Solution Brief

Smart Parking

Groundbreaking 4D Object Detection with DeepScenario and Intel® SceneScape

A smart parking solution jointly enabled by DeepScenario and Intel® SceneScape demonstrates the ability to create 4D digital twins of any parking lot, using existing monocular cameras. Unified by the OpenVINO™ toolkit, the technologies work together to overcome limitations of existing approaches, with extensibility to many other usages, such as smart traffic, port monitoring and Industry 4.0.

The availability of inexpensive equipment, wireless connectivity and supporting technologies has led to massive deployments of video cameras, particularly in public spaces for security and smart city usages. Surpassing one billion installed units in 2021,[1] their proliferation continues, projected to grow from a global market size of $14.8 billion in 2024 to $40.0 billion in 2032, at a CAGR of 13.2%.[2]

These video streams may be monitored by humans or consumed by various machine and deep learning (ML/DL) models, from automated license plate recognition (ALPR) to quality control on production lines. Many solutions rely on 2D images from the worldwide installed base of monocular cameras.

Accurately interpreting 3D space with current image-based 2D solutions has inherent limitations. For example, the lack of depth information may interfere with accurate information on position and orientation of objects, or objects in the foreground can occlude the view of objects behind them. Solutions to capture 3D space such as the use of depth or stereo cameras and LIDARs are effective, but they tend to be cost-prohibitive for large deployments and require replacing existing cameras in the field.

Through their collaboration, DeepScenario and Intel are pioneering new capabilities for live modeling of 3D space over time using existing monocular cameras, providing a 4D representation for advanced monitoring based on 2D images. It combines DeepScenario's AI-powered computer vision software with the Intel® SceneScape spatial awareness capabilities delivered with the Intel® Tiber™ Edge Platform. To demonstrate this combination, a smart parking usage model — with deep extensibility to other usages — provides capabilities such as parking-violation detection and parking lot occupancy monitoring.

Linking the physical and digital world with DeepScenario

DeepScenario, an Intel Ignite and Intel Liftoff startup, delivers 3D computer vision capabilities that turn off-the-shelf 2D cameras into 3D vision sensors. The foundational software is capable of detecting and tracking all moving objects in the scene, such as people, vehicles and equipment, then outputting them in 3D space with accuracy in the centimeter range.

As an example of using this technology in conjunction with Intel® SceneScape, DeepScenario has developed an advanced smart parking solution. Based on video inputs, DeepScenario's model recognizes vehicles in 3D space, categorizes them by type (car, van, truck, etc.) and extracts their 3D bounding boxes and trajectories. The primary use cases for this solution are detecting parking violations and monitoring parking occupancy based on a rich understanding of vehicle position, orientation and dimension.

DeepScenario's 3D computer vision software enables the detection of violations that would be missed by 2D-only solutions, as illustrated in Figure 1. The position, orientation and dimension of the car, unavailable in 2D but present in the 3D representation, is central to recognizing that the car is improperly parked. Even partially occluded vehicles can be detected since the 3D technology takes naturally into account the perspective view of the camera (see Figure 2). This foundational technology also significantly enhances occupancy detection, contributing to a more robust parking management system overall.

By contrast, current parking solutions are generally inadequate and costly, providing only a fraction of DeepScenario's capabilities. Camera-based solutions that operate in 2D only, in addition to the limitations described above, can effectively cover a smaller area per camera, are commonly restricted to specific camera views and suffer from limited accuracy. Single-space sensors for vehicle proximity using detection plates embedded in pavement are likewise inflexible and limited; they are one-dimensional and costly to implement and maintain.

DeepScenario makes it possible to detect vehicles using existing camera infrastructure, providing a simple and cost-effective implementation while dramatically increasing the capabilities possible with the solution.

