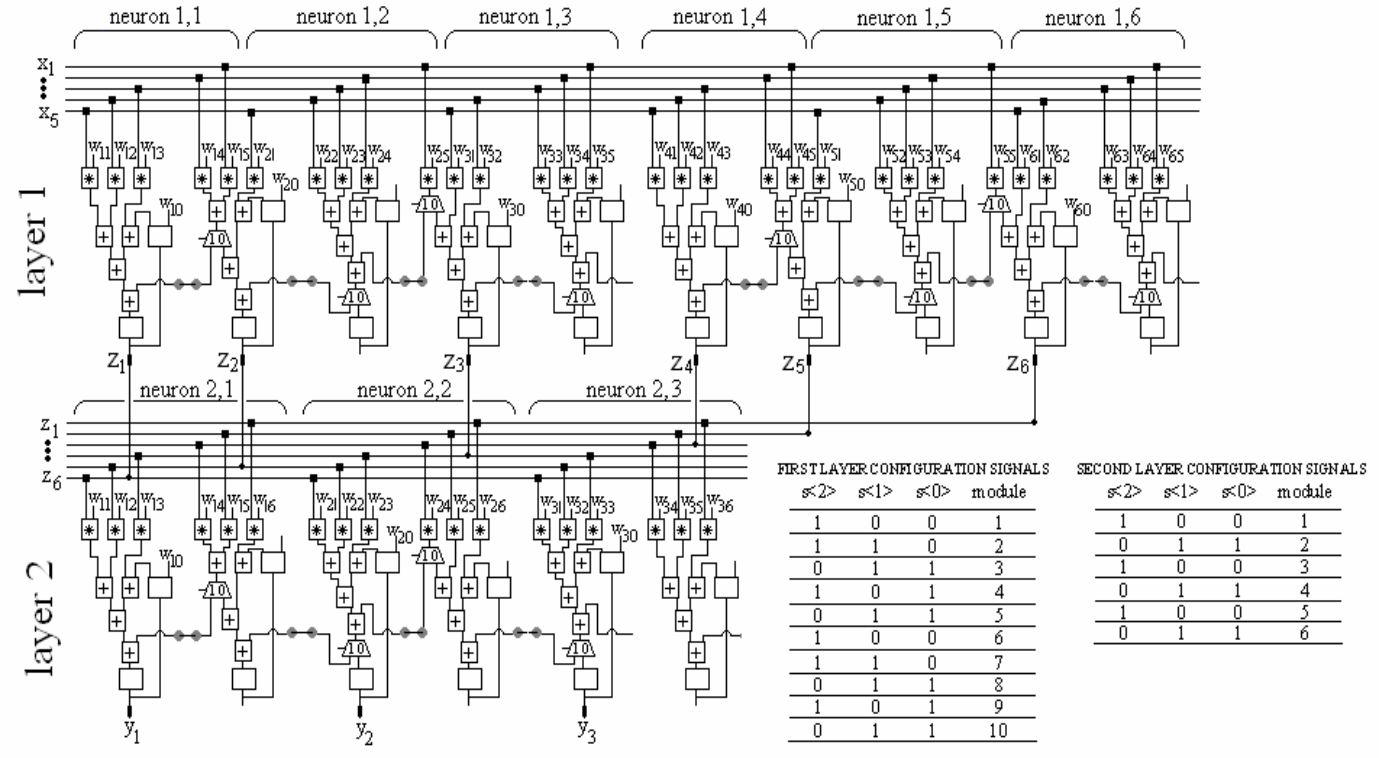


Figure 3
The three weighted input neuron, the basic module of the configurable neural network.



FIRST LAYER CONFIGURATION SIGNALS

s<2>	s<1>	s<0>	module
1	0	0	1
1	1	0	2
0	1	1	3
1	0	1	4
0	1	1	5
1	0	0	6
1	1	0	7
0	1	1	8
1	0	1	9
0	1	1	10

SECOND LAYER CONFIGURATION SIGNALS

s<2>	s<1>	s<0>	module
1	0	0	1
0	1	1	2
1	0	0	3
0	1	1	4
1	0	0	5
0	1	1	6

Figure 4
An example of a static MFNN network. A two-layered feedforward neural network with five input signals. The first layer is configured to include six neurons and the second layer three neurons. The configuration signals of each layer are also listed.

Low-Voltage Low-Power Cellular Non-Linear Network Universal Machine

Gaurav Gandhi
(Professor Tamás Roska)

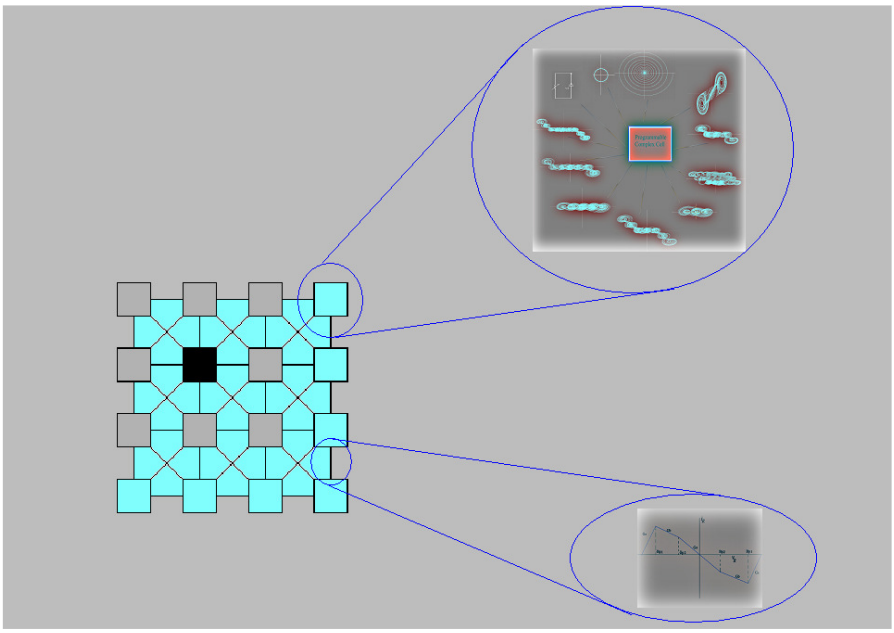
A novel architecture of a fully programmable low voltage, low power, cellular non-linear network univesal machine is proposed. It is programmable both at cell level as well as the connectivity and works as a simple as well as a complex CNN universal machine. It works as a general purpose computer with applications ranging from basic image processing to complex retina modelling.

The programmable cell works in four different basic modes

1. Parellel R-C circuit.
2. A decaying/sustained sinusoid.
3. A chaotic circuit (double scroll).
4. A Multi-Scroll Grid (MSG) attractor circuit.

All these modes are controlled through switches coming from Switch Configuration Register (SCR).

It also encompasses a programmable resistive grid with programmable breakpoints as well as programmable slopes. The intended design is for a piece-wise linear programmable resistive grid, eventough the smooth non-linearity option is also being explored.



A Fully Programmable Low voltage low power Cellular Non-Linear Network Universal Machine

Tactile Sensing:
Cover Geometry & the Inverse-elastic Problem

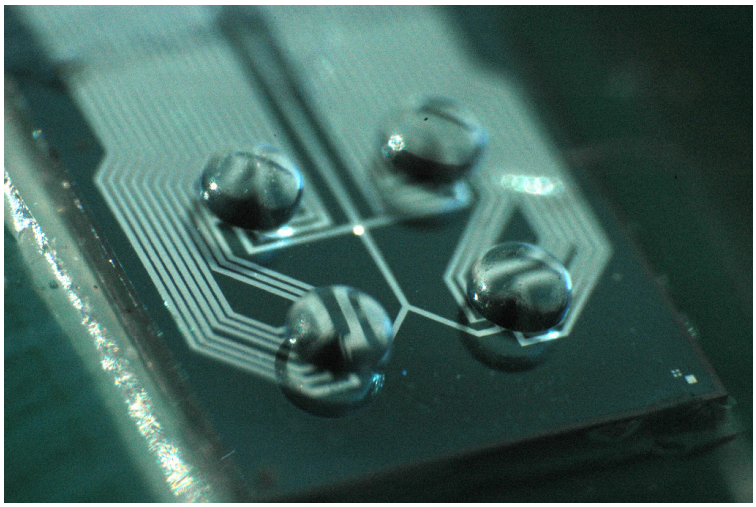
Gábor Vásárhelyi
(Professors Tamás Roska and Ferenc Kovács)

The skin-like elastic cover of a tactile-sensor array plays a fundamental role in determining how the sensor is responding to a spatial/temporal surface stimulus. While the sensor under the elastic layer measures the local strain/stress, we are interested in the stimulating force distribution at the contacting surface. My work deals with the described inverse problem in the stationary case over a three-axial tactile-sensor array, measuring three components of the local strain tensor of the elastic cover.

First, I created a kind of tactile hyper accuracy by giving a simple analytical solution to the case when a flat rubber surface is indented by an arbitrary point load. On the real sensors (made by the Research Institute for Technical Physics and Materials Science (MFA) of the Hungarian Academy of Sciences) I checked the validity of this inverse solution by calculating the location and loading amplitude of a needle, moved along the flat rubber surface. The position of the needle could be reconstructed by the three-component strain signal of one single taxel by 3-5 μm accuracy over and area of around 300x300 μm—creating high-resolution tactile hyper accuracy.

Secondly,—instead of generalizing the solution to more complex cases—I avoided the inverse problem by changing our cover's geometry and making the sensor's functionality more direct. I created hemispherical bumps over the elastic surface and used a finite-element model (made by Balázs Fodor from the TU of Budapest) to show that with the bumps I can discretize the input and detect normal and shear force components independently. I confirmed my theoretical results with texture classification experiments. I pulled different materials over the sensors and extracted typical features from the temporal signals (such as the friction coefficient or surface roughness). Results could be used for real-time classification of different textures.

Using the finite-element results I also showed that the elastic hemispheres can be used to enhance the functionality of an arbitrary pressure-sensor array. Placing the proper cover on a rectangular sensor array we can extract information about *shear* indentation, namely, with the cover we can convert the 1D taxels to 3D ones. After creating the real covers my measurements showed that this conversion is applicable. These new 3D-sensor arrays could be adopted efficiently in an arbitrary robotic task or medical application.



A four element MEMS tactile-sensor array, covered by a skin-like elastic layer. The hemispherical bumps act as artificial fingerprints and modify the overall characteristics of the sensors.

Grasp Planning Based on Fingertip Contact Forces and Torques

Kis Attila
(Professors Ferenc Kovács and Szolgay Péter)

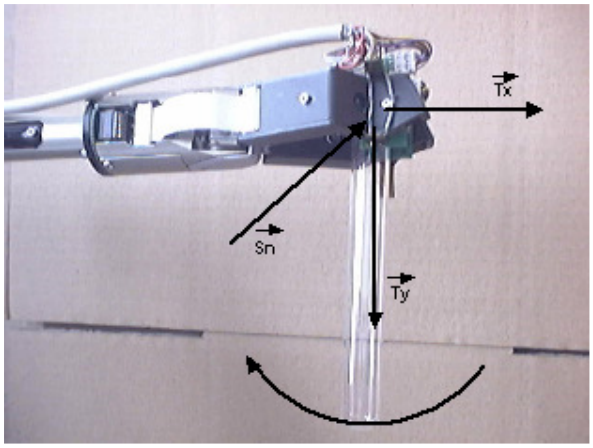
The majority of studies on precision grasps agree that tactile sensing is indispensable for the fine, gentle grasping of unknown, fragile objects. Still only a few papers deal with tactile sensors capable of sensing not only normal forces, but shear forces, and toques as well. This study concerns soft finger contact, where the friction allows it to resist tangential forces and moments up to a friction limit.

