Description for the general public:

Single-pixel imaging in real time - application of machine learning methods to image reconstruction and analysis.

The imaging systems used in everyday life (such as photographic or film cameras) use high-resolution matrices of photo-sensitive elements to record an image. This solution works well for most applications, allowing to capture the whole image almost instantly. However, in some cases, especially for imaging with the use of more exotic ranges of radiation (e.g. teraherz waves), the cost of such cameras is considerably high. For this reason, novel types of imaging systems have been created, which allow to record an image with the use of only a single photodetector. Recording an image with such a simple device requires to make a large number of measurements, each of them providing some partial information about the image. It is achieved by using a special method of sampling, in which a sequence of images (named sampling functions) is projected onto the image of the recorded object, and the total brightness of each of these combined images is measured. The sampling functions may be displayed with the use of matrices of electronically controlled micro-mirrors, which allow for projecting the consecutive images at high speed.

The appropriate choice of the sampling functions is crucial for the number of measurements which need to be taken. In particular cases this number may be significantly smaller than the number of pixels in the image. Recovery of the images sampled using this technique is not simple, it leads to the necessity of solving a system of linear equations, in which the number of equations (equal to the number of measurements) is substantially smaller than the number of variables (values of the pixels in the recorded image). Compressive sensing theory provides computational methods for reconstructing images, based on the assumption that the images are sparse. Sparsity is a property, which makes the images compressible (a similar principle is used in commonly-used formats of image compression, such as JPEG). The problem of image reconstruction becomes even more complicated, when the imaging system is used to capture not only static images, but also video images of objects which are in constant motion. The reconstruction methods offered by compressive sensing, do not perform well in recovering images which are distorted during the measurement. Most of them is also not fast enough, to allow reconstruction of the video images in real time.

In this project, we intend to use artificial neural networks for the purpose of recovering images captured by a single-pixel camera. Artificial neural network is a complex computing system, which is capable of “learning” new skills based on the analysis of a large number of examples. Artificial neural networks are a universal approximation tool and can be trained in performing a broad variety of tasks. For example, they are excellent at analyzing and processing images, or interpreting natural language. Our goal is to make use of their potential to reconstruct the video images captured by a single-pixel camera with improved quality. These solutions will be immensely valuable for the purpose of the development of terahertz or FIR video-imaging systems. We also plan to take advantage of the sparsity of video images in both spatial and temporal dimension to improve the recovery of motion in the videos.

Moreover, visual systems are frequently used for realization of more complex tasks than only displaying an image. For example: detection and identification of traffic signs or deciding whether an image contains a cat. This class of tasks is presently performed with high efficiency by the artificial neural networks. One of the objectives of this project is determining whether a similar range of tasks may be accomplished using directly the signal measured by a single-pixel camera without the necessity of initial reconstruction of the images themselves. This solution would significantly speed up the process of image analysis in real-time single-pixel imaging systems.