The term ‘machine’ is generally understood as a performing a task useful for a man. The machines used in modern industry and science are complex mechanical objects. They consist of many interconnected smaller mechanisms, components and subsystems. An excellent example are industrial manipulators (robots) and machine tools. By using multiple engines and suitable mechanical connections, they have a great freedom of movement and ability to reach anywhere in their workspace. Such devices have to demonstrate not only adequate power, sufficient to fulfill the assigned tasks (ie. moving large parts in car manufacturing process), but also a very high precision and repeatability of the movement. Only then the products, regardless it is a vehicle or a part of small appliances, have acceptable quality, which consists of not only aesthetic appearance but also precision of its parts and accuracy of fit, which in the longer perspective lead to reliable work and longer life-span of products. Speed of movement of parts of the driven mechanism is also a vital parameter; the higher the speed is, the more items can be produced per a unit of time. At the current level of technology, the maximum flexibility of control is available by application of electric motors. Electric drive enables relatively simple motion control of machine elements, fulfilling all requirements for power, dynamics and precision.

The industrial application of electric drive specified in the preceding paragraph is one of many others. Application of controlled drive systems allows accurate tracking of astronomical objects by telescopes. Astronomical observation is a very specific challenge for propulsion systems, where very slow, but steady movement of the telescope barrel is desired. In the current years, application of medical robots, used in surgical operations, becomes increasingly common. Widely known is the DaVinci robot, used in both gastrointestinal and heart surgery. The main advantage of robotic surgery is less invasiveness (wider use of laparoscopy) and very high accuracy. For proper execution of precise movements of surgical robot, not only advanced achievements of mechanics are necessary, but also complex drive control methods.

To meet the strict requirements of precision, modern systems of electrical drive are equipped with extended electronic control systems, currently based on the use of microprocessors. The output signals of the microprocessor are delivered to a power electronic converter, i.e. the device processing large amounts of electric power (in the industry, from single kilowatts to over hundreds kilowatts), which powers the electric driving the mechanism. The use of power electronic converter allows for smooth speed control of electric drive as well as its power and produced torque. The key to the precision of the drive, so important in industrial production and precise research systems, is application accurate speed and position sensors, that are mounted to the rotating shaft of the motor. This way, the microprocessor system can assess in what extent the current position of the mechanism (which can be a robot arm or a machine tool), deviates from the desired position and how the electric motor should be controlled to minimize this difference, called in in the automation control as ‘control error’.

Essential elements of modern machines are parts transferrin the movement from motor to the part executing the real work (the effector). Gears, pulleys, chains, worms, coupling elements, lever mechanisms may be counted among these parts. Each of these elements not only introduces additional energy losses, primarily in form of friction, but also a degree of elasticity. The occurrence of elasticity in the driven system implies presence of mechanical resonances. There are specified frequencies for such connections, at which resonance oscillations of speed are present. These oscillations are generally undesirable and their elimination is required. The appearance of such oscillations during operation of the machine is associated with an increased vibration and noise. What is more, they cause very significant reduction of machine operation quality, e.g. by lowering the manipulator movements precision. It is necessary to take remedial actions in order to eliminate the results of these unfavorable properties.

The easiest solution, but not necessarily the cheapest one, is to equip the machine with additional mechanical damping elements. Unfortunately, it increases costs. It is not the only approach that is currently available. Appropriate control of the drive unit can prevent the appearance of undesirable oscillations. Such an approach does not generally result in additional costs because the drive systems are controlled by advanced microprocessors, as has been already mentioned above. It is necessary to modify the control algorithm, i.e. developing another program for the control microprocessor. The basic method used in the drive system where resonances may appear, is filtration of the signals, i.e. proper processing which removes undesired frequencies. Since the system is particularly sensitive to certain frequencies that cause excitation of vibration, these frequencies should be eliminated at the stage of control. In other words, the filtering of the signals is based on avoiding of excitation with the signals, which may cause uncontrolled oscillations. The signals at frequencies other than the resonant are not eliminated and are transmitted directly, since are harmless to the drive system,. The process of filtration itself takes place inside the microprocessor system and consists in proper mathematical operations on signals processed in the control program.

Although the issue of signal filtering is fairly well researched and developed, tuning of the filter still remains a significant challenge. As the radio signal is received well only when the radio receiver is properly tuned to the frequency of the broadcasting station, similarly, the filter operating in the microprocessor has to be adjusted in accordance with the resonant frequencies of the controlled mechanical system. In other words, before we proceed to the filtration process, we need to have prior knowledge about the frequencies to be eliminated by the filter. Unfortunately, the complex devices often have multiple resonant frequencies to be damped. Additionally, in many cases, their position changes during the system operation. In such circumstances it is necessary to apply automatic tuning, not only for the filter but also for the controller. This property is called adaptation of the control system, since it adapts to the changes in the controlled system. The program, which is executed by a microprocessor of control system remains unchanged, but its parameters (for controller and filter) must undergo successive change, together with changes in the mechanical system. This area is a great research field for this grant funded by the NCN.

Besides other advanced methods of control, artificial neural networks will be included to the field of research work of the grant. The artificial neural networks constitute a very specific group of mathematical objects, that imitate in some extent the behavior of biological neurons. As a biological neuron, they have a single output, the output signal is dependent on states on inputs of the the artificial neuron. Neurons, combined even in a simple network, including a few “cells", reveal an ability similar to learn. This process is obviously not a spontaneous phenomenon. A sufficient control of the learning process is necessary, in order to check if the network output states correspond to expectations, and to determine whether the network responds to the selected situations in an expected way. The process of learning (training) of the network is always under the control of an appropriate algorithm. Specially prepared artificial neural networks may become a control algorithm for a drive system (a neural controller), which, due to the mentioned training mechanism, will exhibit features of adaptation, variable states of the machine.

In the research on the issue of oscillations damping in the complex mechanical systems, an innovative approach of two-sided axis drive will be applied. In contemporary applications, each axis is commonly driven by a single motor. It is possible to apply a second power unit, with adequately smaller required power and located at a considerable distance from the first motor, e.g. at opposite end of the mechanism. This modification of construction displays different mechanical and control properties. It is anticipated that the tests performed within research work in this grant confirm that presented briefly driving solution, although simple in its idea, combined with advanced methods of regulation, such as the mentioned neural controllers, enable better control results, especially extended dynamic (in this case understood as more rapid acceleration and breaking processes), better precision of movement, so desirable in the applications listed previously, from the driving telescopes, through mechanical systems present in the manufacturing industry, and finishing in the drive control of specialized robots.