An experimental system is presented, comprising: (1) Two 3D tactile arrays (2*2 taxels (tactile pixels) each) mounted on a two-fingered robot hand, (2) a closed loop controller. This arrangement allows detection and classification of typical tactile events, improving the control of grasping.

The sensing, processing, actuating systems are strongly coupled, and they work together in order to realize an intelligent, closed-loop control of the autonomous robotic arm. We propose an efficient and fast method to detect and identify the sliding and twisting motion of the touching objects. This kind of actions cannot be detected with sensors sensing only the normal (perpendicular) component of the forces acting between the surfaces.

In this experimental setup the sensing elements are Si-based tactile sensors with 500*500 μm^2 taxel size. The size of the array is 2*2 taxels. Each taxel consists of four piezorezisitive elements. The sensing elements are mounted on a two-fingered robot hand. The actuator is controlled in closed loop. An integrated sensing-processing-actuating system has been developed. The motivation behind our work is the perception of the importance of comprehending and knowing the forces that are developed between contacting surfaces. In different areas of science (in geology for earthquake prediction, in robotics, automation etc.) and industry (motor-car-, aeronautical-, construction industry), it is essential to be able to read and process the above 3D pressure fields.

A method to detect and identify the twisting forces acting on the contacting surfaces of objects is presented. The overall pressure map is decomposed in three orthogonal pressure maps, all of them being processed by the processing unit.



Twisting force applied to the grasped object

Color Processing in Wearable Bionic Eyeglass

Róbert Wagner
(Professor Tamas Roska)

Abstract

Abstract - This report presents color processing tasks of the bionic eyeglass project, that helps blind people to gather chromatic information. A color recognition method is presented, which specifies the colors of objects on the scene. The method adapts to varying illumination and smooth shadow on the objects. It performs local adaptation on the intensity and global chromatic adaptation. Another method is also shown that improves the extraction of display data based on chromatic information.

I. COLOR PROCESSING FOR BLIND PEOPLE

1) Determination of the color of the scene.

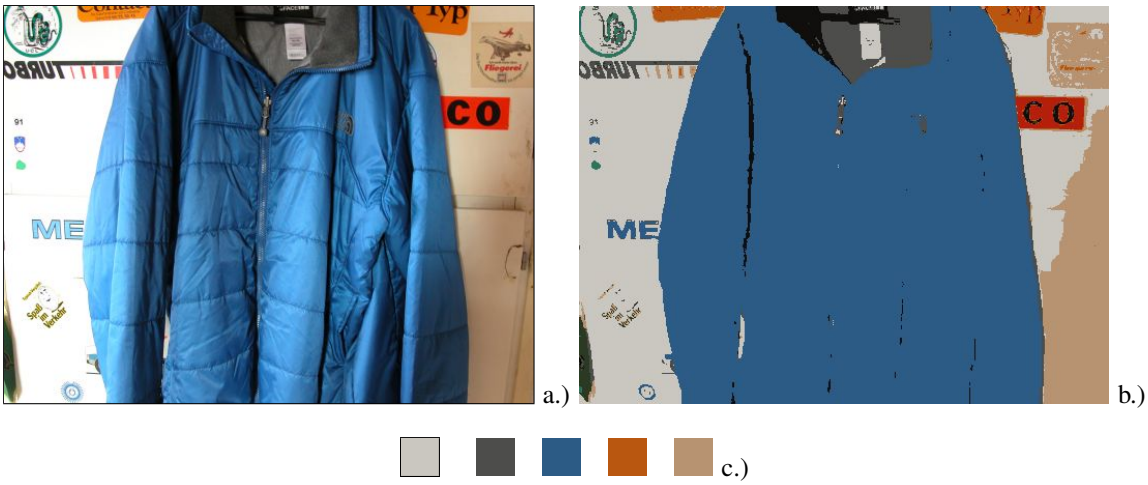


Fig. 1. Clustering and merging of clusters. a.) shows the original picture taken by a standard digital camera. b.) shows the clusters after merging of similar clusters. The main cluster colors can be seen on c.)

2) Filtering based on color to extract non color related information. (e.g. displays)

Here our aim is to extract useful information of the scene based on chromatic information. We filter out displays of predefined colors.

Fig. 2. Color filtering. a.) shows the original picture taken by a mobile phone, b.) shows the color compensated version. On c.) we can see the result of filtering for green-yellow color.

REFERENCES

[1] T. Roska, D. Bálya, A. Lázár, K. Karacs, and R. Wagner, "System aspects of a bionic eyeglass," in *Proceedings of IEEE International Symposium on Circuits and Systems (ISCAS)*, May 2006.

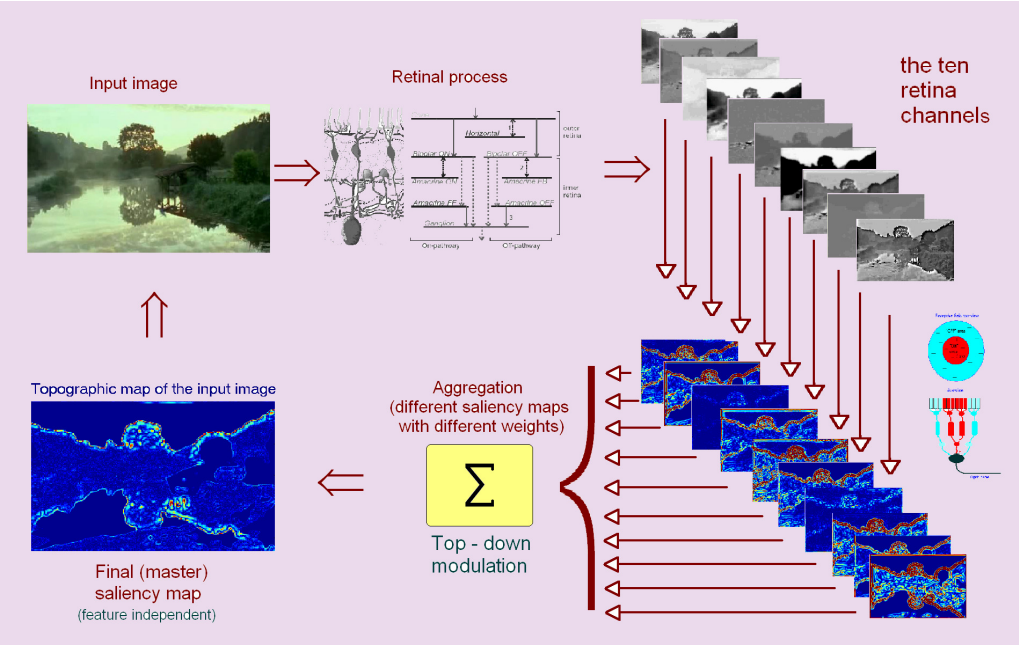
Modeling Bottom–Up Visual Attention

Anna Lázár
(Prof. Tamás Roska and Dr. Zoltán Vidnyánszky)

Visual attention is an ability that characterises animals whose nervous system is in excess of a certain state of development. This ability is to direct the gaze rapidly towards objects of interest. But since the issue, that what is interesting and what is not, strongly task- and environment dependent, the 'objects of interest' are changing rapidly, and the whole function turns out to be very complex and manifold.

From an engineering viewpoint, selective visual attention is a method that filters out the important parts of the visual scene from the irrelevant crowd, in real time. Normally, for a 'general system' (which can be either a living creature or an artificial one), the visual scene is full with irrelevant and redundant information, so processing the whole visual scene is not only wasteful but also needless. Accordingly, a system that *attends* may perform high processing quality in real time.

Selective visual attention is a co-operation of two methods, namely the "top-down" (task-dependent, voluntary) and the "bottom-up" (image based, unintentional) functions. During my researches I created a neuromorph bottom-up model, that is based on the "usual" principles of the BU method. That is dissolving the incoming visual information according to so called low level visual features and creating saliency maps based on these channels. Novelty in my model, that meanwhile the present models uses heuristic low level visual features, my model applies real retina channels instead. The creation of these channels are based on biological measurements that were consummated recently. I also made human eye-movement measurements to test the predictions of the model and for adjusting the free parameters according to the human attention system. With these measurements I determined the most effective receptive field sizes for each retina-channel thus I created an attentional system that operates similar to the human atentional function under bottom-up conditions.



The diagram of the bottom-up mechanism.
In the first step the input image (top of the picture, left hand-side) is decomposed into ten different retina channels (-topographical maps in different brain areas: the higher activity a neuron shows, the darker colour on the monitor appears.) In living beings this is a pre-attentive feature extraction mechanism which operates over the entire visual scene in a highly parallel way. Ones the input vision is decomposed, each retina-channel creates its own saliency map. For defining the individual points saliency value, I used different sized, circle-shaped receptive fields (RF), on and off. The next step is the aggregation. The final (or master) saliency map is practically a weighted sum of the feature-based saliency maps. The weighting of these feature-dependent maps are under top-down modulation, if it is present. (bottom of the picture) Then the winner-take-all mechanism chooses the final saliency map's most salient point: this point wins the attention, the others are suppressed. The corresponding picture-portion "appears in the fovea", this is the small part of the visual scene that is processed in detail and the rest is processed roughly.

Motion Field Analysis

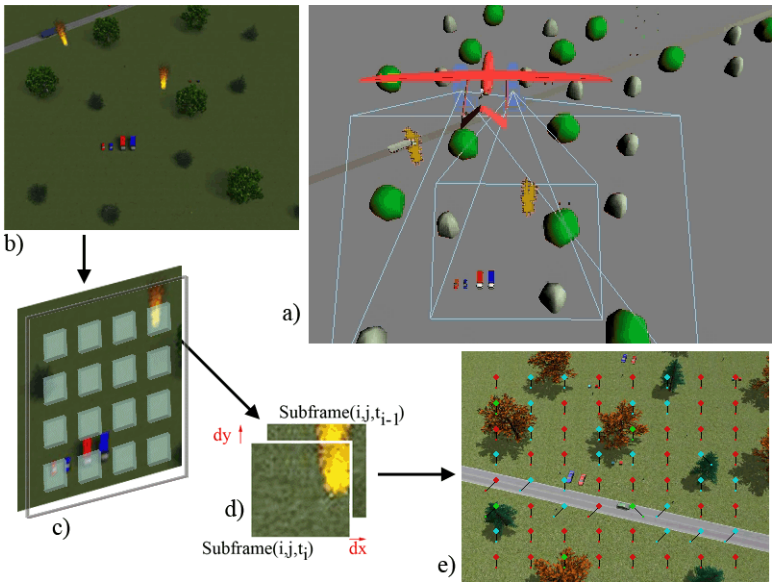
Gergely Soós
(Advisors: Csaba Rekeczky, Gusztáv Bártfai)

Changes in the environment arise the need for animals to accommodate or even to react. Large percent of events can be detected in the visual field therefore it is the main perceptual modality in mammals and thus humans as well. *Image flows* are 2D projections of the 3D world, captured by the vision system. It consists of intensity values that are coming to each perception element. We can project into 2D space also the motion of the objects, this is the *motion field*.
When objects in the environment change only their position (lighting conditions remain, objects are rigid, etc.) the caused changes in image flows are mainly spatial, which means pixel elements keep their intensity values but change their position. We can assign a speed value to every pixel. These movement vectors together form the *optical flow*. Optical flow is correlated to the motion field except in case of some illusions (e.g. aperture problem). By calculating optical flow we can estimate movements of objects or ego motion of the observer. I focus on the cases when these two effects are coincident.