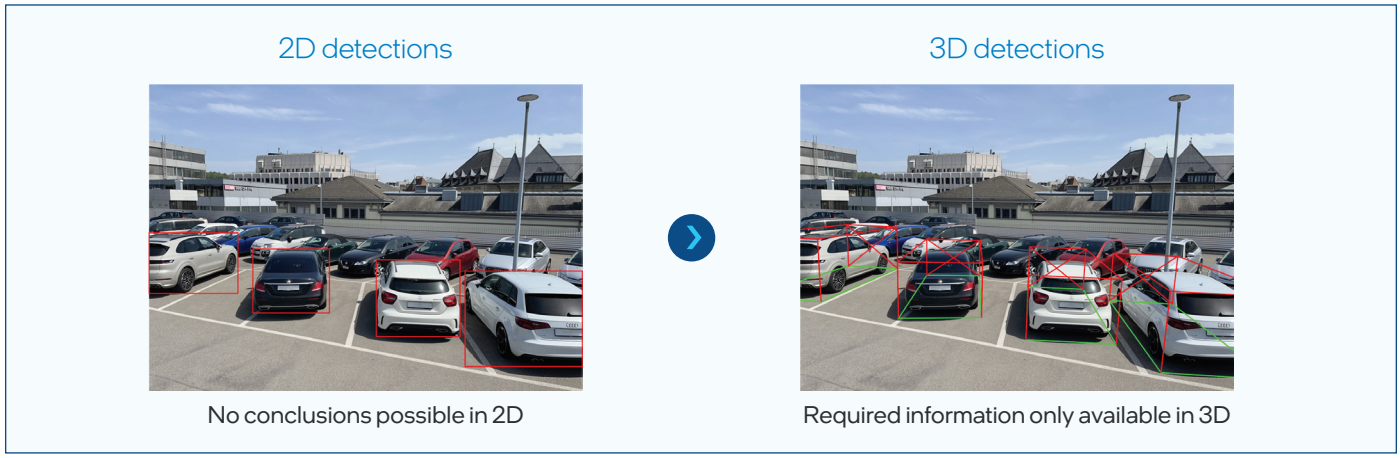

Figure 1. 3D computer vision is needed to detect parking violations.

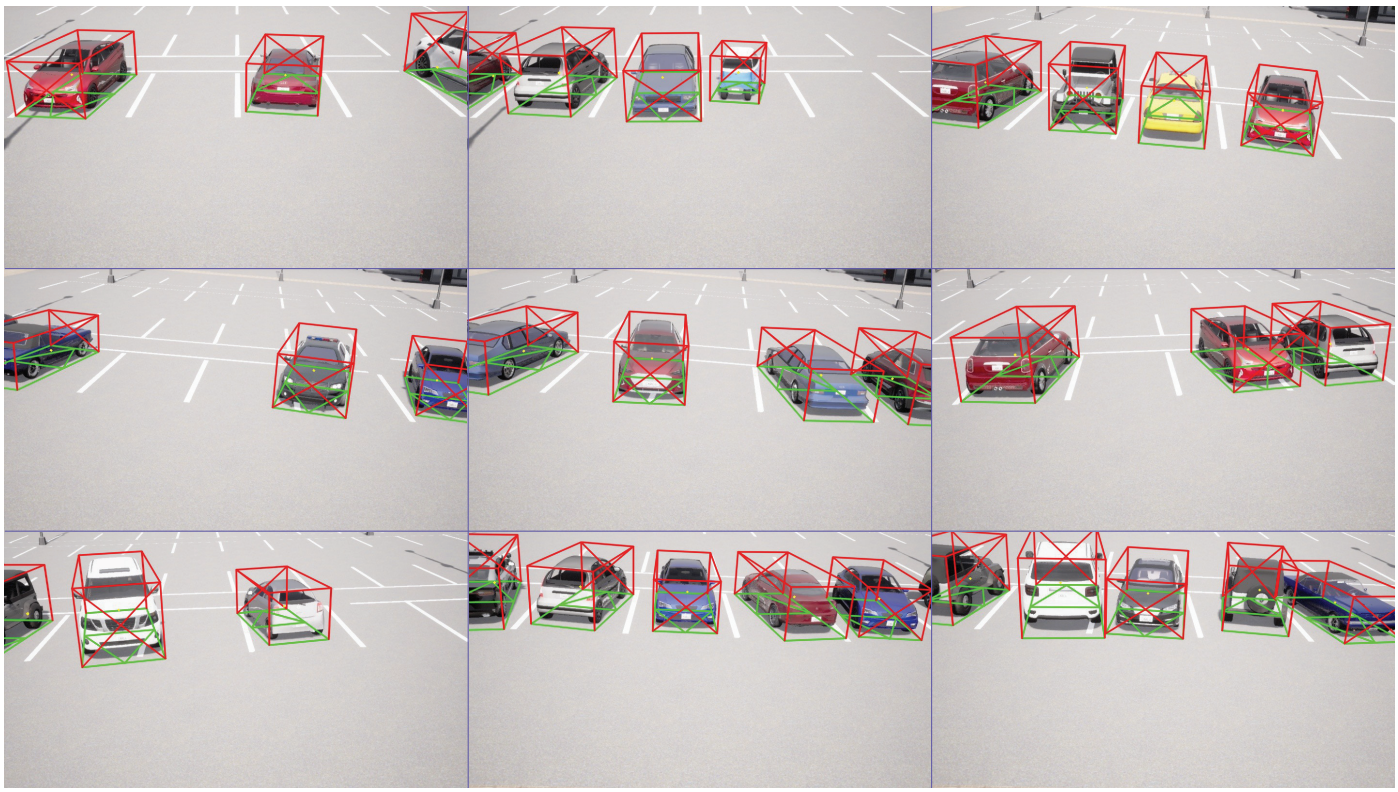

Figure 2. Monocular 3D detection in simulated parking scenarios.

Live, 4D spatial awareness with Intel® SceneScape

Intel® SceneScape synthesizes data from multimodal sensors and other sources to provide data-based spatial awareness. It combines those inputs in much the same way that humans combine multiple senses and existing knowledge to understand the world. Thus, each data input — cameras, microphones, thermometers and others — provides context for all other inputs. Intel® SceneScape can then generate live 4D digital twins as virtual representations of the physical world, based on real-world data and updated over time.

Near-real-time environmental feeds from cameras and other sensors may be combined with historical data, maintenance records, engineering drawings and other sources to add context to the insights available from the digital twin. The digital representation can be used to track present operations, run hypothetical scenarios based on proposed changes to the environment and make predictive decisions for the future.

