EXECUTIVE SUMMARY

Intelligent Sensing: The Impact of AI on Sensor Capabilities

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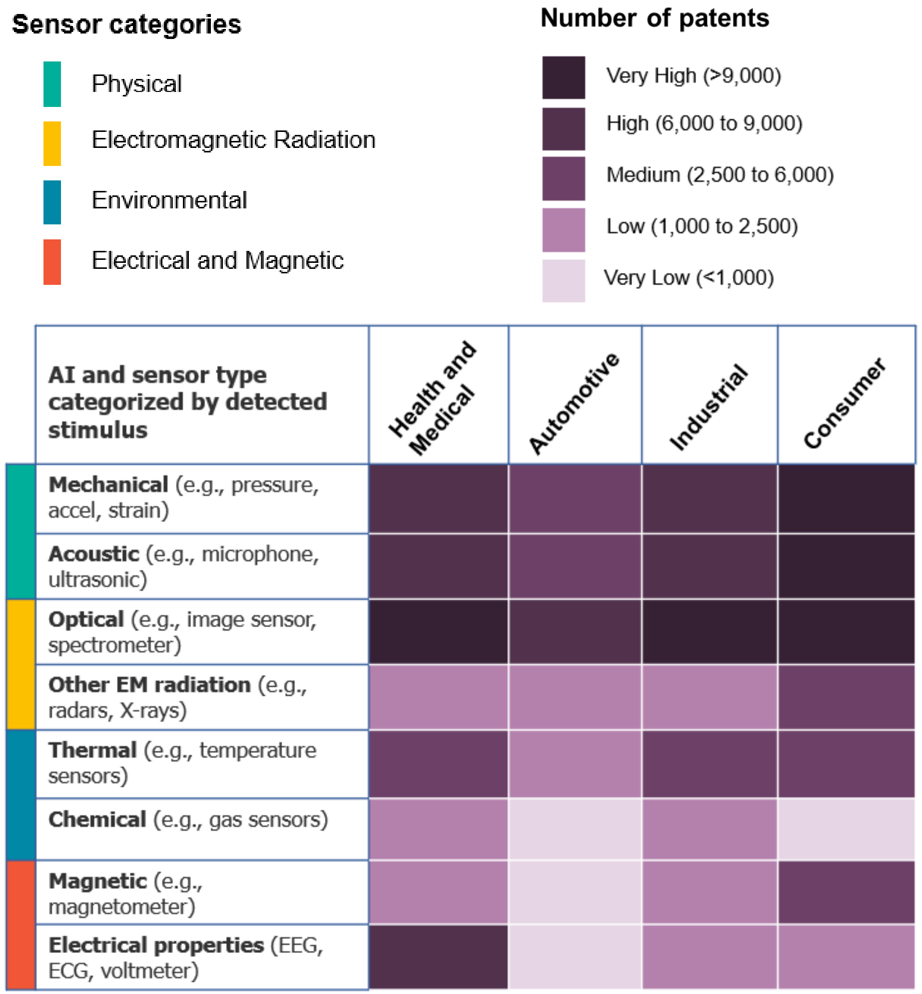
Executive Summary

The rapid advancements in artificial intelligence (AI) technologies have given rise to powerful new methods to analyze and derive novel insights from sensor data streams and external datasets. While this trend, classified as AI-defined sensing, is already apparent in areas like computer vision for analyzing image sensor data, these new software capabilities are unlocking applications for a range of sensor types, including mechanical, acoustic, and thermal sensors, greatly increasing the utility of sensors and driving market demand.

We analyzed the world's patents and used the Lux Tech Signal to identify which sensor types see the largest impact from AI and in which industries and applications this trend most commonly finds use. In four industry verticals analyzed we found: Consumer applications see the most activity and automotive the least, with industrial and health applications falling in the middle. Optical sensors with AI show the greatest amount of innovation activity, followed by acoustic and then mechanical. Other sensor types, such as magnetic, electrical properties, and temperature sensors, find pockets of innovation in specific verticals (e.g., electrical properties in health and magnetic in consumer verticals).

Sensor users and integrators should use the analysis to identify applications where AI-defined sensors can enhance their products or operations. Sensor component companies should identify sensor types and applications where AI-defined sensing will be commonly used and should look to build new software capabilities or form partnerships to capture more of the value created by this trend.

