The aim of the project is to design a smart expert system dedicated for detection of damage and degradations in composite structures such as reinforced concrete. An expert system is a system that contains knowledge consisting of the rules of "if ... then ...". Therefore, this kind of system allows simulating the human/expert decision process. Generally, the M5 method allows us to some degree observe connections between the physical changes in the object, and changes in resonance frequencies. However, changes are very difficult to interpret. By learning the rules of the association, it will be possible to link the frequencies at which an object naturally vibrates (resonant frequencies) with specific defects. An expert system will also enable a good system setup.

The natural frequencies of any object are unique to each object like a fingerprint is to a person. Changes in such frequencies are always correlated with physical changes in the object. This observation is widely used to detect the defects and malfunctions of many different objects, from transformers, engines, turbines or other machines to buildings and aircrafts. The identification of natural frequencies can be also used to detect the material and size of the sample. Currently, even simple telephone applications enable the identification of e.g. kind of coin or whether a bullion coin is real or fake.

There are many different methods to produce and detect vibrations. A vibration inducing device may take various forms, from a hammer to a laser. The sensor (measuring instrument) also can be done in many different ways from a simple microphone to a laser vibrometer or accelerometer. Vibrations (mechanical waves) are usually detected on the object surface, or in the air (sound). Here is a problem! In many cases, the object is not accessible and generated sounds are undetectable. Is it even possible to identify resonance frequency in such a situation? The authors of the project think so. This project aims to create a new method, designed to evaluate such objects. The authors of this application believe that the method can be completely contactless. That means, the device does not even need to touch the tested object. To achieve this goal, completely different than the typical approach to the design and configuration of excitation and measurement systems is needed.

The concept of the proposed method was invented during the previous study on testing reinforced concrete structures. The degradation of reinforced concrete structures caused by corrosion is a huge problem around the world. For example, on Aug. 14, 2018 Morandi Bridge in Genoa, Italy, collapsed, sending vehicles and tons of rubble to the ground 150 feet below and killing 43 people. Corrosion was a major factor in this collapse. Such disasters occur more and more often. However, this problem is much more general. According to the Federal Highway Administration, about 30% of buildings are to some extent affected by the corrosion. The general global cost of corrosion reaches even 2.5 trillion dollars. The authors already prove that the occurrence of reinforcing bar corrosion changes the resonance frequencies of the entire facility. However, due to concrete damping, it is very difficult to detect these changes. The method can make it possible because M5 allows us to avoid the problem of damping, and this is just one of the many examples where the method can be used. However, how does it actually work?

In the M5 the alternating magnetic field generated by the excitation element (rotating permanent magnets or electromagnet) permeates the tested object. If there is any well conductive or ferromagnetic object near the excitation, it interacts with the alternating magnetic field and the resulting force will cause vibrations of the tested elements. The vibrations are induced directly in tested, not through the whole structure. Three different phenomena can affect the vibration of an object: magnetic interaction, magnetostriction and eddy currents (Lorentz force). The significance of individual phenomena varies depending on the tested material. Magnetic interaction is crucial for ferromagnetic objects. On the other hand, eddy currents are becoming more important when high conductivity materials like aluminum, copper, etc are tested. Eddy current creates a magnetic field that opposes the change in the magnetic field that created it. The vibrations are transferred by magnetic coupling directly to the permanent magnet placed above the tested object and these vibrations are monitored. Because the magnet is mechanically connected to a measuring instrument (e.g. accelerometer). Finally, the achieved signals are amplified and converted into digital form. Then they are further processed to achieve the frequency characteristics. The smart supporting expert system will make the M5 method more effective and sensitive. But it is not all, the system will also allow recognizing types of defects.