Project proposals 2016

As noted, most of the proposed projects are possible to expand into M.Sc. thesis projects. Please let us know if you might be interested in this option as well. You can learn more about each of the projects by asking the project supervisors.

1. LASSO-based pitch estimation

Sparse reconstruction modeling is a currently active area of research. In this project, you will work with the so-called LASSO to estimate the fundamental frequency of a signal consisting of a number of superimposed pitches. The pitch model is useful for signals for which the spectrum can be decomposed into a sum of spectral lines or sinusoids such that each sinusoid has a frequency that is an integer multiple of the fundamental frequency. You will investigate if the LASSO can be used to solve the fundamental frequency estimation problem alternating between updating the relative amplitudes within each possible pitch and using the LASSO to choose which pitches are in the signal.

Supervisor: Stefan Ingi Adalbjörnsson

2. Modeling of pitch variability with the aim of early detection of Parkinson disease

Parkinson’s disease is a neurological disorder affecting the central nervous system. Among the common symptoms of Parkinson’s disease are tremors, rigidity and also voice disorders. This project will focus on one such voice disorders: the inability of keeping a steady pitch while speaking. A pitch is a set of harmonically related sinusoids whose frequencies all are integer multiples of one single frequency, called the pitch frequency, and is well suited for modelling of the voiced parts of human speech. In this project, you will investigate the possibility of describing fast pitch frequency variations using parametric models. You will do this for recordings of your own voice as well as voice recordings of people with Parkinson’s disease. If you’re a singer, you have the opportunity of modelling your own vibrato!

Supervisors: Filip Elvander, Ted Kronvall, Andreas Jakobsson

3. Dictionary selection techniques for the LASSO estimator

In this project, you will develop a new LASSO-based approach for finding the frequency content in a signal. If one suspects that a signal contains a small amount of sinusoids, a common technique is to form a dictionary containing different candidate sinusoids, and solve a minimization problem to find which candidates that approximates the signal the best. To get really good estimates, one must often use a vast amount of candidates, which makes the computation burdensome. In this project, you will look into a way of collecting many different sinusoids into a single candidate, yielding a much smaller dictionary and thereby decreasing the computational burden. This new technique may be especially useful when the signal is non-uniformly sampled. This project gives you a good understanding of the very useful LASSO method, as well as giving you the chance to work on something that has never been done before.

Supervisor: Johan Swärd
4. **Group-constrained spectral estimation using SPICE**

In spectral estimation, properties such as resolution, statistical efficiency and computational cost all play a role in the choice of method for a particular problem. In this project, you will consider the SParse Iterative Covariance-based Estimation approach (SPICE) to estimate a spectra consisting of several narrowband spectral lines. This method has the benefit of being hyperparameter-free, i.e., it does not require any tuning parameters, which is of great practical interest. In particular, we consider the application towards audio processing, where a musical tone, for instance, has a spectral representation consisting of a number of frequencies with an integer relationship, i.e., a pitch. The project’s objective is to examine the possibility of deriving a new method, Group-SPICE, which tries to estimate a group of frequencies that has such a pre-defined relationship. To that end, you will work with tools from statistics, analysis, and linear algebra.

**Supervisor:** Ted Kronvall

5. **Detection of cod**

In later years the populations of cod in Swedish waters have drastically decreased due to overfishing, eutrophication and pollution. Cod returns every year to the same spawning ground where a large number of fish gather and spawn. A special feature of the cod is that it can produce sound by squeezing the swim bladder with specialized muscles. Today we have only a rough idea of the locations of the spawning ground and at the moment, these areas are quite large. Using acoustical instruments together with state-of-the-art statistical signal processing, it might be possible to pinpoint the current location of the spawning cod, in order to protect them from fishing and other activities during the spawning period. Doing so, the future for the cod would look brighter. This project aims at building a cod detector.

**Supervisors:** Shiwen Lei, Erik Gudmundson (FOI), Andreas Jakobsson

6. **Optimal sampling selection in non-uniform spectral analysis**

Traditionally, the most common way of sampling a signal is to use equal spacing between the measurement times, e.g., $y(t)$ for $t=1,2,3,...$ This is denoted uniform sampling. Recently, a lot of attention has been devoted to non-uniform sampling, which makes it possible to use fewer measurements than in traditional sampling. In this project, you will be investigating how one can find the optimal sampling pattern given a known signal. For instance, if one suspects that the signal contains a sinusoid with frequency $f$, how should one sample the signal to best be able to detect the frequency? How does this change if we instead have two sinusoids? Using the Cramér-Rao lower bound as the objective function, you will find the optimal sampling pattern for different signals and compare it to the traditional uniform sampled case. This project will give you an insight into a very hot and interesting topic in the signal processing research field.

