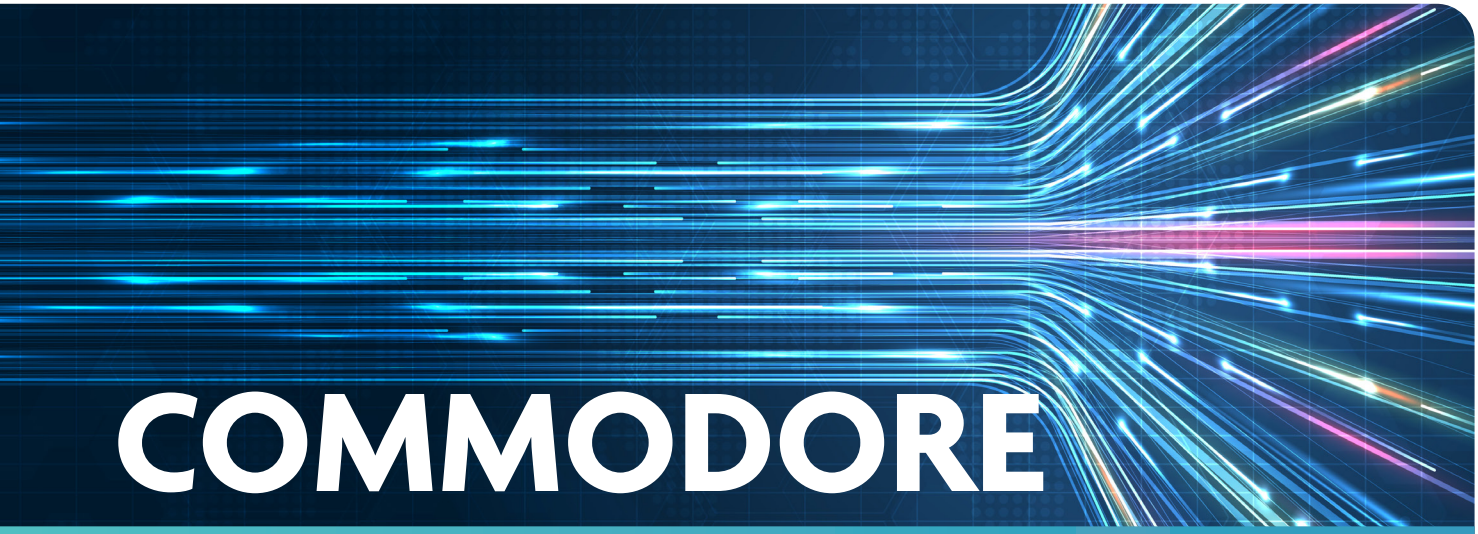

COMMODORE

COncrete Maturity MOnitoring and DegradatiOn pREdiction

The building construction sector is one of the largest sectors in the world and is forecast to grow by another 85% to $15.5 trillion by 2030. Despite its maturity, it is still challenged by a number of technical inefficiencies, amongst which the strength measurement of the concrete during and after construction, which is hard to estimate accurately in-situ. Well-known maturity models use the evolution of the temperature of the concrete. But these models show errors of up to 30% even in lab environments, as the maturity and related compressive strength are also influenced by the concrete mixture and the weather. Another potential maturity indicator that is not yet used in commercial solutions is the electrical conductivity, which shows a decrease while curing. But such solutions would require a readout of the sensor values either via wired connections out of the concrete, prone to damage, or via a short-range wireless connection. Lastly, for concrete degradation monitoring over long periods, there are no monitoring solutions available yet.

FRAMING THE RESEARCH OBJECTIVE

What has been the project's objective?
(in response to the limitations outlined in the previous section)

The CoMMoDore project partners set out to improve the available monitoring solutions for concrete maturity. First, they wanted to remove all wires and ensure a one-month long-range cloud connectivity to facilitate fully automated readings. A second goal was to extend the models currently used towards AI-driven grey-box multisensor curing models. Further, CoMMoDore aimed to investigate the feasibility of using sensor readings at different concrete depths, as a way to estimate the progress of the de-passivation front. Finally, the project wanted to investigate liability aspects and possible certification schemes for a next-generation AI-based solution.