I participate in an ongoing project called Autonomous Aerial Reconnaisance and Navigation (ALFA). The aim is to produce long term navigation algorithm that can control the autopilot of a light weight airplane (a). The vision system is the key element of the processing but inputs from telemetry sensors are also used. We process image flow (b) at a sparse grid (c). We estimate optical flow by calculating displacement for sub frames (d). Resolution is a trade of between accuracy and frame rate.

My work was to create segmentation method in motion field based on optical flow. As input I use the displacement vectors and confidency measures. I converted (dx,dy) representation into (r,fi) vectors, and aligned data into topological maps. I did grouping based on similarity and applied ununiform diffusion for each clusters. Diffusion focuses were grid points, where confidency values were high. The output mapped to the input can be seen in (e).

This method smooths the noisy values produced by bottom level algorithms while it keeps characteristic values. Homogenous regions grouped by first step may refer to single objects. Filtering can be used to detect outliers. Outliers probably show objects that are really moving and need to be analyzed in detailed. Excluding outliers and vectors with low confidency we can do ego motion estimation with higher reliability.



Overview of steps for creating optical flow estimation:
a) capturing image flow (3D model) ; b) high resolution input; c) sparse grid processing;
d) displacement calculation in each grid point; e) map displacement vectors to HI-RES picture

Higher-Level Multimodal Information Fusion

Zsolt Szálka
(Advisors Csaba Rekeczky and István Szatmáry)

Information fusion is an actively researched area in the recent years. With the improvement of sensor technologies different sensors became better, smaller and cheaper. My work is part of the ALFA project, a project for autonomous aerial reconnaissance and navigation. In this project several sensor types – providing information from different modalities - are used for reconnaissance purposes. Speed-, altitude- and gyro-sensors provide non-topographic information while normal and infra-red camera provides topographic information. The integrated evaluation of these modalities is the main goal of my work.

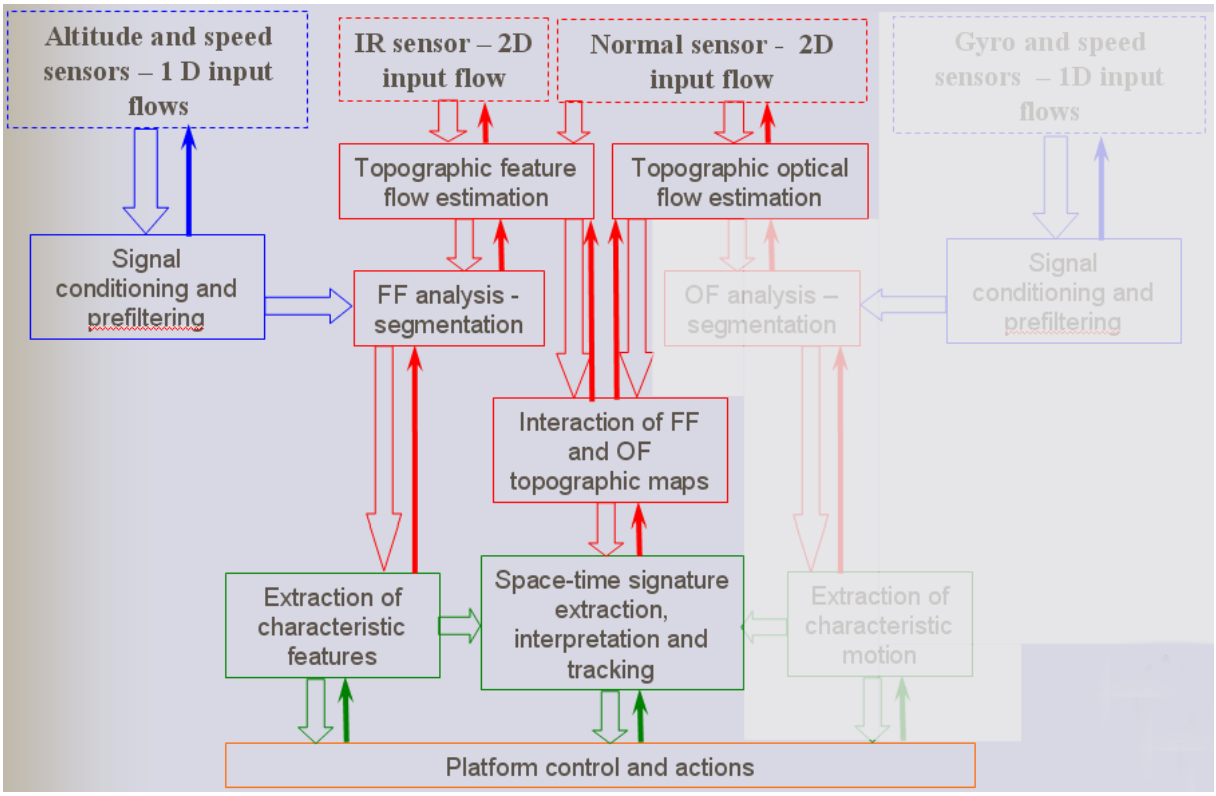


Figure 1.: *System architecture of multimodal information fusion. Information integration can be made on different levels. While topographic image fusion is a low-level fusion, feature- and decision-fusion is called higher-level fusion according to the actual data interpretation level. While topographic image fusion provides information like "hot and bright pixels on the scene", feature-level fusion says: "Object is hot, greater than 5m and slower than 50kmph". The highest-level of fusion is decision fusion, which concludes: "There are hot and smoking object on the left, their size is growing, turn left to reconnaissance the object from closer."*

In my work, I research topographic image fusion techniques on normal and infra-red images, like linear mixing, non-linear mixing, wavelet-, pyramid-decomposition techniques, Frequency domain transformations, Gradient maps.
Short-term goal is to develop an infra-red driven attention-selection mechanism which selects regions of interest on normal camera input according to features localized on infra-red input. This attention-selection architecture includes local adaptive preprocessing like intensity range selection, morphological processing like opening and closing. After preprocessing feature extraction and built on it location selection will be performed providing region of interest information for processing and analyzing normal spectral input on higher resolution. This means that the normal spectral input will be processed only in the selected sub-windows, which improves color-, motion-, and morphology-analysis efficiency.
Long-term goal is to develop a information fusion system architecture (see *Figure 1*) for a flying platform. This architecture includes topographic normal and infra-red spectral inputs and non-topographic (altitude, speed, ego-motion) information fusion. All these modalities can play roles in lower- and higher-level fusion techniques as well.

A Revised Neurobiologically Inspired Model of the Cochlea and an Attached Auditory Image Processing Network

Tamás Harczos
(Professors Tamás Roska, György Karmos and Frank Klefenz)

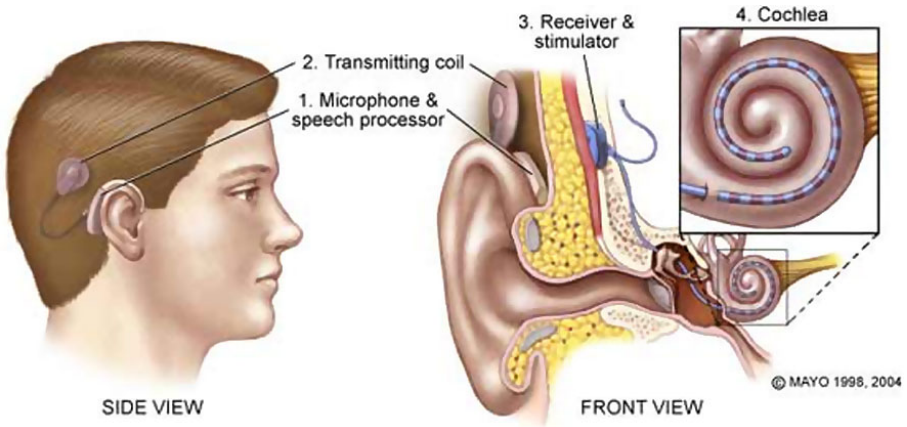
One may underestimate the significance of hearing, but in today's world this sense is getting more and more important. On the other hand, there are more than 30 million deaf people around the world. Only in Hungary there are around 50000 deaf and several hundred thousand people hard of hearing. The most common causes are inflammation originating from the middle ear, or noise injury. General hearing aids usually cannot help the deaf, because of the damage in the inner ear. However, the so called cochlear implants (which are special kind of neural prostheses) are able to partly recover hearing. Based on a recent report, around 250 thousand people have been implanted until now, which makes not 1% of the deaf population, plus many of the implantees are using out-of-date devices.

Recently, I had the opportunity to assist at the rehabilitation of a deafened girl at the Semmelweis University. I learned that currently available cochlear implant devices are extensively used; they provide great improvement of life quality of implanted people. However, current techniques (also called as cochlear implant strategies) converting audible sounds into nerve activity are far from a perfect solution. The Medical Audio Technology group of the Fraunhofer Institute, Germany and I are working hard to soon provide a more sophisticated way of converting sounds into nerve action potentials, which can be used to drive future cochlear implant devices.

In our model, the velocity of the basilar membrane excited by a time varying audio signal is computed according to the Extended Zwicker model as given by Baumgarte in 2000. The mechano-chemical coupling is mediated by the forced movement of the stereociliae of the inner hair cells, which depolarizes the cells resulting in neurotransmitter vesicle releases. This process is modelled according to the rate kinetics equations by Sumner et al. in 2002. The post-synaptic potentials affected by the released transmitters is finally calculated in the way shown by Hodgkin and Huxley in 1952.

During the last year I was given the chance to research in diverse, but at the same time, convergent topics related to cochlear implants. I saw an implantation and experienced the thrilling recovery of a 5-year-old prelingually deafened girl. Driven by this motivation I reviewed current processing strategies and tried to conciliate them with our proposed new calculation model. Implementing an inverse transformation, I have satisfied myself that the simulation of our elementary model performs well. I pointed out several improvement points at the model itself, and I proposed essential modifications respecting the neural network used to learn the shape of delay trajectories in the neural activity plots.

My future work incorporates research on understanding what implant users perceive, extension of the current ear model for even more realistic results, and improvement of the automated speech recognizer back-end.



Typical set-up of a cochlear implant system with behind-the-ear speech processor.

