INSTITUTE OF
ELECTRONICS AND
COMPUTER SCIENCE

NEXT-GENERATION

IOT PLATFORM

USING

INTELLIGENT ALGORITHMS

IoT solution
to monitor in real time
the condition of buildings, engineering structures
and bridges around the clock
using data-driven approach

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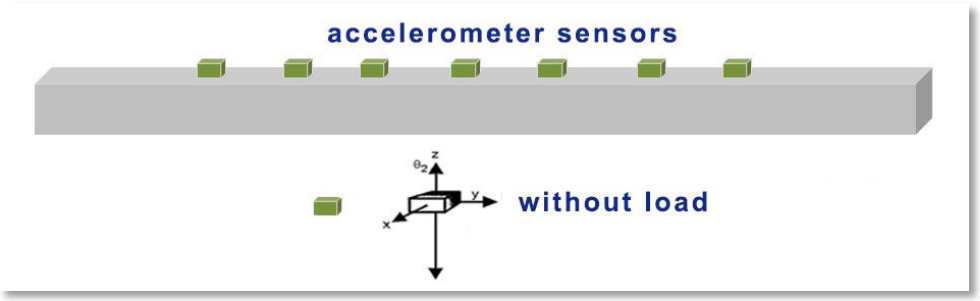
Currently, on a global basis, retroactive methods for measuring deformations in buildings and engineering structures are used, i.e., when the deformation becomes visible. There is no affordable technology currently available in the market that would allow receiving live data about the likely deformations and vibrations of building structures.

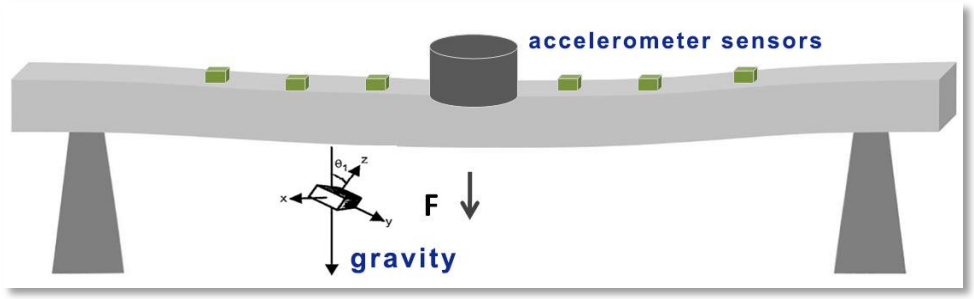
The group of scientists of EDI Scientists developed IoT solution that provides the possibility to use predictive analysis before changes could lead to structural problems.

EDI (Institute of Electronic and Computer Science) incubated and developed deep-tech sensor technology 'deflexio' allows to capture real-time data of deformation and vibrations in buildings and engineering structures.

The sensor system is built of serially connected sensor nodes consisting of accelerometer sensors, that provides sensor orientation measurements relative to the direction of earth gravity (like a digital inclinometer). (Picture 1 and Picture 2.)
Sensor nodes are attachable to critical parts of the structure. Intelligent algorithms have been developed and used, enabling system to reconstruct the shape of the structure simultaneously from multiple sensor measurements.

