Condition of bridges, nuclear power plants or roller-coasters monitored with a new system

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Researchers are developing an intelligent system to monitor the condition of valuable structures automatically, at times even in real time. The system has the ability to alert users of damage.

This enables owners to prevent the exacerbation of the damages as well as better preparation against destruction caused by natural disasters, for example.

Intelligent sensors are attached to the structure to be monitored that will then measure the movement of the structure. Using a wireless radio connection, pre-processed measurement data is automatically transferred to a computer that analyses the measurement results. The aim is to detect the existence, location, size and gravity of any damage to the structure. The data can also be used to make predictions on the remaining lifetime of the structure.

Will a bridge collapse in an earthquake?

The monitoring is needed particularly for targets that are important from the viewpoint of infrastructure or the safety of which is especially essential. It is also worthwhile to keep an eye on other valuable structures, such as historical monuments. Comprehensive monitoring can save human lives as well as generate savings in repair costs.

"There is a large number of potential applications: bridges, skyscrapers, pipe systems in nuclear power plants, wind parks, cranes, space crafts, ships, theme park rides," lists Jyrki Kullaa, the leader of ISMO project focused on developing the system.

Monitoring the condition of buildings is particularly important in areas afflicted by natural disasters. In addition to regular controls, the system is able to monitor the condition of the structures in real time, where necessary.

"For example during earthquakes, it is possible to detect whether a building or a bridge is in danger of collapsing. This way, the amount of destruction can be minimised as evacuation and other measures of precaution can be carried out in time," Kullaa explains.

Change in vibration reveals the damage

Monitoring the condition of a structure can be based on repeated vibration measurements conducted at different times. Possible damage is detected through identification of any changes in the period after the installation of the sensors. For example, reduced vibration frequency within a structure indicates damage to the structure and a decrease in rigidity. Other factors affecting vibration, such as temperature and dampness, can be eliminated from the data. The project has also identified other key values in detecting possible damage.

"All structures vibrate at different frequencies. You could say that they have their specific frequency fingerprint. For example, a wooden table vibrates differently to a metallic guitar string," Kullaa explains.

The vibration of a structure is a rapid phenomenon. To detect it, the sensors in the system must be able to perform as many as 1,000 measurements per second, which poses challenges for wireless systems. The measurements are also strictly synchronised: the sensors must function with perfect simultaneity, with a maximum difference of five milliseconds.

The number of sensors has an impact on how comprehensive the measurement data obtained from the structure is. In principle, a single sensor can be sufficient to detect the damage, but the element of wirelessness enables easy positioning of multiple sensors. The system associates the damage with the sensor closest to it, meaning that the location of the damage is identified with greater accuracy the larger the number of sensors installed.

For example, the three consecutive bridges Tsing Ma, Ting Kau and Kap Shui Mun in Hong Kong are monitored by an armada of a total of 900 sensors.

Sales of the system pose a challenge

"How to motivate the owner of a bridge to invest in the system when the bridge will most likely only begin to disintegrate after decades of use? The monitoring equipment is often adopted into use after being required to do so by the authorities or after a negative event has already taken place. Technology has a habit of progressing through accidents," Kullaa says.

The costs of the system consist of the initial investment, installation and

maintenance. Maintenance has been made as effortless as possible: the system has the ability to alert the user if one of the sensors is broken. The sensors have also been made as energy efficient as possible.

The system is likely to be adopted into wider use once it is cheaper than manual controls, for example.

More information: mide.aalto.fi/ISMO

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