Sound Source Localization Supported by a priori Information of the Acoustic Environment

Zoltán Fodróczi
(Professor András Radványi)

The inverse problem of localizing a source by using signal measurements at an array of sensors is a classical problem in signal processing from the sonar or radar technology to acoustic engineering. A subset of these efforts is the speaker localization. This problem found to be surprisingly difficult and there is no robust method to localize anisotropic sound sources, i.e. human speakers in everyday reverberant environment. Although in 1976 Knapp and Carter proposed the generalized cross-correlation method to solve this problem, and since then several new ideas have been proposed.

In my work I defined a new signal model that explains why nowadays source localization systems fail. Using this model, I showed a mathematical method using that, the effect of reverberation can be predicted in the cross-correlation function of two signals. By this method the cross-correlation function can be predicted for every possible source location point, and in case of anisotropic sound sources for every possible source direction. By applying an existing sound source localization algorithm, I developed a method that integrates the predictions resulting in the so called reverberation effect maps. These maps serve typical features for the source location in a reverberant environment.

In order to solve the inverse problem, I proposed a novel algorithm that extracts the most probable effects of reverberation from existing cross-correlation functions. Using these extracted effects, the feature of observations is produced.

Using the foundations of machine learning and patter recognition, I created a method that finds the best matching prediction to our observations, resulting the hypothetical source location point.

I integrated an existing computational acoustic software into my framework that allowed the application of the proposed theory to arbitrary room geometries.

At the end of paper, I verified the performance of the proposed algorithm to up-to-date source localization methods. Result proves that the new method capable to localize human speakers even in those cases, when traditional localization systems fails.

The acoustic model and the photo of an auditorium in Pazmany University. The proposed method makes possible the integration of computational acoustic i.e. the information of the acoustic environment, into a real time sound source localization algorithm.

Stochastic Simulations on the CNN Universal Machine

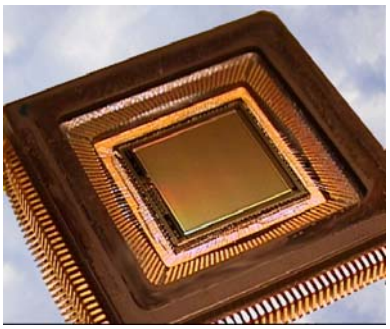
Mária Ercsey-Ravasz
(Supervisors: Dr. Prof. Tamás Roska and Dr. Prof. Zoltán Néda)

The new paradigm represented by Cellular Neural/nonlinear Networks (CNN) and the CNN Universal Machine (CNN-UM) revolutionized many areas of information technology. Most promising applications are for image processing, robotics or sensory computing purposes, but the CNN architecture seems also promising when considering complex problems in natural sciences. Studies dealing with partial differential equations or cellular automata (CA) models prove this. In natural sciences, especially physics however, many of the interesting problems deal with stochastic cellular automaton, random initial conditions or other Monte Carlo (MC) type methods on lattices (spin problems, population dynamics models, lattice gas models, percolation, optimization problems etc...). My goal was to investigate the possibility for implementing some widely used stochastic simulation techniques in physics on the CNN-UM and to develop new kind of methods suitable for the CNN-UM architecture.

After developing a realistic random number generator based on a chaotic cellular automaton perturbed with the natural noise of the CNN-UM chip, which can generate binary values with any given probability, this year I used this random number generator for implementing stochastic (Monte Carlo type) simulations on the CNN-UM. Two very important problems of statistical physics were implemented: the site-percolation problem and the two-dimensional Ising model. Both models represent a whole class of problems of statistical physics. This way developing algorithms suitable for the CNN architecture, represents a new way of handling this kind of problems and could help reducing the huge simulation times.

Monte Carlo simulations are very important in physics, but most of the algorithms are of serial nature. In case of the Ising model (and similar 2D spin-problems) I developed an algorithm suitable for the parallel architecture of the CNN. This is a modification of the very much used Metropolis and Glauber algorithms. These algorithms were all tested and properly working on the ACE16K chip implemented in the Bi-i v2. Computational time measurements suggest that the developing trend – increasing the chip size and the number of local logic memories - of the CNN-UM chips could assure an important advantage for the CNN-UM in the near future.

For the future my goal is to develop optimization algorithms suitable for the CNN architecture. There is a class of problems (NP-complete and NP-hard problems) for which the optimization algorithms are very time-consuming, because the time needed is exponentially growing with the size of the system: spinglasses, graph coloring problems, protein folding etc. These problems have also very wide applications in information technology, for example in wireless communications the same optimization problem appears as in the case of globally connected spinglasses. Because very few good algorithms exist, and for bigger systems is almost impossible to find the optimal state in real time, algorithms suitable for the CNN-UM could represent totally new solutions for these problems.



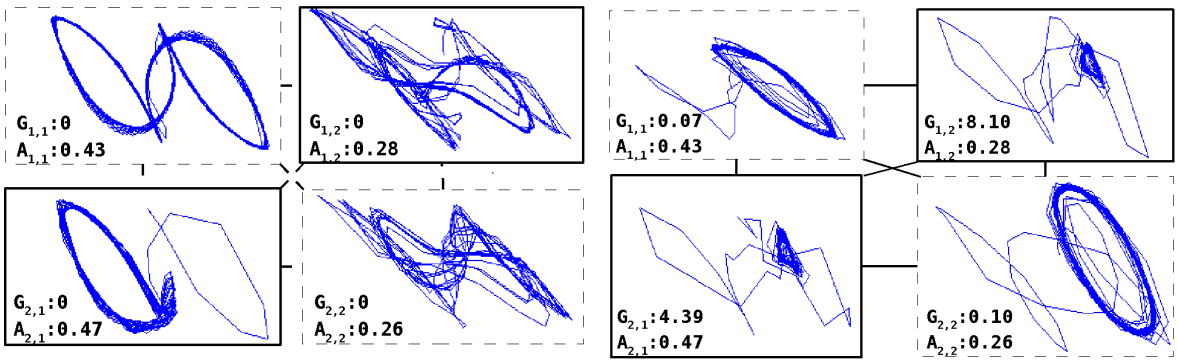
*The ACE16K chip, with an 128*128 array of cells, and the Bi-i v2, an extraordinarily high-speed, compact, standalone, intelligent camera, equipped with an ultra fast ACE16K focal-plane array processor.*

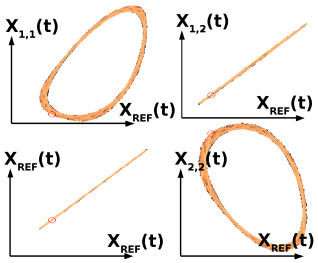
Learning Partial Synchronization Regimes with Imposed Qualitative Behavior on an Array of Chua's Oscillators

Dániel Hillier
(Professors Csaba Rekeczky and Tamás Roska)

Research on synchronization in coupled chaotic oscillators was so far mainly focusing on deriving conditions for synchronization. Here we present a case study showing how global optimization methods can be used to reveal rules of synchronization potentially playing a role in information processing.
There are some examples in the literature where non-linear optimization was applied successfully to drive a dynamical system from an equilibrium point to another. In order to investigate the signal and image processing ability of an array of chaotic oscillators, we designed a non-linear global optimization framework. The power of using global optimization is that we do not need to make any restrictions about network size or topology.
The first task is to define a training set: we have to specify which cells have to be synchronized. A closely related task is to define a proper cost function so that the array configuration with the least cost really solves the task we wanted. The most straightforward cost function uses only the time evolution obtained from the numerical integration of the network.
The optimization proceeds as follows. First, define initial conditions, select a set of cells to be synchronized and define the measure of synchronization. Also set realistic bounds on array parameters that will be optimized.
Then run the optimization. You may only learn the coupling of each cell (denoted by matrix G on the figure) or also the bifurcation parameter denoted by A. Observe that for a 5x5 array, this means 50 variables which is a fairly large parameter space.
The optimization gives array parameters as solution. Further investigations are needed to determine the validity of the solution to other initial conditions and to estimate the region of parameters where the solution holds.
Our approach can be a useful tool to test hypotheses made on coupled networks of chaotic oscillators. Rules (either theoretical or empirical) believed as generic can be transformed into a cost function. Then a global optimization process can maximize the cost function, i.e. it looks for solutions that violate the rule formulated as a cost function. Finding no such solution can be a strong evidence supporting the validity of the original rule.

This study showed that by using a global optimization framework it is possible to get insight into the complex interactions of coupled chaotic oscillators. Our method can be useful in guiding investigations and confirming results from theoretical analysis.





Trajectories of the array of Chua's oscillators with set of parameters optimized to make cells framed with continuous line to synchronize and those enclosed with dashed line to desynchronize. The coupling and bifurcation parameters are shown below each oscillator. Top-left: Uncoupled array that – after switching on the coupling – behaves like shown on top-right trajectory plots. Cost function imposed zero Lyapunov exponents for all cells. Bottom part: Synchronization error shown as norm(X_{REF}) versus norm($X_{r,c}$) between a cell to be synchronized and all other cells for the system. For upper part of the figure: time horizon shown is 0 to T. For the error plot: errors shown for stationary behaviors from T to 2T.

Simplified Protein Models in Molecular Dynamics Simulations

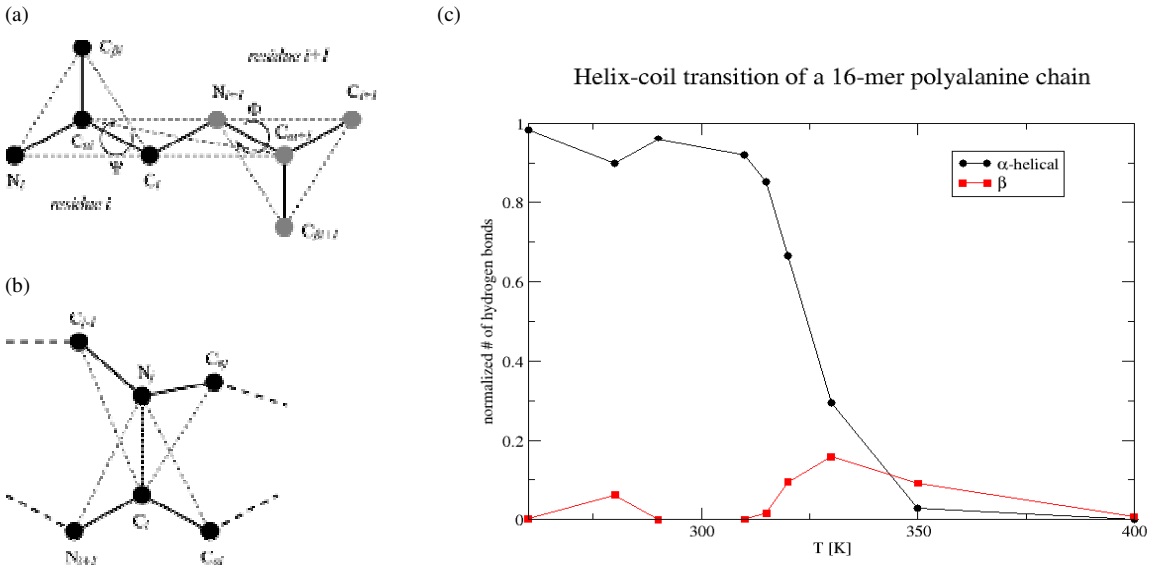
Gergely Gyimesi
(Professors Péter Závodszky and András Szilágyi)

The traditional approach to computational biophysics studies of molecular systems is brute force molecular dynamics simulations of these systems under conditions of interest. The aim of these "high-resolution" models is to include as much detail as is known about the physical geometry and interactions in real proteins, to develop an "ideal" protein model that can be applied to any biophysical system. Molecular dynamics simulations traditionally employ continuous potentials such as the Lennard-Jones potential and an iterative numerical solution of the Newtonian equations of motion. These methods have been widely used in studying protein dynamics, however, an intrinsic limitation lies in their inability to span time scales from femtoseconds (10^{-15} s) to seconds.