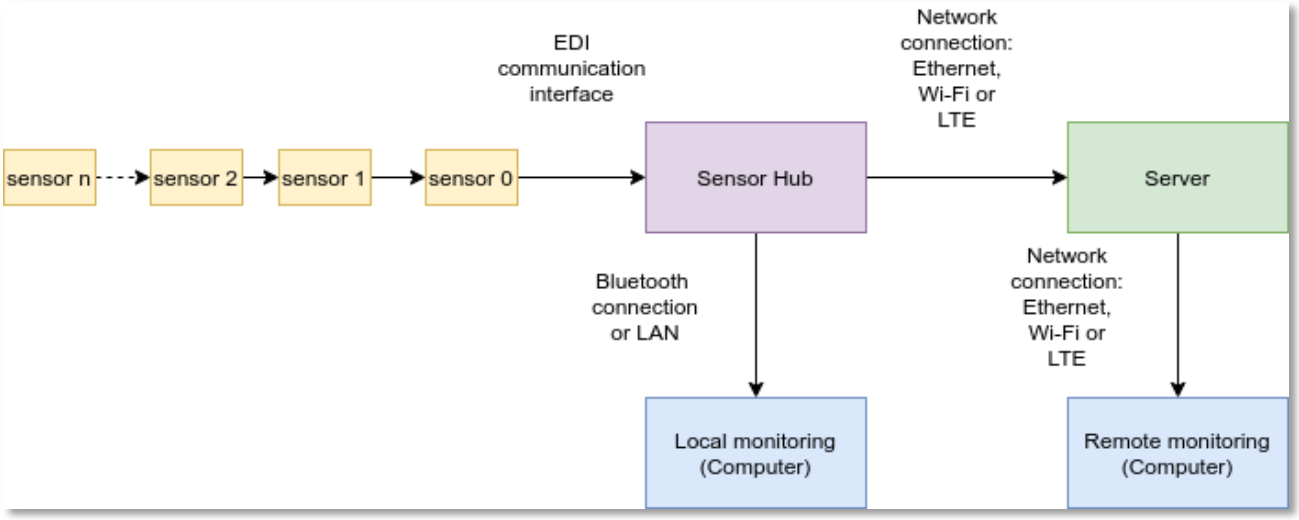


Picture 1.



Picture 2.

All sensors are connected with wired sensor connections, providing energy efficient data transfer, and power distribution for sensor nodes.



Picture 3. IoT solution system architecture

Sensor nodes are connected to central data access hub, that is connected to Internet, through either Wi-Fi connection, or LTE mobile network, providing remote monitoring capabilities. Technology comes in two configurations, depending on how sensors are connected:

- Individual sensors connected with cables and embedded in humidity resistant casings.
- Sensor nodes integrated on flexible PCB.

Currently used sensor nodes provides inclination measurement accuracy < 0.5°, laboratory tests for deformation measurements of 2 m long structure showed maximum error of 3 mm. We have performed tests, to test the system operation in different environment conditions: variable temperature and high levels of humidity and we have developed sensor communication solution, that provides sensor connection of >100sensor nodes.

Functionality of the technology

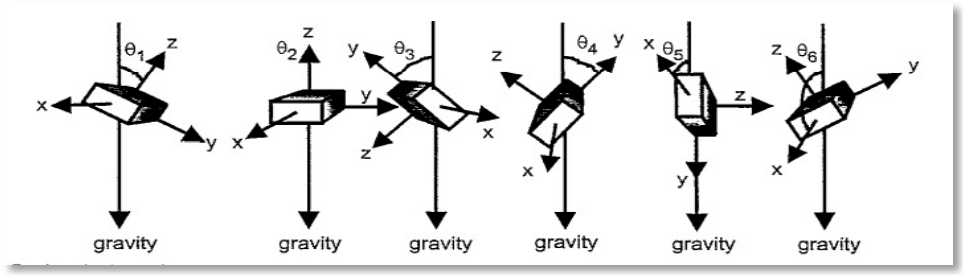
The basic functionality of the technology is engineering structure deformation monitoring over time. The information about deformations is measured using sensor nodes, that are attached to critical parts of the structure using either adhesive or mounted with screws. Sensor data can be monitored in real time and can be transmitted remotely over Internet to central server for remote monitoring.

Potential applications of the technology includes:

- Snow load monitoring on rooftops.
- Existing building safety surveying near construction sites.
- Bridge monitoring.
- Formwork monitoring.
- Building monitoring in seismically active regions to ensure building safety.