**Supervisor:** Johan Swärd

7. **Classification of bird song**

Can you differ the birds in the garden when you hear the song? ‘Kvitteromat’ is a new app, which identifies bird species based on the recorded song. However, it is sensitive to noise and presents three different choices as the final result. The aim of this project is to classify a few of our most common bird species from their song, using common time-frequency methods and existing and novel time-frequency features. A challenge is to minimize the required song length. Several different recordings from three species will be available in mp3-format. Recordings of three species with similar songs will also be available for further evaluation of the methods.

**Supervisor:** Maria Sandsten
8. Modeling seismic waves
The double Fourier transform (space and time) is a common tool for analysing seismic data and extracting the discrete number of propagation modes of surface waves (e.g. Rayleigh waves). However, very often, there are gaps in the observations and/or non-uniform distance between the receivers. Moreover, the frequency- wavenumber spectrum can usually retrieve only broad bands associated with the different propagation modes, which mask and mix up the modes, and makes hard their precise localization and selection. We are looking for a better estimation of the spectra to handle the non-uniform sampling in space and to optimize the filtering procedure for selecting solely the principal mode of propagation. The final goal is to obtain the phase (and amplitude) values as function of the receiver offset for each frequency of the selected mode. This, in turn, will allow the use of surface waves for detecting heterogeneities and reconstructing 2D S-wave velocity distributions in the propagation medium.

Supervisors: Matteo Rossi (Teknisk Geologi, LTH), Andreas Jakobsson

9. Cross-term relocation using time-frequency phase-kernels
When estimating the time-frequency distribution of a process containing multiple components one will get the unfortunate effect of cross-terms. A common way to deal with these is to apply some ambiguity kernel function, which will remove cross-terms, but the kernel will also smear the auto-terms. Another idea is to simply move the cross terms to some other location in the spectrum where they don’t disturb the interpretation of the true components, meaning that the auto-terms will retain optimal concentration. In this project you will implement code for a complex-valued ambiguity kernel, a phase-kernel, that relocates cross-terms and evaluate and compare the performance.

Supervisors: Isabella Reinhold, Maria Sandsten

10. Sparse and cross-term free time-frequency distribution
Hermite functions are often applied as data windows for the multitaper spectrogram. The number of windows to be used for a specific multicomponent signal is not easy to decide. Recently, an algorithm was proposed for optimization of the multitaper spectrogram with respect to concentration and suppression of cross-terms. The Hermite functions are analysed in the ambiguity domain where the optimal solution depends on the location and spread of signal auto-terms. Different sparsity and concentration measures were investigated. Another possibility is to apply the idea of a matched Gaussian multitaper spectrogram. The aim of the project is to compare these two approaches and compare the results from some optimization algorithms. The project requires some interest and knowledge in optimization.

Supervisors: Maria Sandsten, Isabella Reinhold

11. Non-linear combination of scaled reassigned spectrograms
The reassignment technique is used to increase the localization for signals that have closely located time-frequency components. For Gaussian components the reassignment based on an optimal (matched) window spectrogram will result in a single point where all mass is located. For non-optimal windows, the reassignment procedure can be optimally rescaled to fulfill the single point mass location using concentration measures. Non-linear combinations of spectrograms for different window lengths have previously been suggested, and in this project the performance of different non-linear combinations of optimally rescaled reassigned spectrograms should be evaluated.

Supervisors: Maria Sandsten
12. Time-frequency analysis of the Heart Rate Variability
High frequency heart rate variability (HF-HRV) mirrors the respiratory cycle. Individuals suffering from work-related stress, or burnout, have been found to show decreased HF-HRV, combined with cardiovascular disease. In this project the time-frequency coherence between the HF-HRV and the respiratory frequency should be evaluated for a novel type of measurement – a chirp-breathing task. In this specific task, test participants breathe, following a metronome of slowly increasing frequency during 4 minutes, and the ElectroCardioGram (ECG) is measured and converted into the HRV signal. The aim is to evaluate the time-frequency coherence from real data measurements of a larger sample of women and men (20-65 years old) at three different stages of work-related burnout.

Supervisor: Maria Sandsten, Peter Jönsson (Psychology, Kristianstad University)

13. Detection of high-frequency oscillations in EEG using time-frequency analysis
For people with severe epilepsy, brain surgery is sometimes the only treatment option. In the presurgical assessment of patients, intracranial EEG-registration is sometimes performed to help finding the area of the brain that generates epileptic seizures and, thus, may be a candidate area for surgical removal. Intracranial recordings contain not only the usual EEG activity, but also high-frequency oscillations (HFOs). Visual detection of the HFOs, which is the present standard, is an extremely time-consuming task. Thus, the development of automatic detection algorithms for HFO is warranted in order for this technique to become a clinically relevant application. The project will focus on the use of time-frequency tools in combination with singular value decomposition to extract suitable features.