An alternative approach is hypothesis-driven and based on tailoring simplified protein models to the systems of interest. DMD methods define discrete interaction potentials between atom pairs. The use of such step-potentials decomposes the trajectory of the simulated system to instantaneous collision events separated by ballistic runs where no forces are exerted on the individual atoms. Both the collision and the ballistic motion of particles can be described analytically, thus avoiding explicit numerical integration errors and enhancing the speed of simulations over several magnitudes. Such simplifications make DMD simulations sufficiently rapid to access the dynamics of large molecular complexes on a biologically relevant time scale.

Our goal is to implement an extensible and scalable molecular dynamics framework using the DMD approach to study the dynamics of proteins and protein complexes. As a test system, we chose to study the helix-coil transition of a small 16-mer polyalanine peptide because it has been extensively studied by experimental and simulation methods. Using our simulation framework it has been possible to reproduce the sharp helix-coil transition observed in the temperature dependence of the folding of small peptide systems.

In our view, DMD simulation methods represent a significantly underutilized approach in molecular modeling, and can be applied successfully to problems where the conformational properties and association of small peptides and proteins (10-50 amino acids) need to be studied. Such applications include the investigation of the hypothesis that certain protein folds evolved from the association and eventual fusion of smaller peptides, and the analysis of the association mechanism of protein dimers whose chains are unstructured in monomeric form and acquire a stable tertiary state only upon association.



The four-bead protein model used in our simulations. (a) Backbone atoms and constraints. (b) Hydrogen bond geometry. (c) Secondary structure content of the peptide structures from the simulated trajectories at each simulated temperature.

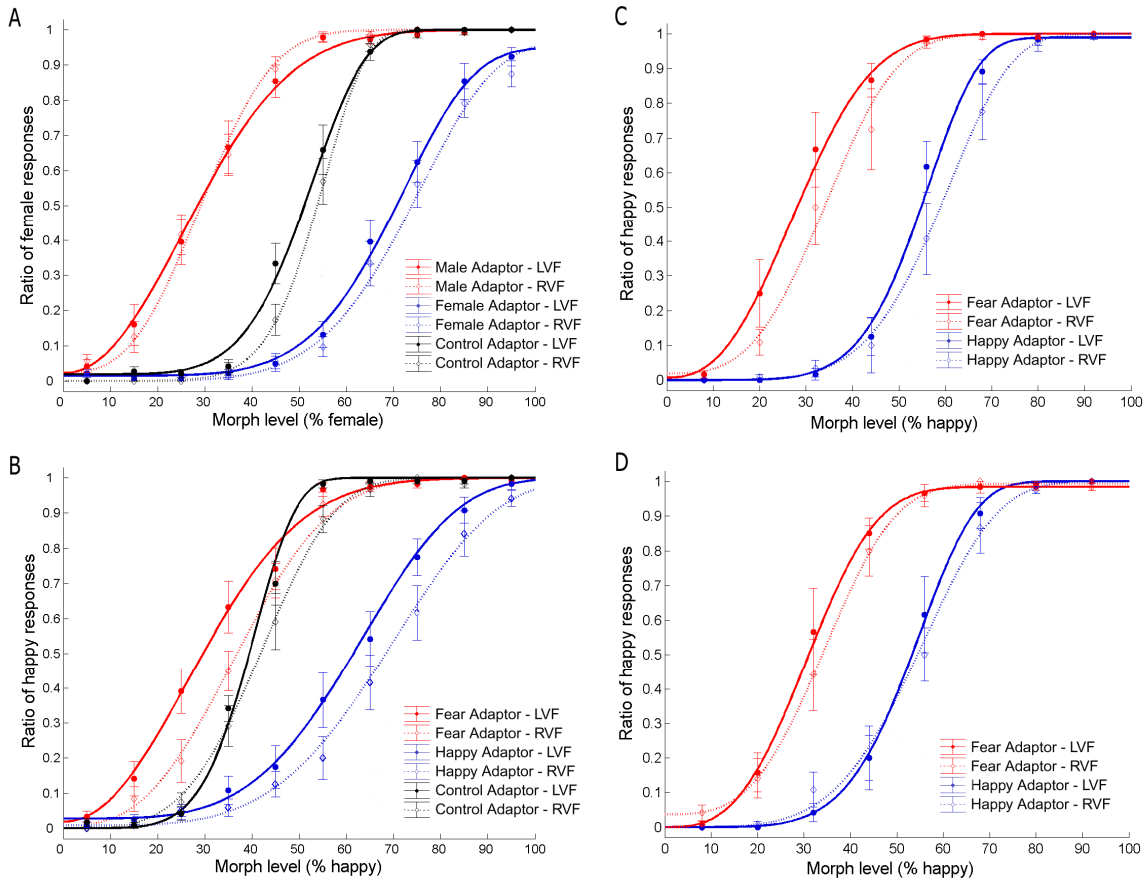
Hemisphere-contingent face aftereffects reveal asymmetric processing of facial emotions

Éva Bankó

(Supervisor: Zoltán Vidnyánszky)

We investigated hemisphere-specific coding of facial attributes at the higher, shape-specific stages of visual processing using face adaptation. Adaptation to bilaterally presented faces, which differed either in emotional expressions (a fearful and a happy face) or in gender (one female and one male face) evoked strong hemisphere-contingent facial aftereffects. After adaptation to emotional faces, a given test face was more likely to be judged as happy when it was presented at the location of the fearful adaptor and conversely, as being fearful when displayed in the location of a happy adaptor. Analogous findings were obtained with adaptation to a female and a male face pair, demonstrating that high-level shape-specific processing in the two hemispheres can be adapted to different facial attributes simultaneously.

Importantly, the hemisphere-contingent aftereffects demonstrated an asymmetry in the processing of emotional faces: aftereffects were stronger when fearful and happy adaptors were processed by the right and by the left hemisphere, respectively, as compared to when their hemispheric representations were reversed during adaptation. There was also an emotion-specific effect of visual attention: processing of fearful facial expression was largely automatic and lateralized to the right hemisphere whereas processing of the happy facial expression depended on the attentional resources available and is lateralized to the left hemisphere. Our findings suggest that hemisphere-contingent facial aftereffects represent a powerful tool for studying hemisphere-specific processing of facial attributes, including emotions.



Psychometric functions obtained (A) in the Gender condition, (B) in the Emotion condition and (C,D) in the Emotion condition with task during adaptation. Solid and dashed lines indicate adaptation in the left and right VFs, respectively. Strong hemisphere-contingent aftereffects can be seen both in the Gender (A) and Emotion (B) conditions, but only in the Emotion condition show the adaptation effects hemispheric asymmetry. (C) In the easy task condition hemispheric asymmetry of the adaptation effects is still apparent both in the case of fearful and happy adaptors (although in the later case it does not reach significance), whereas (D) in the difficult task condition, only aftereffects evoked by the fearful adaptor show hemispheric asymmetry.

Amblyopia:
Early Detection and Examination of Visual Attention

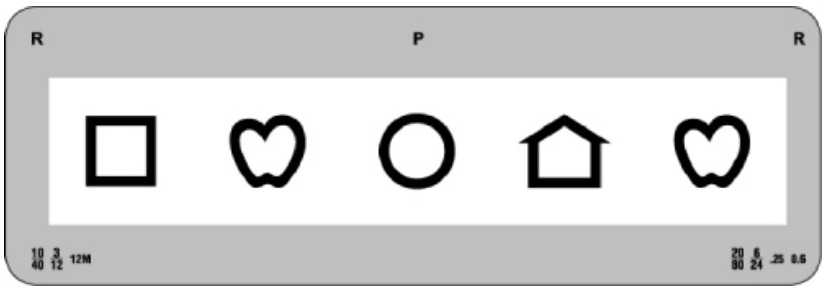
Patricia Domsa M.D.
(Professors János Németh and Zoltán Vidnyánszky)

Abnormal visual experience during early visual development results in dramatic deficits in the properties of neurons in cortical area V1 (refs. 1–3) and in visual perception. For example, if one eye is turned (strabismus) or anisometropia occurs during early childhood, the resulting amblyopia (from the Greek amblos, blunt, and opia, vision) leads to a loss of visual acuity, contrast sensitivity and position acuity. Amblyopia has traditionally been defined as a "decrease of visual acuity caused by pattern vision deprivation or abnormal binocular interaction for which no causes can be detected by the physical examination of the eye, and which in appropriate cases is reversible by therapeutic measures." At present the accepted definition of amblyopia is "Reduction of visual acuity that results from interruption of normal visual development during the sensitive period". The term functional amblyopia often is used to describe amblyopia, which is potentially reversible by occlusion therapy. It is thought that the main site of the abnormal developmental changes in amblyopia is V1, where there is a dramatic loss of binocular neurons, and neurons driven by the amblyopic eye have lower contrast sensitivity and may sample the image sparsely.

Most data show that about 2% of the general population has amblyopia, with recent large population studies falling in the range of 1.6– 3.6%, amblyopia is usually unilateral but could be bilateral. Amblyopia was shown in the Visual Acuity Impairment Survey to be the leading cause of monocular vision loss in adults aged 20-70 years or older.

First aim of our work is to develop a new screening program, for early detection of amblyopia. We plan to test visual acuity with Lea-symbols, contrast sensitivity and stereo vision by anaglyphic test. We develop test applications for entry level PC-s. The screening program should be done as early as in the kindergarten at the age of 3-4. No experts needed for the screening only the help of the staff. High percent of the child population should be involved. We collaborate with the University of Veszprém in developing our software.

In our basic science study we studied subitizing and tracking in anisometropic amblyopic patients to test the notion that amblyopia also has consequences for higher visual areas. It is known that brief counting is inaccurate in amblyopia. We tested 15 control persons and 15 anisometropic amblyopic patients.
Aspects for data analysis: data can be found in the literature, that non-amblyopic fellow eye works slightly worse we would like to reassure it in our study. Performance of our amblyopic patients with visual acuity below 0,5 were much lower, not because of their visual acuity. We found great interpersonal differences in performance of patients with the same visual acuity. We suppose coping strategies play important role in the performance of our amblyopic patients, so we plan a psychological test for this.



Lea- symbols

Back-to-front: Improved tactile discrimination performance in the space you can't see

István Kóbor

(Supervisor Zoltán Vidnyánszky)

Our brains typically localize sensory events – including touches and sounds – according to an externally-defined coordinate system, which is dominated by vision. The remapping of tactile stimuli from body-centered coordinates – in which they are coded initially – into external coordinates is fast and effortless when the body is in its "typical" posture (i.e., with the left hand on the left of the body and vice versa for the right hand).