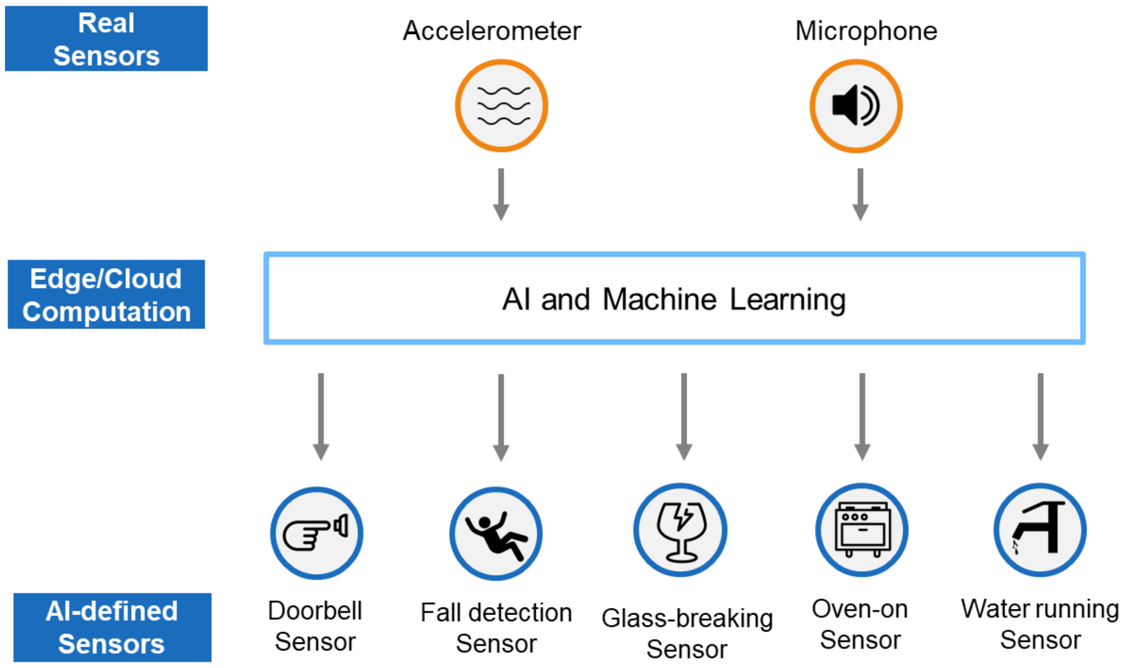


Patent activity since 2012 heatmap shows the use of each sensor type combined with AI for each industry vertical

The advent of artificial intelligence technologies is rapidly improving the capabilities of software-defined sensors

With the advent and proliferation of artificial intelligence (AI) technologies – concentrated in machine learning – the capabilities of software-defined sensors are increasing at a breakneck pace. AI for analyzing sensor data (now classified as AI-defined sensors) enables far more robust predictions and classifications using sensor signals compared to other methods like physics-based models. While this trend of AI adding new functionality to sensors is already readily apparent in some use cases (e.g., computer vision), sensor types ranging from temperature sensors to magnetic sensors will be impacted by this trend.

As an example of this trend, in a smart home setting, one could now use the same hardware package of a microphone and accelerometer to create a doorbell sensor, a fall detection sensor, a glass-breaking sensor, an oven-on sensor, etc., all by encoding the “sensor” in AI within the same hardware package. As AI capabilities continue to improve at rapid clip, we expect this trend to enable many new sensor applications, driving sensor demand sizably.



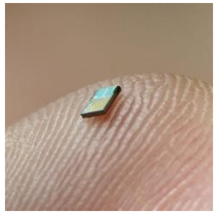
AI-defined sensors encode the sensing functionality inside AI models. Source: Lux Research

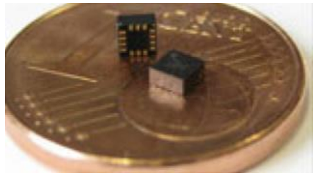
Sensor volumes increase as prices continue to rapidly drop, shrinking margins and driving even higher demand