Supervisors: Maria Sandsten, Christine Ekdahl Clementson (Clinical Neurophysiology, SUS)

14. Pitch perfect: building a MIREX evaluation system
MIREX (Music Information Retrieval Evaluation eXchange) is an annual evaluation of algorithms connected to processing of music signals. The tasks that the algorithms are evaluated on include estimation of tempo, beat, musical key, and instrument identification. One of the most interesting categories (and a hot research topic) is multi-pitch estimation and tracking, that is, estimation of the musical notes that are being played in the music piece. In the MIREX evaluation of this category, the competing algorithms are ranked based on how many pitches they correctly identify (true positives), how many they miss (false negatives), and how many erroneous pitches they find (false positives). In this project, you will implement a system for doing such an evaluation. You will also apply different multi-pitch estimators to music databases and see how well they fair in finding out what is played.

Supervisors: Filip Elvander, Ted Kronvall

15. Spectral analysis of non-linear signals
In a recent master thesis project at the Department of Mathematical Statistics, a novel technique for non-linear non-destructive testing of materials has been developed (Dahlen, 2013). The proposed method can be used in the field of material characterization and structural health monitoring since it has the potential to sense the very beginning of micro damage, which is not visible to the eye. The proposed method is based on the free reverberation of a sample after a single mechanical impact excitation using a sum of time-varying amplitude polynomial phase signals (parametric model). So far the method has been tested on relatively small concrete samples with low damping properties. In larger samples or other materials with more material damping the decay of the samples resonant frequency is much quicker making the extraction of a non-linear signature more difficult. In this project, alternative spectral analysis techniques are investigated for the extraction of non-linear effects in non-destructive testing of materials.

Supervisors: Andreas Jakobsson, Nils Rydén (Teknisk Geologi, LTH)
16. Improved spectral analysis of Lamb waves

Lamb waves are guided elastic waves propagating in a free infinite plate with finite thickness. At each frequency several modes (defined by phase velocity, wavelength, or wave number along the surface) can propagate simultaneously. The velocities of Lamb waves are dispersive which means that the velocity changes with frequency. Lamb wave dispersion curves can be calculated from the elastic constants of the plate using the Lamb wave equation. In non-destructive testing of plate like structures with unknown thickness or elastic constants, peaks in the 2D spectrum are compared with corresponding theoretical dispersion curves to estimate the unknown plate properties. The normal response of the plate from an impulse source is measured using a linear array of receivers and stored as a matrix with about 40 samples in space and 1000 samples in time. The relatively small number of samples in space results in poor resolution of the spatial periodicity limiting the overall resolution of the measurements. It should be beneficial if multiple modes could be resolved at each temporal frequency resulting in several measured dispersion curves, which can be matched with theoretical modes.

Supervisors: Andreas Jakobsson, Nils Rydén (Teknisk Geologi, LTH)

17. Artefact detection in EEG signals

Brain activity is measured using EEG signals in both humans and animals. EEG signals benefit the possibility of measuring the activity in the brain with very good time resolution and a moderate spatial resolution. It is also relatively cheap and possible to do non-invasively. However, interpreting the signals is not obvious. The frequency content of the signals is used to track activity, different sleep stages, to detect epileptic seizures or to investigate the effect of treatments on the EEG signals/neural communication of the brain. At Lundbeck A/S, we are interested in automatically detecting the occurrence of some micro events in the EEG called spindles. These are small bursts of rhythmic activity with a well-defined frequency and time duration. Traditionally, these bursts are counted manually. We would like to automate this with an algorithm that can detect the spindles. This will save time, eliminate a tedious work, and improve the objectivity of the detection, since an algorithm has the benefit of using the same spindle definition all the time. Lundbeck A/S will provide the relevant data material. The development of an automatic detection algorithm is a part of a larger project where we are working on creating new and better ways of treating Schizophrenia. Schizophrenia is a severe mental disorder that affects around 0.5% of the population. Current treatment is far from perfect, most patients are only partially helped and side effects of the medication are common. Hence, there is a large unmet need for better treatment, which we are trying to fill.

Supervisor: Lars Arvastson, Andreas Jakobsson

18. Estimating angle of arrivals of angular spread sources using the LASSO

Most spatial sources experience some form of local scattering due to reflectors close to the transmitting/reflecting source. This scattering will result in an angular spread in the spatial spectrum that should be taken into account when constructing the beamformer. In this project, we will examine the possibility to adaptively form the LASSO dictionary such that it allows for angularly spread sources, and, if we have time, the possibility of array calibration errors.

Supervisor: Ted Kronvall, Andreas Jakobsson

The projects can be performed individually or in groups of up to four. By February 10th, please let us know your group’s project preferences, ranking 1st, 2nd, and 3rd choice to allow us to distribute the projects fairly. If you have your own project suggestion, please let us know as well, giving a brief description of the project. Please also feel free to approach the suggested supervisors to discuss the different projects, and don’t hesitate to get in touch if you have questions!

Andreas & Maria