We investigated any differences in the spatiotemporal coding of tactile events presented in frontal space (a region where visual inputs tend to dominate) versus in the space behind the back (a region of space that we rarely see) in professional piano players and in non-musicians. Even though tactile temporal order judgments were much better in the musicians overall, both groups showed a much reduced crossed hands deficit when their hands were crossed behind their backs rather than at the front.

These results suggest that because of differences in the availability of visual input, the spatiotemporal coding of non-visual stimuli in front versus rear space is different.

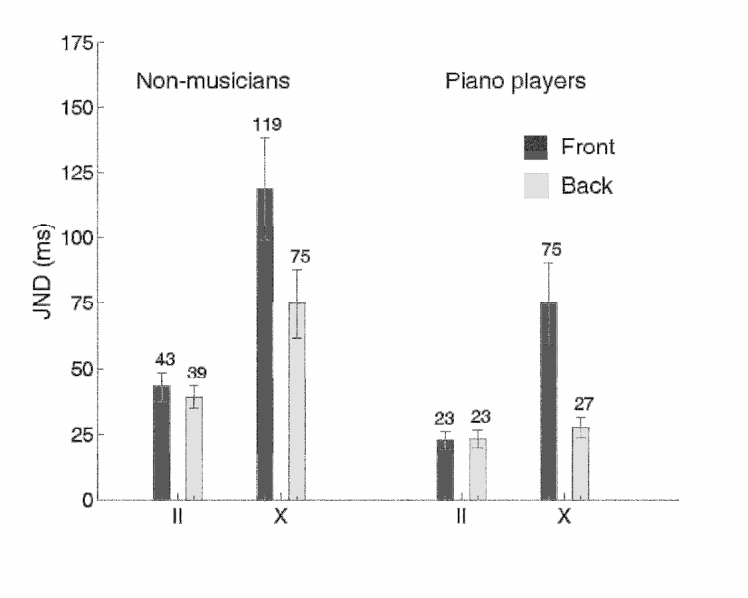


Fig. 1. TOJ performance. Average JNDs (calculated by subtracting the SOA needed to achieve 75% performance from that needed to achieve 25% performance and dividing by two) are shown for the non-musicians and pianists for all four conditions tested (II = uncrossed posture; and X= crossed posture). JNDs were determined independently for all observers based on the slope of the Weibull functions that were fitted to the individual data obtained in the four conditions (see Fig. 1 for the Weilbull fit to participants' mean performance). Error bars represent the between observer S.E.M.

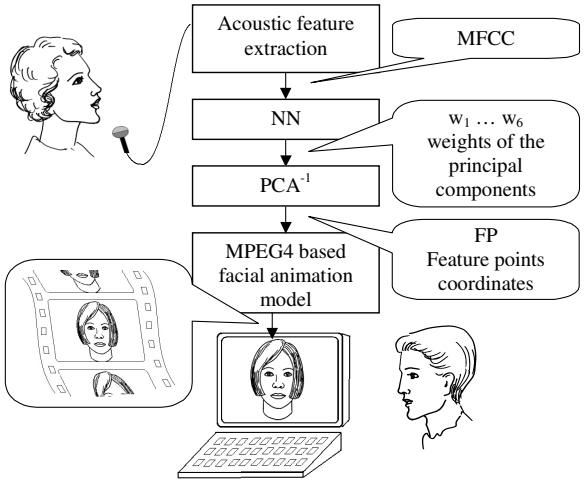
Lip-readable Speech to Animation Conversion

Tamás Bárdi
(Dr. György Takács)

The primary aim of our project was to develop a communication aid for deaf persons which can be implemented in a mobile telephone. In our system a partially animated face is displayed in interaction with deaf users. The control parameters of the animation are calculated directly from the input speech signal. It is known that showing the face itself is a limited representation of the human speech process and contains inherent errors, though deaf people have fantastic abilities in understanding speech based on lip reading only. In spite of the limitations deaf persons aided with special software on the platform of high-end class second or third generation mobile phones could naturally communicate with hearing people.

This research study was explicitly dedicated to help deaf and hard of hearing people. Because we had had no relevant former experience in audiovisual speech processing we could keep in focus the special needs and abilities of hearing impaired people throughout the development, from the beginnings. The main guiding principle of our system construction was that the experiences of our lip-reading tests and the available knowledge about this type of communication in human sciences should be linked to and applied in the technical implementation at as many points as possible. It is shown in the following sections that these links were used in design and collection of the training database, in PCA analysis, and also in working out the parametrization of signal processing methods in acoustic feature extraction.

A very important element of this newly developed concept is to train the system on a unique audio-visual database collected from professional interpreters/lip-speakers. Their articulation style and level are adapted to deaf communication partners. Our implemented conversion system is PC-based software. Here we survey the complete system at a glance, as it is shown in the Figure.



Structure of the implemented speech to facial animation system.

PUBLICATIONS

[1] G. Takács, A. Tihanyi, T. Bárdi, G. Feldhoffer, B. Srancsik: "Speech to facial animation conversion for deaf applications" *14th European Signal Processing Conf.*, Florence, Italy, September 2006.

[2] G. Takács, A. Tihanyi, T. Bárdi, G. Feldhoffer, B. Srancsik: "Database Construction for Speech to Lip-readable Animation Conversion" *48th Int. Symp. ELMAR-2006 on Multimedia Signal Processing and Communications*, Zadar, Croatia, June 2006.

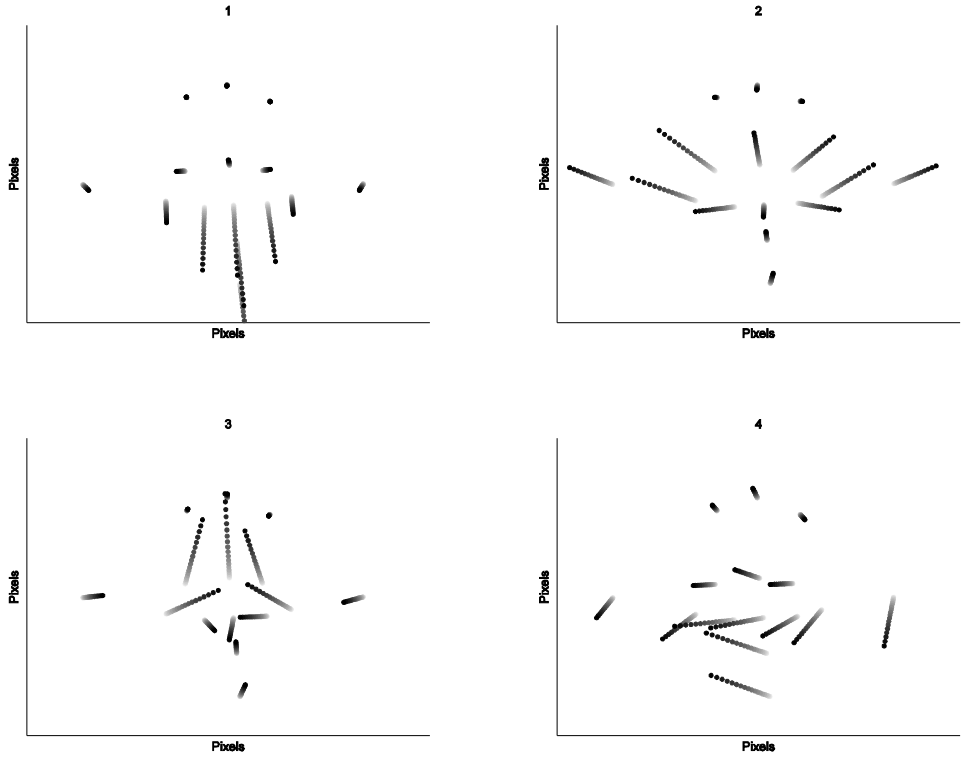
[3] G. Takács, A. Tihanyi, T. Bárdi, G. Feldhoffer, B. Srancsik: "Signal Conversion from Natural Audio Speech to Synthetic Visible Speech" *ICSES-2006 Intl. Conf.*, Lodz, Poland, September 2006.

[4] T. Bárdi "High Resolution Speech F0 Modification" *3rd Speech Prosody Intl. Conf.,* Dresden, Germany, May 2006.

Voice Driven Talking Head Model for Deaf Customers

Gergely Feldhoffer
(Professors György Takács and Attila Tihanyi)

A speech to facial animation direct conversion system was developed as a communication aid for deaf people. Utilizing the preliminary test results a specific database was constructed from audio and visual records of professional lip-speakers. The standardized MPEG-4 system was used to animate the speaking face model. The trained neural net is able to calculate the principal component weights of feature points from the speech frames. PCA and ICA were compared. The whole system can be implemented in standard mobile phones. Deaf persons were able correctly recognize about 50\% of words from limited sets in the final test based on our facial animation model.



PCA components of a professional speaker. The components are shown as motion directions from the neutral face.

Publications:

Gy. Takács, A. Tihanyi, T. Bárdi, G. Feldhoffer, B. Srancsik "*Speech to facial animation conversion for deaf applications*" European Signal Processing Conference – EUSIPCO 2006, Florance

Gy. Takács, A. Tihanyi, T. Bárdi, G. Feldhoffer, B. Srancsik "*Database Construction for Speech to Lip-readable Animation Conversion*" Conf. on Multimedia Signal Processing – ELMAR 2006, Zadar

Gy. Takács, A. Tihanyi, T. Bárdi, G. Feldhoffer, B. Srancsik "*Signal Conversion from Natural Audio Speech to Synthetic Visible Speech*" – Int. Conf. on Signals and Electronic Systems - ICSES 2006, Lodz

NP Alignment in a Linguistically Enriched Translation Memory

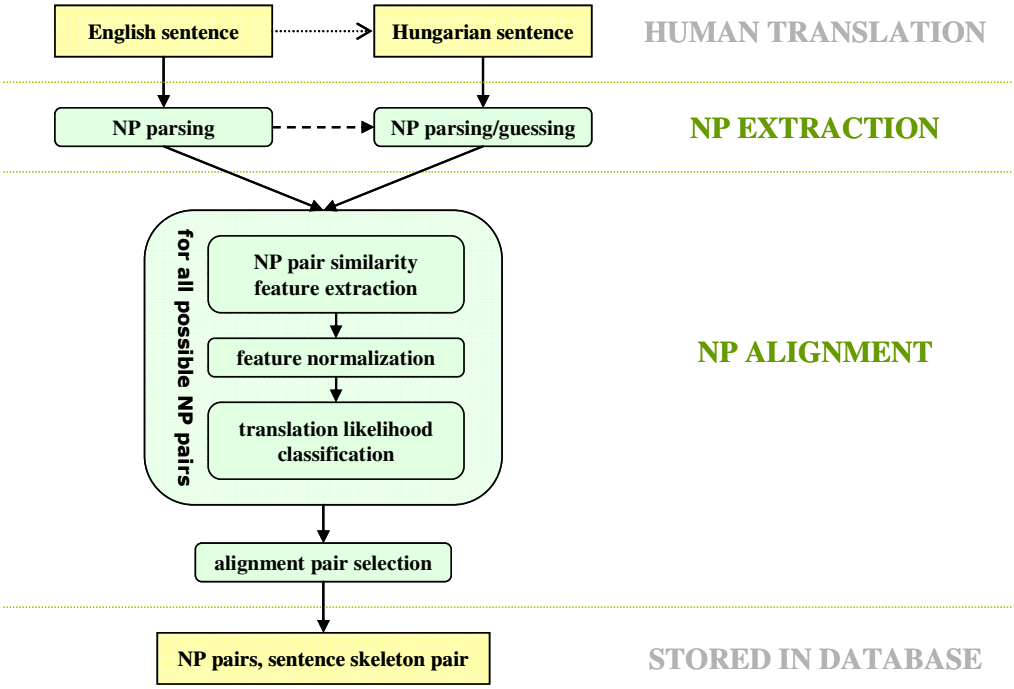
Gábor Pohl
(Supervisor: Gábor Prószéky)