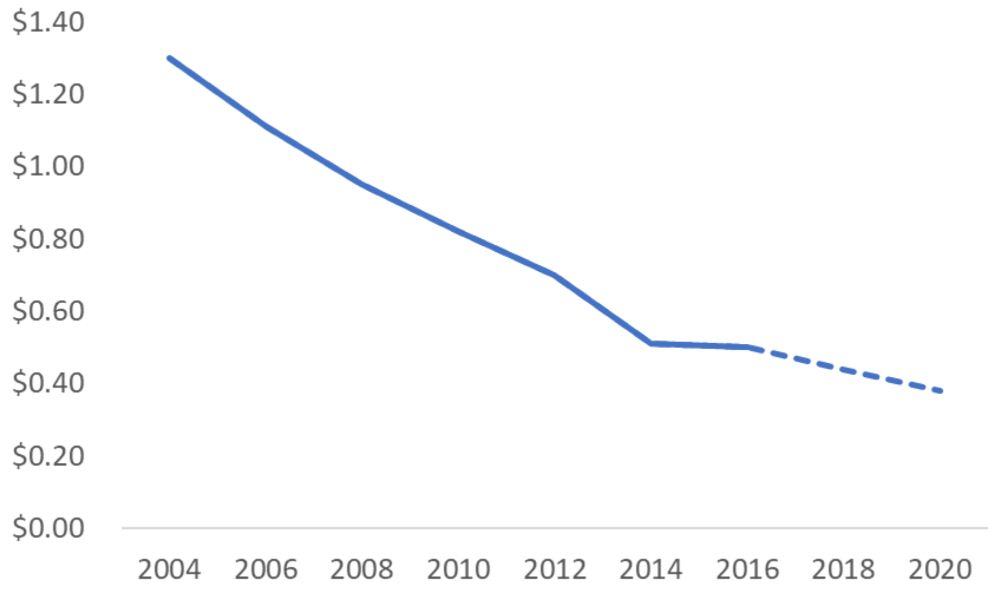
Sensor costs, particularly MEMS and image sensors, have seen costs repeatably drop over the last few decades. These falling costs are in part due to heavy competition, miniaturization and improved manufacturing processes, as well as huge volume boosts due to waves of consumer electronics adoption (e.g., smartphones).

With falling sensor costs – yet stable or improved capabilities – sensor adoption has grown tremendously. With increasing connectivity and IoT devices deployed, many estimates routinely forecast sensor growth to exceed trillions of units in the coming years.

Going forward, future developments in manufacturing methods and increased competition could continue to lower sensor costs, boosting further adoption. However, as sensor costs drop and competition increases, finding margins in the sensor industry will become more elusive; sensor vendors will need to uncover ways to add additional value to their components in an increasingly commoditized industry.







Average costs and projected costs of IoT sensors. Data estimated from Yole Development, Goldman Sachs, and GE.

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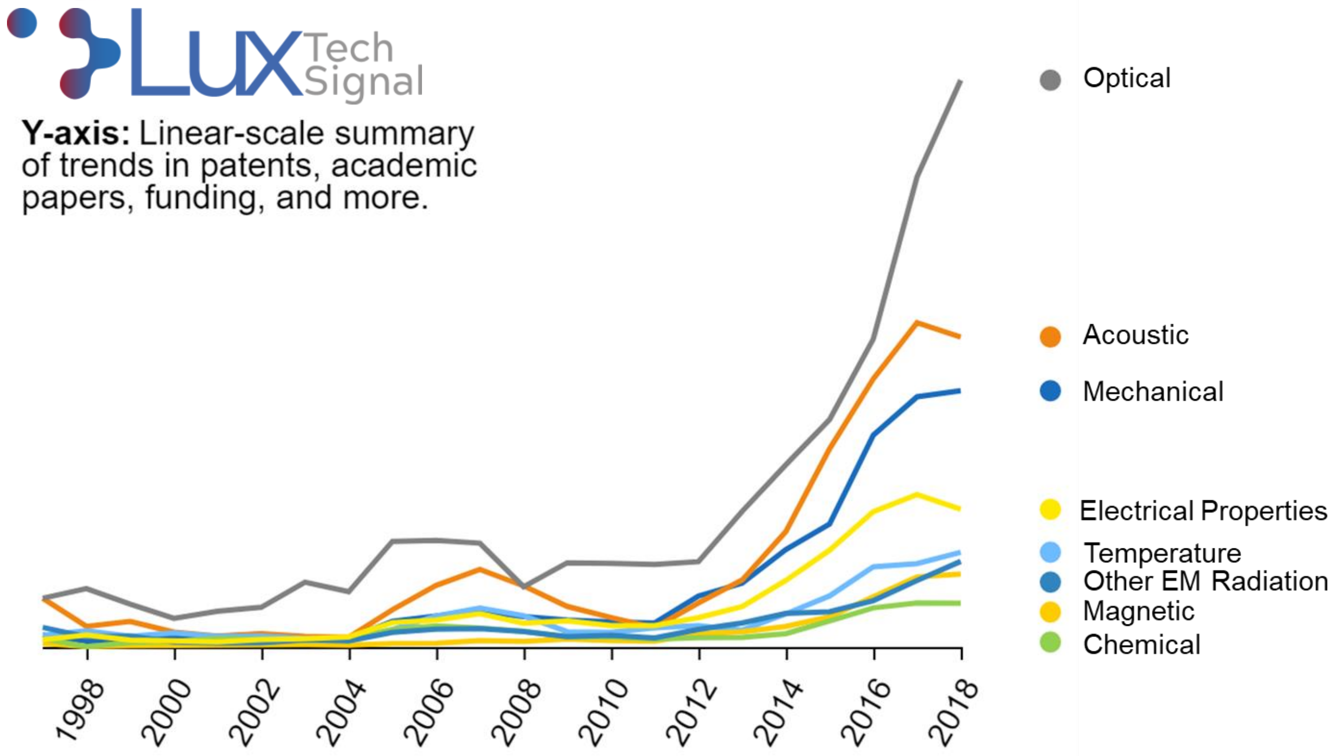
Using the Lux Tech signal, we identify innovation trends for AI in each category of sensors