THREE MAIN OUTCOMES

These are the three main outcomes of the CoMMoDore project:

1) **A fully embedded temperature and resistivity sensor with long-range wireless communication capabilities**

Imec NL designed a PCB with an array of electrode-based resistivity sensors along with an energy-efficient temperature sensor. The distance between the electrode arrays and the size of the electrode are carefully designed so that the electrodes can reliably measure the resistivity in the concrete and capture the resistivity profile in the concrete cover. The design of the sensor has been optimized for both reliability as well as energy efficiency. Imec WAVES realized an in-to-out concrete wireless link using NB-IoT by designing a custom NB-IoT antenna operating in the 800 MHz band (LTE band 20) for integration in the concrete sensor module. The characterization of the dielectric properties of various types of concrete (within the project) allowed us to take the concrete surrounding the sensor node into account

in the antenna design and resulted in an optimized in-to-out communication link.
Unitron designed the read-out electronics and the wireless communication board as well as the cloud infrastructure to process the sensor measurements and store them in the cloud for later AI processing. They also integrated all electronic components into one housing assembly for ease of installation and minimal impact on the concrete microstructure.

2) An AI-based concrete strength estimation model

UGent DBm and Yazzoom used the resulting data to build performant AI-based predictive models for concrete maturity. Depending on the type of concrete, prediction errors between 9 and 16% were obtained. This compares well to traditional models, which usually have an error around 20%. The researchers also found a promising correlation between the electrical conductivity along the concrete cover and the progress of the depassivation front, an early indicator for rebar corrosion.

3) A certification and liability approach of the AI-based strength estimation of concrete

SECO developed an adapted certification approach to cope with next-generation AI-based estimation solutions and made a comparison with the existing certification framework for ready-mix concrete. Further, based on an analysis of the Belgian regulatory framework for contractual and extra-contractual liability, the KULeuven CiTiP group proposed recommendations to contract parties and policy makers for the use of AI-based solutions in the construction sector. These recommendations are aimed at addressing gaps and imbalances caused by the nature of AI-based products and should result in more predictable liability outcomes for the parties involved.

NEXT STEPS

The proof-of-concept of the maturity case was promising. Therefore, Unitron has adopted parts of the solution, especially the low-power design, in their existing IoT products resulting in an increased battery lifetime. Currently, Unitron is performing tests with the proof-of-concept at several construction sites. They are actively looking for partners to further test and develop the solution.

Future research could consider sensor designs for monitoring the transport of chloride in the concrete cover, as this is also a prominent cause of concrete structural health deterioration. Another promising research avenue would be the exploitation of the impact of concrete maturity on the antenna characteristics forms.

FACTS

NAME	**COMMODORE**
OBJECTIVE	An AI-driven wireless sensor solution for monitoring the curing and degradation process of concrete
TECHNOLOGIES USED	NB-IoT, AI, antenna, sensor, temperature, resistivity, liability, certification
TYPE	imec.icon project
DURATION	01/01/2021 – 30/06/2023
PROJECT LEAD	Hendrik Caron, Unitron Group
RESEARCH LEAD	David Plets, imec – WAVES – UGent
BUDGET	2,011,488.24 euro
PROJECT PARTNERS	Willemen Groep, Unitron, Seco Belgium en Yazzoom
RESEARCH PARTNERS	UGent – DBm
RESEARCH GROUPS	imec – WAVES – UGent, KUL – CiTiP , stichting imec NL

The CoMMoDore project was co-funded by imec,
with project support from Agentschap Innoveren & Ondernemen

WHAT IS AN
IMEC.ICON PROJECT?

The imec.icon research program equals demand-driven, cooperative research. The driving force behind imec.icon projects are multidisciplinary teams of imec researchers, industry partners and/or social-profit organizations. Together, they lay the foundation of digital solutions which find their way into the product portfolios of the participating partners.

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