Translation memories (TM) store segment pairs of human translations. When a new document is translated, already stored translation segments are automatically retrieved from the memory. In traditional TMs whole sentence pairs are stored and searched in the memory. In order to increase recall, in MetaMorpho TM—our linguistically enriched TM—not only whole sentences are stored and searched. Noun phrases (NP), and the sentence skeleton (derived from the sentence by substituting NPs with symbolic NP slots) are also stored and searched in the database. When a sentence is looked up in the memory, the most probable translations of its skeleton and NPs are morphologically altered and combined to form a possible translation sentence. In MetaMorpho TM, NPs are extracted and aligned (the corresponding pairs are identified/linked) automatically.

So far MetaMorpho TM is English-Hungarian only (other language pairs are not implemented yet). NPs of the English sentence are extracted by the MetaMorpho parser. In order to extract Hungarian NPs efficiently, I developed a new means of extracting Hungarian NP candidates without a deep parser. Parsed NPs of an English sentence are mapped to the words of the Hungarian translation and the shortest span containing all matched words is expanded to a full Hungarian NP using simple syntactical rules.

In the NP alignment process, features characterizing the similarity of an NP pair are extracted for all possible NP pairs. During the feature extraction process, words of the two NPs are matched using stemmed dictionary matching, cognate matching, and POS matching. Then a classifier, trained on a hand-aligned corpus, determines the matching probability of the NP pairs. Linear and logistic regression based classifiers performed the best on the extracted and normalized features.

Combining the guided Hungarian NP extraction technique and the new alignment method, classification precision higher than 90% could be reached in the first experiments.



NP extraction and NP alignment in MetaMorpho TM. During the NP extraction process Hungarian NPs are extracted without deep parsing, the extraction is guided by the NPs found in the English sentence. In the alignment stage, means of stemmed dictionary matching, cognate matching, and POS matching are applied in order to extract feature values describing the similarity of NP pairs. A classifier is trained on the normalized form of the extracted features.

The Evaluation of Memory-based Translation Aids and Index for Linguistic Similarity Search

Gábor Hodász
(supervisor: dr. Gábor Prószéky)

The paper gives an overview of two important field of memory-based translation systems: evaluation methods and indexing methods for approximate string matching. After a short comparison with the well-discussed methods of evaluation of Machine Translation (MT) Systems I give a brief overview of current methodology on memory-based applications. I propose a new aspect, which takes the content of memory into account: a measure to describe the correspondence between the memory and the current segment to translate. Moreover I present a new indexing method designed specially for the linguistic similarity measure developed in the earlier years. This index uses morpho-syntactic stemming, contains only content-words (non-stopwords) ordered in suffix-array. I use separate but similar indices for sentence skeletons and NPs to satisfy the special requirements of our linguistically enriched translation memory.

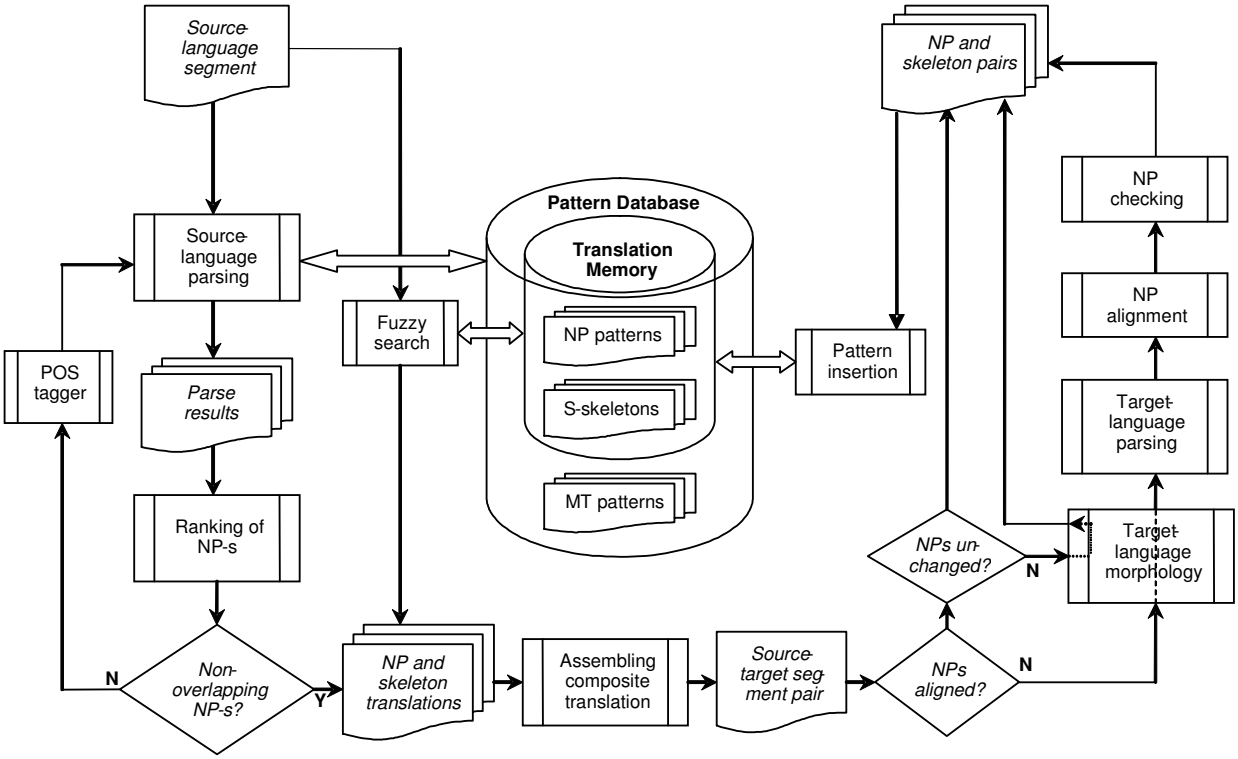


Figure 1: The basic processes of MetaMorpho TM

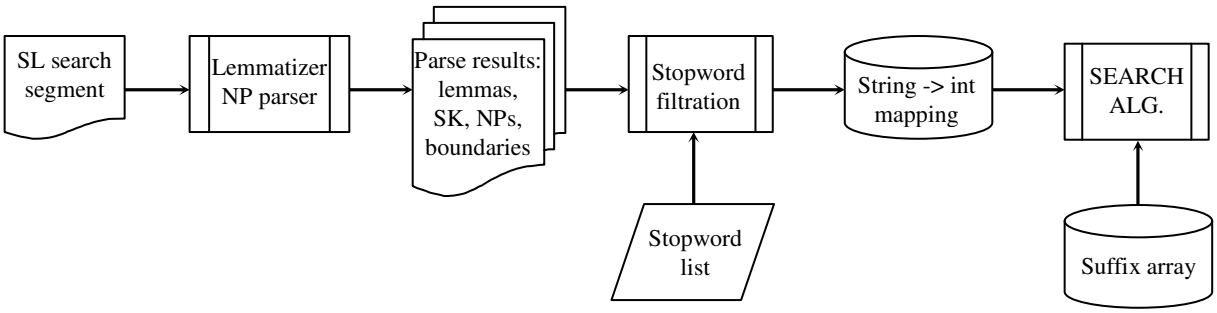


Figure 2: Indexing - Preprocessing search patterns

Markovian Approaches Regarding Change Detection on Video Sequences and Airborne Images

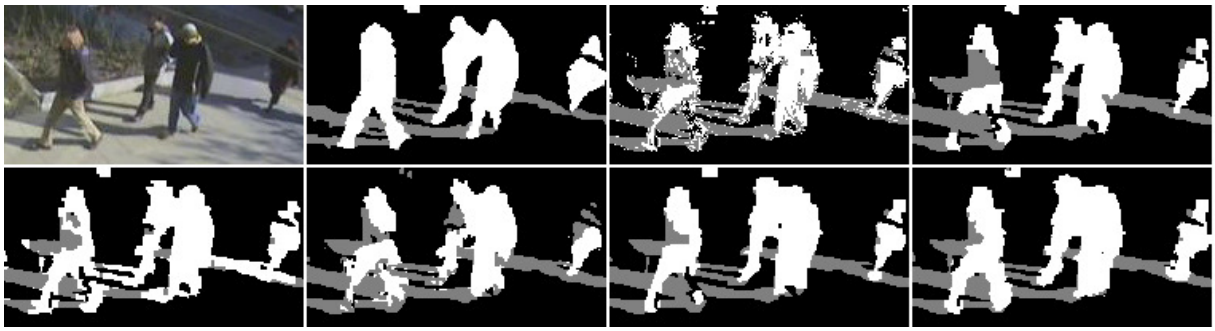
Csaba Benedek
(Professor Tamás Szirányi)

Change detection is an important early vision task for many image processing application. Shape, size, number and position parameters of the foreground objects can be derived from an accurate silhouette-mask and used by several applications, like people or vehicle detection, tracking and activity analysis. Regarding the conditions and goals I can separate different classes of change detection algorithms. In this academic year, I was working on three different problems from this topic.

Task 1: Foreground-background-shadow segmentation on images of low or unsteady frame-rate video sequences captured by static cameras. I assume that a considerably long video sequence is available. The goal is the accurate retrieval of the object shapes for furthering post processing. My model works without detailed a priori object-shape information, and is also appropriate for low and unstable frame-rate video sources. I presented three novelties versus previous approaches: (1) I gave a more accurate, adaptive shadow model, and showed the improvements in scenes with difficult lighting and coloring effects, furthermore motley background. (2) I gave a novel description for the foreground based on spatial statistics of the neighboring pixel values, which enhanced the detection of background or shadow-colored object parts. (3) I integrated pixel intensities with different color and texture features in a general probabilistic framework and compared the performance of different feature selections. Finally, a Markov Random Field model was used to enhance the accuracy of the separation

Task 2: Moving object detection on airborne images captured by moving cameras. In this case, I work only on two images. The task contains motion compensation in reasonable time, removing registration errors and removing paralaxis distortion. Changes are marked via pixel differences. A probabilistic model was proposed to elliminate these artifacts. The goal was to find the location of the objects.