Methodology: The Lux Tech signal was used for each sensor type combined with AI and machine learning to determine which sensor types see the most innovation and traction in this space. For more details on the Tech Signal methodology, please see this analyst insight.



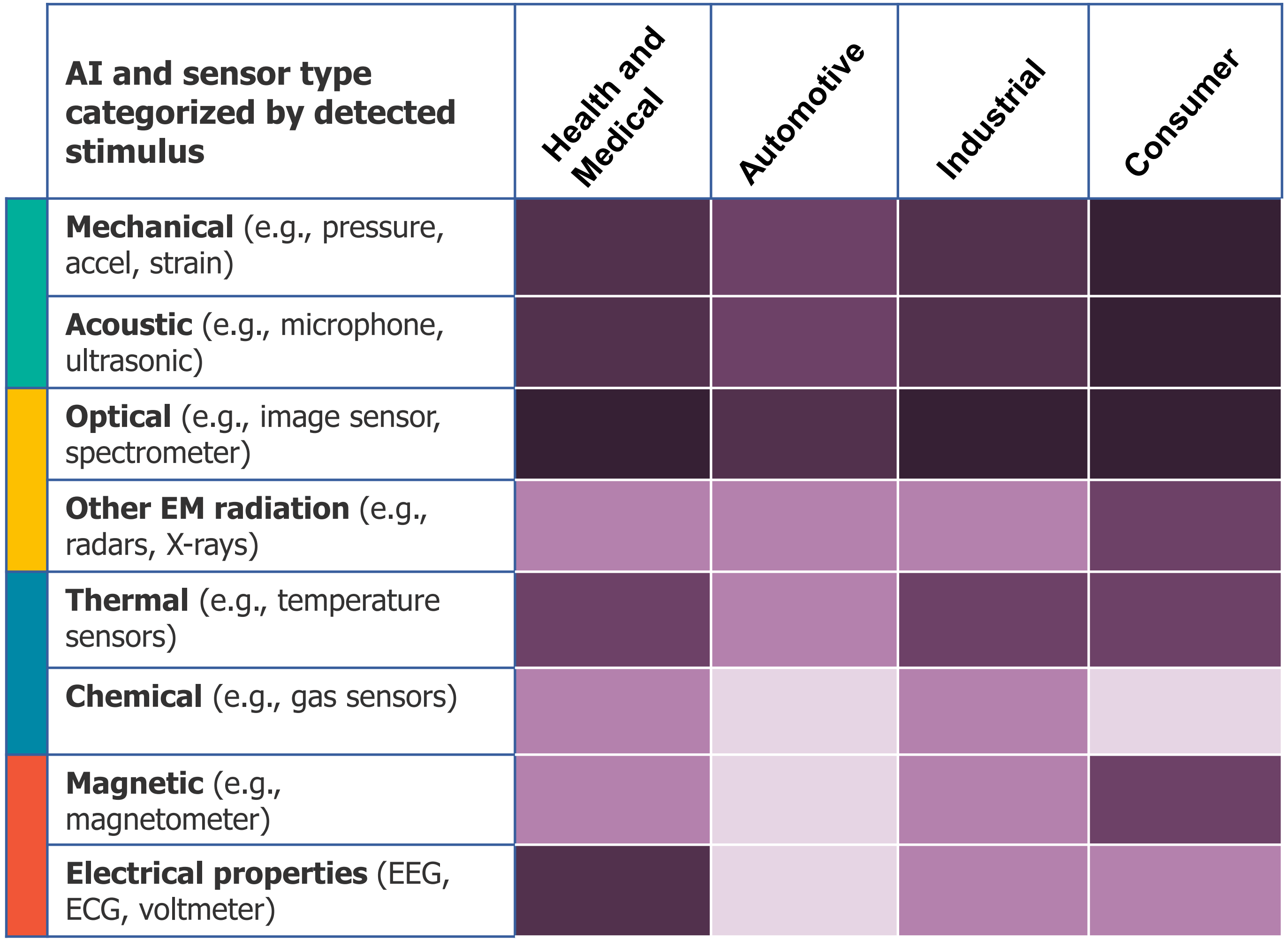
The Lux Tech Signal for AI and its use in applications for each sensor category

Unsurprisingly, given the vast amounts of innovation in computer vision, optical sensors see the most traction and a rapid growth rate picking up around 2012.