Intel® SceneScape has the ability to fuse together multiple cameras and other sensors, to recognize that a single object should only be represented once as a composite in the digital twin. In the case of smart parking, this capability enables vehicles to be modeled in the digital twin using multiple camera perspectives. It also contributes to the ability to transparently add other sensor modalities to the representation, as outlined in the next section of this brief. In addition to cameras, Intel® SceneScape supports any number of other sensor types, including time-series data such as ambient temperature, barometric pressure and air quality.

Implementation of DeepScenario and Intel® SceneScape for smart parking uses an overhead-view representation of the static environment. This could be a floor plan, a building information model (BIM) or a 3D scan, for example. LIDAR smartphone apps potentially provide a simple, low-cost approach. For outdoor spaces, the solution can use geographical data from sources such as Google Earth. Calibrating the sensors is accomplished easily using a simple interface to identify common points in the scene among multiple camera views to provide a shared system of reference coordinates. No special expertise or equipment is needed to generate accurate spatial awareness.

Streamlining and extending live object detection with OpenVINO

Intel® Distribution of OpenVINO™ toolkit streamlines the processes of building, optimizing, deploying and running deep learning models based on popular frameworks, including for human-like vision perception. It supports a "write-once-deploy-everywhere" model based on an intermediate representation (IR) to efficiently optimize and deploy deep learning models across different types of hardware, including CPUs, GPUs and discrete accelerators.

OpenVINO accelerates the inference pipeline while making it straightforward to deploy the functionality of DeepScenario. It also anchors the software layers of the solution together. Specifically, because Intel® SceneScape is built on OpenVINO, any model supported by OpenVINO is also supported by Intel® SceneScape. DeepScenario's edge intelligence technology supports OpenVINO, so it runs on Intel® SceneScape with optimized performance, right out of the box.

In addition, any other OpenVINO-compatible deep learning model — solving for various use cases — can be readily added to the solution. For example, adding ALPR functionality would only require an additional model for license plate detection and optical character recognition. Such models can be obtained from the OpenVINO Model Zoo or sourced from elsewhere based on popular frameworks including PyTorch and TensorFlow.

Inference can be run directly on external models in their source formats, with conversion to OpenVINO IR handled dynamically and transparently. This approach is convenient for experimentation and development, although converting models to OpenVINO IR is preferable for production solutions to optimize performance. OpenVINO provides both a Python API and a command-line tool to perform that conversion. Intel® SceneScape chains together the model workflow, along with DeepScenario's 3D object detection, and outputs results based on the composite pipeline.

Both OpenVINO and Intel® SceneScape are part of the Intel® Tiber™ Edge Platform. Intel® Tiber™ Edge Platform enables enterprises to build, deploy, run, manage and scale edge and AI solutions on standard hardware with cloud-like simplicity. Built on extensive edge expertise, it's designed for the most demanding edge use cases and to accelerate edge AI development while reducing costs.

The remainder of this section highlights a selection of additional use cases where the combination of DeepScenario and Intel® SceneScape offers advanced capabilities compared to existing approaches in practice.

Smart traffic management

Smart traffic management provides a connected approach to minimizing congestion and improving safety and public health. In addition to camera-based live 4D vehicle detection, smart traffic solutions may incorporate additional data capture mechanisms to assist with detecting near misses, improving vehicle counts and optimizing pedestrian safety. These solutions may also interact with infrastructure such as connected traffic lights, toll gates and traffic pricing systems.

Port monitoring

Port environment monitoring systems help improve the efficiency, safety and sustainability of ports and maritime environments. 4D situational awareness of ships, shipping containers, personnel and equipment provided by DeepScenario and Intel® SceneScape can be combined with monitoring and measurement of factors such as weather, tides and current. The composite result can feed into a digital twin model for monitoring and analysis.

Smart manufacturing

Industry 4.0 and smart manufacturing can combine the 4D visuospatial understanding enabled by DeepScenario and Intel® SceneScape with other inputs such as sound, vibration and temperature. Based on those inputs, a digital twin of industrial sites' operational technology (OT) can provide insights that drive usages such as worker safety, predictive maintenance of capital equipment and tracking of people and assets in facilities.

Conclusion

The powerful combination of DeepScenario's technology for 3D object detection with Intel® SceneScape spatial awareness provides live insights about the real environment. The smart parking solution described in this brief is the actionable basis for real-world implementations, as well as a sample pattern for an open-ended variety of use cases. It increases the value of existing cameras and other data sources, providing the means to automate robust interpretation of the physical world with low TCO.

Learn More

www.deepscenario.com

www.intel.com/scenescape

Solution provided by:

intel + DeepScenario

[1] Geographical, March 7, 2023. "Who's watching: the cities with the most CCTV cameras." https://geographical.co.uk/science-environment/whos-watching-the-cities-with-the-most-cctv-cameras.

[2] Market Research Future. "CCTV Camera Market Research Report Information." https://www.marketresearchfuture.com/reports/cctv-camera-market-8160.

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