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Ekkono Solutions AB

Virtual Sensors

A Virtual Sensor is like a digital twin that can replace or complement a physical sensor. With Edge Machine Learning* you can learn individually onboard the connected device and save cost on expensive or redundant sensors, have a backup in case the battery runs out, and even get values from where it otherwise would be impossible to deploy a sensor.

A *sensor* measures a value or detects a change in state; Temperature, pressure, torque, weight, humidity, rotation etc. Multiple sensor values are usually combined – a.k.a sensor fusion – to give a more comprehensive picture; Like the ball bearing temperature that depends on current load, ambient temperature, and rotation speed. A *virtual sensor* calculates a value, based on multiple input variables, that is a replacement or a representation of a sensor value. With virtual sensors that use machine learning it is possible to learn complex correlations, and even predict values. There are plenty of reasons why you want to, or have to, go virtual on sensors.

1. Use Cases

Sometimes, the environment where you need to install a physical sensor is too hostile or hard to deploy in. Deploying a pressure sensor might require that you drill holes in pipes that can become yet another potential point of failure. Still, pressure might be a relevant value either as a health indicator, or as an input value to another health indicator. By combining temperature, flow volume and the power consumed for the process, you might be able to calculate the pressure and monitor that it is within the expected range.

Another opportunity is to replace expensive sensors. Let's say that you have legal requirements to measure NOx emissions from your motor. The NOx sensor is expensive to buy, and it requires frequent re-calibration, which makes it expensive to operate. However, it stands in relation to the emission temperature and the amount of fuel that is consumed. After running an installation period where the virtual sensor benchmarks against the actual NOx sensor – to learn the local conditions, like surrounding temperature and how the machine is actually being used – the virtual sensor can take over.

You might even be able to remove physical sensors all together at the design stage or in production. This is applicable to the Automotive industry. A car is a Lego construction with components like seats, drive line, electrical systems, climate control and steering being provided by different suppliers. Each component is more or less autonomous, which is why you have so many processors (CPU/ECU/MCU) in a car. And each component requires its own set of sensors. This means that there is major redundancy in sensors onboard a car. In a margin-constrained environment like

* Edge Machine Learning means running machine learning (ML) at the edge of the network – onboard the connected device. Ekkono develops an Edge Machine Learning software. In Ekkono's case, it is possible to do incremental learning at the edge, which means that the ML model continuously gets better but also that it gets personalized as it is fed with sensor data while in production.

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Automotive, it is a major benefit to reduce cost by replacing a sensor with a virtual sensor that calculates the value instead.

Edge Machine Learning also enables the use of less expensive sensors. The reason is that when you look at an individual car, you need the difference over time rather than the precise sensor value. This enables the use of less expensive sensors than if you need calibration down to the third decimal (if you compare sensor values between your entire installed base of machines/vehicles).

Last but not least, you can run a virtual sensor as a backup for a physical sensor. Like when a sensor runs out of battery or fails for another reason. Then the virtual sensor can replace it while you maintain it. Having a virtual sensor as a backup might allow you to do planned maintenance rather than an emergency operation because some of the visibility was lost.

2. Machine Learning

But do we need machine learning for this? Not all virtual sensors need machine learning. A simple equation can be enough. But complex mathematical models are often hard to deploy and maintain over time. With Edge Machine Learning you can constantly learn from data, and even predict what that sensor value will be based on super-local conditions and how the individual machine, device or vehicle is being used.

The benefit of machine learning is that it learns from data instead of a developer having to program every alternative scenario. This makes virtual sensors a good example for using machine learning since most machines and vehicles operate in different environments and with unique configurations.

3. Calibration and Installation

Will you always, like in the use case with the NOx sensor above, need a physical sensor to start with to "calibrate" the virtual sensor? Yes and no. In the NOx example you have to, as you need a reliable reference point for the calculation, and you need an actual value to train against. Especially since there are legal requirements. In other cases, it might be feasible to use a generic model for such a sensor. Or it might be more relevant to see the difference over time, or to create a health indicator sensor that is a combination of multiple input values from the machine.

4. Conclusions

Edge Machine Learning is excellent for predicting sensor values. Complex predictions can represent a health indicator, or even replace a physical sensor by acting as a Virtual Sensor. Now you can replace a hard to deploy, intrusive pressure sensor. Or the expensive NOx sensor that requires constant recalibration. Or support the temperature sensor that fails when the battery runs out.

- Edge Machine Learning is perfect for Virtual Sensors
- They can replace intrusive and hard-to-deploy sensors
- They can replace expensive sensors that need re-calibration
- They can reduce cost of components (COGS), e.g. in Automotive

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- They can work as a backup if a physical sensor fails, e.g. due to running out of battery

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Ekkono #openfika is a short open, online fika† session, hosted by Ekkono, on hot, contemporary and relevant topics, where a 15 minutes presentation is followed by discussion and Q&A. Keep an eye on www.ekkono.ai and LinkedIn for the next #openfika session.

Ekkono Solutions AB is a software company that develops Edge Machine Learning. Our product is the result of seven years of research at the University of Borås, Sweden, and assists product OEMs in different industries to rapidly develop smart features onboard their products, using machine learning to make them self-learning and predictive. For more information, visit www.ekkono.ai.

† fika (wikipedia.org); Swedes have fika (pronounced ['fiːka]), meaning "coffee break". The tradition has spread throughout Swedish businesses around the world. Fika is a social institution in Sweden and a common practice at workplaces in Sweden. Fika may also function partially as an informal meeting between co-workers and management people, and it may even be considered impolite not to join in.

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