Acoustic sensors and mechanical sensors see the next most activity, with acoustic sensors overtaking mechanical around 2014. Acoustic sensing's strong interest in recent years is in part due to advancements in voice recognition and natural language processing capabilities.

Electrical sensing sees a moderate amount of activity, particularly in healthcare-related sensors like EEGs. Finally, we find activity in temperature, magnetic, and other electromagnetic radiation sensors starting to see growth, while chemical sensing remains relatively low and stable, with hints of future potential.

The patent activity since 2012 heatmap shows the use of each sensor type combined with AI for each industry vertical



Number of patents of each sensor type in each vertical segment

- Very High (>9,000)
- High (6,000 to 9,000)
- Medium (2,500 to 6,000)
- Low (1,000 to 2,500)
- Very Low (<1,000)

Sensor categories

- Physical
- Electromagnetic Radiation
- Environmental
- Electrical and Magnetic

Automotive: Use cases and innovative developers

Primary Use Cases:

- **Entertainment:** As we noted in the report on connected vehicles, consumers have an increasing expectation for cars to act as media hubs. AI-defined sensors provide opportunities for consumers to interact with the car in a seamless fashion.
- **Safety:** Safety-related applications include those related to autonomy, driver assist, and driver/passenger behavior monitoring.
- **Performance:** AI also provides opportunities to add new and improved capabilities to automotive components through more intelligent sensing (e.g., seats that automatically identify a user or identify road conditions more accurately).

Innovative Startups

BeBop Sensors develops custom flexible pressure sensors for automotive suppliers, among others. Machine learning and AI could be used to classify pressure events like person identification.

Guardian Optical Technologies uses a 3D camera and AI-based computer vision for a range of in-cabin car monitoring automotive use cases, including seatbelt reminders, forgotten infants, and intruder detection.

Nauto offers a deep learning-enabled dashboard camera that captures real-time events that occur inside and outside the car for vehicle fleet management applications.

Metawave develops a metamaterial-based radar for long-distance object detection, tracking, and recognition; the actuation of the radar beam is controlled by AI software.

Case Study: Reality AI and the Koito Group use machine learning on the edge to improve accuracy of adaptive driving beam (ADB) headlights

INTRODUCTION

Koito is a leading exterior automotive lighting OEM. The company was interested in building a more accurate adaptive driving beam (ADB) solution for its headlights, in which a panel of LED lights would selectively turn off so as to illuminate the surroundings without blinding oncoming drivers.

RealityAI
Make sense of the physical world

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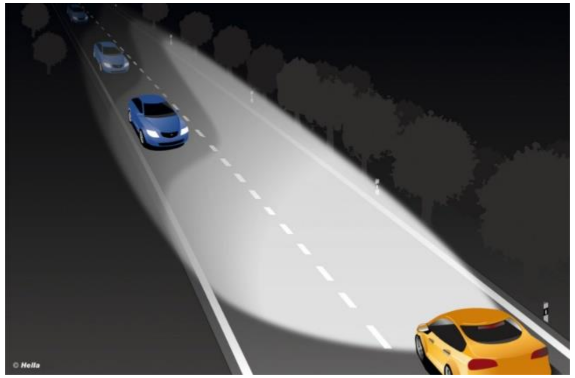
WHAT AI-DEFINED SENSORS ARE USED FOR

The North American Lighting Silicon Valley Lab, a division of the Koito Group, partnered with Reality AI, which specializes in developing lightweight machine learning models to be run on small microcontrollers. The solution they developed consists of a basic image sensor embedded in the headlights with machine learning running on a low-power electronic control unit (ECU). These capabilities allow Koito to add additional value to its lighting products without significantly increasing costs or power consumption.



Lux Take

A common barrier to running machine learning models is the need for extensive amounts of processing power (e.g., GPUs or constant connectivity to the cloud where the models can be run). The solution Reality AI developed shows how deep learning is by no means the only way that AI can add value to products and how relatively small, optimized models can be run on existing microcontroller hardware. ADB also provides a taste of the applications that will be enabled by the advent of machine learning on the edge, such as using a microphone to detect tire pressure or even pedestrians near the car.

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