Picture 4: sensors installed on a crossbeam

Accelerometer sensors are used as sensing devices. MEMS technology accelerometers are used that provide small size sensors as integrated circuit, providing digital readout from the sensors. Accelerometers provide acceleration measurements in three orthogonal directions. During static conditions, accelerometer sensors measure the acceleration due to Earth's gravity. This effect can be used to estimate sensor orientation relative to the gravity vector, by measuring direction of acceleration in sensor measurement frame of time, it is possible to follows slow structure shape



Picture 5. Measuring sensor orientation relative to the Earth's gravity vector

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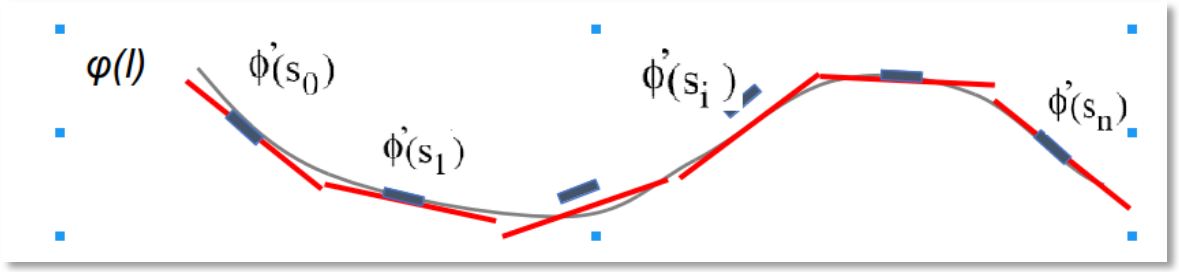
changes sensors also provide measurements dynamic acceleration, which can be used for vibration amplitude and frequency measurements. (Picture 5) This can give indication, that some parts of the structure have been weakened and requires attention.

The accuracy and resolution of the surface reconstruction depends on the number of sensors used. The more sensors are used, the higher resolution and accuracy of reconstruction. For operation, each sensor node must be supplied with electricity and for shape reconstruction, data from each sensor node must be sent to central processing device. This introduces a challenge, how to connect large number of sensors in one system and manage sensor data communication and provide data transfer.



Picture 6: Structure shape reconstruction using inclination values.

Technology provides technical solution for sensor connections and remote data transfer. For local sensor data aggregation Deflexio technology provides custom wired sensor connection solution, that allows connection of several hundred sensor nodes, and provides data transfer and electric energy distribution for the sensor nodes. It provides serial *daisy chain* sensor connection by using four electric connections between sensor pairs. These connections are:

- Positive power supply connection.
- Ground connection.
- Data signal connection.
- Clock signal connection.

Remote monitoring data can be sent to central server trough Internet. Technology provides connection to Internet by Ethernet cable, Wi-Fi connection, or mobile LTE network. Whichever solution is more convenient for particular use case.

To summarize, technology provides:

- Sensor connection solution for power distribution and data transfer, allowing connection of several hundred sensor nodes.
- Communication solution for remote data transfer using Internet (hardware and software).
- Sensor node and central sensor hub hardware and firmware.

- Software for structure deformation reconstruction from accelerometer sensor measurements.
- Two types of form factors:
  - Individual sensor nodes in humidity resistant casing connected with cables (Picture 7)
  - Sensor nodes integrated on flexible PCB (Picture 8)

Picture 7: Sensor node in humidity resistant casing.

Picture 8: Sensor nodes on flexible PCB.

EDI solution capabilities allow to further configure technology, considering end-user application. Several field tests have been conducted in order to make sure that this technology can withstand real-life environment. Technology was tested in different conditions, for instance:

- for snow load monitoring (installed on shopping mall roof);
- deformation monitoring during bridge load-tests (installed on the bridge bearing structures),
- -deformation monitoring of podium structure to ensure deformations do not exceed the limits (during the event when spectators are located on the podium).

Field tests has proven that technology is ready to use in the “real-life” scenarios.

IoT solution can be customized according to the end user-defined applications and specific requirements.

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