Task 3: Structural change detection on registered airborne images captured with significant time difference. The task is high-level change detection instead of the pixel differences. The goal is classifying the structural changes and marking e.g. the changes in urban areas, forests. Pixel-level comparison suffers from problems, since simple illumination-changing rules often fail in a complicated environment. Area-based comparison offers a more natural way for solving the problem: I segmented the different images into smaller parts, and compared the corresponding segments.



*Task 1: segmentation results. Above (left to right): original image; ground truth; result of the detector without MRF; result without our foreground model Below: result without our shadow model; 7. model working in the RGB color space; CIE L*u*v* space; CIE L*u*v* space with textural features.*

Framework for Geometrical Scene Analysis Using Co-Motion Statistics

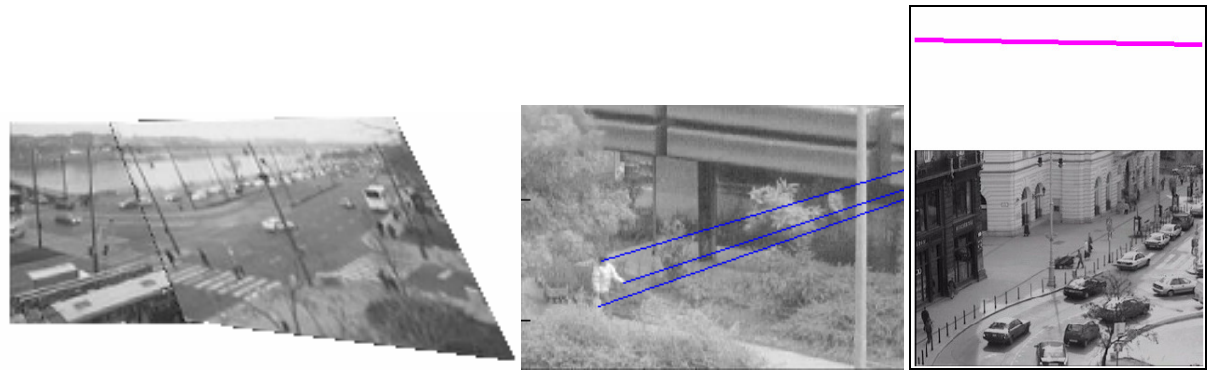
László Havasi
(Professor Tamás Szirányi)

In recent years there has been a dramatic increase in the number of video surveillance systems in use; and these have in turn generated a large quantity of archived video recordings, which are usually stored without any image-processing. In most cases for such recordings one does not know the relative and global geometrical properties of the surveillance cameras. The literature on video indexing on the basis of the content or context is a rich one, and this is in fact one of the most popular current research areas. Also there are several publications on techniques for the extraction of various features such as depth, color, shape, motion etc. Despite this, there is a striking lack of publications concerning the extraction of geometric characteristics from images contained in video recordings. A statistical framework is introduced which allows us to derive three key geometrical scene parameters: the homography, horizontal vanishing line (VL), and focus of expansion (FOE or light vanishing point, VP)

The FOE relates to a particular class of scene, namely those which contain a planar surface which shows reflected images, or on which cast shadows are seen, together with the original objects (the camera-mirror case). The estimation of the vanishing point enables the modeling of the reflections or shadows. The transformation between different views is termed homography, and our initial idea relating to this problem is inserted into a general statistical framework. The vanishing line is useful for camera orientation and extrinsic parameter determination.

The main practical advantage of our proposed method is that there is no need for any time-consuming processing steps; and also, it enables all of the above-mentioned parameters to be determined. Furthermore because of the statistical method employed it is a robust procedure, and sub-pixel accuracy may be achieved. These properties are especially important in the analysis of outdoor surveillance videos. In videos captured by analog surveillance cameras the contrast and focus are often badly adjusted, and thus precise measurements are not possible in individual frames. This consideration led to our concept of summarizing the information from a sequence of a number of frames (as many as possible) in order to achieve higher accuracy in the averaged retrieved information.

We performed a practical evaluation of the method in which both indoor and outdoor videos were used as input. In future work, we intend to investigate the estimation of the necessary video length, and by extension the time to accomplish synchronization between videos; the use of the method in handling image-sequences from non-static cameras will also be explored.



Homography computation, reflective surface detection and geometrical modeling and horizon determination in our statistical framework.

Optimal Statistical Energy Balancing Protocols for Wireless Sensor Networks

Barnabás Hegyi
(Professor János Levendovszky)

Due to the recent advances in electronics and wireless communication, low-cost, low power, multifunctional sensor nodes have become available, and thus wireless sensor network applications such as military field observations and living habitat monitoring have received increasing attention. In contrary to ad hoc and other wireless networks, nodes in a wireless sensor network are of limited energy, communication and processing capacity. Consequently, conventional communication protocols are not applicable, the development of energy efficient routing mechanisms are needed. There have been several energy balancing protocols proposed to maximize network lifespan in case of deterministic traffic (Heinzelman et. al., Lindsey et. al., Tan et al., Haenggi et. al.). The original contribution of our approach is that we investigate novel optimal energy efficient routing protocols for wireless sensor networks with statistical load.

We consider a 1D sensor node array with the base station located at one end. The sensor nodes can receive packets from their far side neighbors, while they can send packets to their nearside neighbors or straight to the base station. Node distances are mapped to transmission energies through an appropriate radio propagation model. If routing in the network is performed according to the chain protocol, each sensor node forwards its packets to its nearside neighbor. In this case, obviously, the entire network traffic goes through the sensor node closest to the base station and this node will be the bottleneck node as far as the lifespan of the network is concerned. In order to circumvent this effect, we propose the so-called random shortcut protocol, in which nodes randomly choose to send their packets either to their nearside neighbor or straight to the base station. An generalization of the random shortcut protocol is the case when packets are forwarded to any of the nearside neighbors or to the base station in a random manner. The probability distributions of the random target selection of packet forwarding are optimized in order to maximize network lifetime.

We treat wireless sensor networks with statistical traffic both in discrete and continuous time. In the discrete time case, each node generates packets according to a binomial process, while, in the continuous time model, packets are emitted in compliance with a Poisson process. Each sensor node is modeled as a queuing system; hence the wireless sensor network is represented by a queuing network. In the discrete time model, there is a single packet forwarded by a node at each time instant as long as its queue is not empty, whereas, in the continuous time case, the interval between two forwarding time instants is considered to be independent variable subject to exponential distribution.

In order to be able to handle the problem analytically, we make the following assumptions: the steady state distribution of the system is considered and the energy consumption of the nodes is calculated with the use of an average transmission energy quantity. We developed a packet-level simulation package to verify of our analytical approximations.

The simulation results show that significant energy saving can be achieved with the use of the proposed, novel energy balancing protocols. Our future work is to establish an intelligent monitoring system in Jedlik lab in order to experimentally verify our theoretical results.

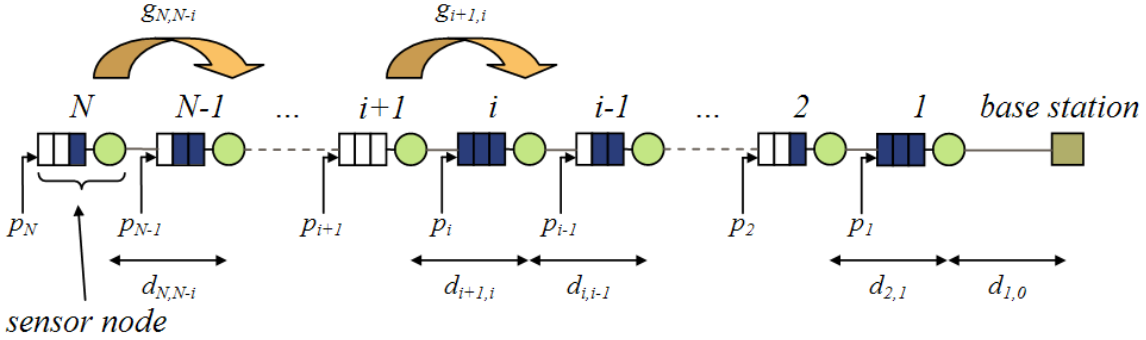


Figure 1: Sensor nodes modeled as queuing systems with the base station at one end.

Prediction of Epileptic Seizures

Béla Weiss
(Professors Tamás Roska and György Karmos)

Epilepsy is the most common disorder of nervous system just after stroke, and affects almost 60 million people worldwide. Medications control seizures in only 2/3 of those affected, and another 7%-8% are potentially curable by surgery. This leaves fully 25%, or ~15 million people whose seizures cannot be controlled by any available therapy.

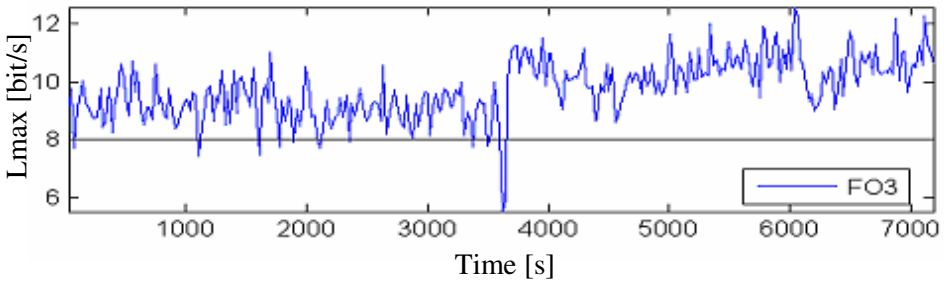
The most important query in therapy and presurgical monitoring of patients suffering from this disease is: is there any way to predict epileptic seizures?

For many years it was thought that there are not any precursors in EEG signals, but in last years new methods were proposed for a short a long time prediction.

The aim of this research was to find appropriate features in foramen ovale (FO) electrodes for a long term prediction of seizures of five patients with temporal lobe epilepsy.

Results:

We cannot predict seizures with sufficient sensibility/selectivity by comparing the accumulated energy of preictal and interictal states. Artefacts and the state of consciousness affect this ability significantly.
Examination of the chaotic behavior of the human brain gives positive results. The level of chaotic behavior was analyzed by calculation of short-term largest Lyapunov exponents (Lmax) for all depth electrodes, considering the non-stationary characteristics of these signals. There is an assumption that the seizure means synchronization of the physiological EEG. This has to result a new trajectory in the state space and a less chaotic behavior. The underneath figure shows the Lmax values of third FO electrode (the nearest electrode to the seizure generating foci) in patient 1 for a period of 2 hours (1 hours before and 1 hour after the beginning of the seizure). At the centre is a drop that represents the less chaotic behavior under seizure. Before the seizure we can observe drops of Lmax values to. Choosing appropriate threshold value we can predict the oncoming seizures because these drops were found just in preictal periods. In postictal and interictal periods the FO signals are more chaotic. These results were found for all analyzed seizures (seven seizures of five patients in wakefulness). Further we will have to analyze seizures from different consciousness states, optimize our algorithm and implement it on CNN architecture for real-time prediction.



Largest Lyapunov exponent values for a two hour period.
The biggest drop of Lmax value is observable in the middle of the figure, during the seizure.
Smaller drops, which occurred before the onset of the seizure can be used for forecasting.