

# Enhancing business resilience with computer vision

With huge volumes of video being generated, there's increasing demand for computer vision and video analytics solutions. Discover the technologies and best practices that can help you deploy them successfully.

## Executive Summary

The next few years will see an increasing number of systems using artificial intelligence (AI), computer vision and deep learning to analyze videos and images. The applications are broad: from healthcare to public safety; and from retail to online media.

As all industries look to adapt to new social and economic circumstances post-pandemic, computer vision offers great potential for innovation to drive resiliency and growth. Adding visual intelligence at the edge can help support social distancing, for example, by automating processes or enhancing crowd management.

Even as these technologies present opportunities, they also bring challenges. These include availability of compute resources at the edge and the need to rapidly upskill to keep up with demand for video-based applications. However, by planning with the edge in mind, using trusted technologies, and beginning with a pilot project, you can build successful and resilient computer vision solutions.

Intel and its ecosystem offer optimized solutions to help achieve your aims. Intel's technologies include a range of processors, so you can balance power consumption and performance to right-size your hardware for the constraints of the edge. There are accelerators, including the purpose-built Intel® Movidius™ Vision Processing Unit (VPU), designed specifically to accelerate computer vision and AI inference workloads at the edge. Intel also provides field programmable gate arrays (FPGAs), and a reference design for a vision accelerator based on them.

To develop algorithms, the Intel® Distribution of OpenVINO™ toolkit enables you to more quickly develop computer vision applications that scale across different processors and accelerators. You can also take advantage of performance optimizations.

As companies such as Outdu, Philips and Advantech have shown, these technologies can form the foundation of powerful computer vision solutions.

## Business Challenge

According to Gartner, 65 percent of enterprise-captured videos and images will be analyzed by machines rather than humans by the year 2023<sup>1</sup>. That represents a sharp increase, up from 10 percent in 2018, reflecting the huge growth in AI capabilities and requirements in recent years.

One reason for that success is the growth of deep learning. IHS Markit notes that deep learning algorithms are better than traditional analytics products at simulating human vision. This enables them to better differentiate between objects and behaviors, increasing accuracy. Deep learning is also enabling greater volumes of video data to be processed more quickly, according to IHS Markit<sup>2</sup>.

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<sup>1</sup> Market Insight: Tech CEOs Must Leverage Ecosystems and Partnerships for Business Success With AI-Enabled Vision Systems, Gartner, 6 August 2019.

<sup>2</sup> Market Insight: A revolution in video surveillance – Deep learning video analytics, IHS Markit, 24 July 2017.

There is a wide range of applications for computer vision. Some will see humans supported by computers in existing image processing tasks, such as content moderation, security camera monitoring, and medical diagnoses. Others are entirely new use cases, made possible by computer vision. These include quality control in manufacturing; identity validation; and retail video analytics, where footfall, inventory and queues can be analyzed automatically. New public safety applications will become possible as security and IT technologies come together to enable real-time processing of camera feeds and automatic incident detection. For example, busy areas like train stations can use computer vision to monitor passenger volumes and automatically close ticket barriers when necessary to prevent overcrowding.

Whatever the application, the increased use of video and image data creates fresh challenges for those businesses that use computer vision.

Many organizations have become accustomed to more granular and more regular data gathering in recent years. Internet of Things (IoT), image and video applications represent a significant increase in data volumes. An image at a resolution of 2 megapixels could be as large as about 3 MB in size. When streamed at 30 frames per second (FPS) even in a compressed format such as H.264, that amounts to about 1.3 MB per second, or 4 GB per hour.

Data volumes of this magnitude, which may require analysis in real-time, present a number of challenges. Most obviously, all this data must be stored somewhere. In particular, if data must be retained for compliance, record-keeping or evidence reasons, the cumulative data volumes can quickly become large. Bandwidth and network latency may prove to be a bottleneck if visual content has to be sent across a network for analysis in a data center.

Video and real-time image processing are compute-intensive activities, so in some cases the existing compute resources may not be powerful enough. A legacy retail platform used for stock management may struggle to handle the increased processing demand for visual processing. Adding software for visual processing, potentially with accelerators, can also increase the complexity of the solution, complicating operations and support activities.

Security is an important consideration for any computer system today, and capturing image or video content will only increase the need for robust security measures. Sensitive data could be inadvertently recorded, by videoing the location of a person at a particular point in time, for example. Some visual data is inherently sensitive, such as medical imagery, security captures, or facial recognition data.

Organizations implementing computer vision systems must ensure they have a platform that is capable of storing, processing, communicating, and securing their visual data effectively.

## A Strategy for Implementing Computer Vision

When faced with these challenges in implementing computer vision, there are two facets to the solution: hardware and software. Often, the computer vision intelligence is hosted at the edge to avoid the latency, cost and complexity of backhauling video to a data center for processing.

Software can be optimized to extract more performance from the existing hardware. In some cases, it will not be necessary to modify the application code or the AI model. This is because the underlying frameworks and libraries can be optimized to make better use of processor resources and any available accelerators. This approach scales well across large organizations, because it does not require any hardware upgrades, but it may be a temporary fix. If you wish to adopt more ambitious AI solutions in the future, the hardware platform might not be powerful enough. Where the platform is capable of handling machine vision workloads, software optimizations enable you to extract optimal performance. Using compute resources effectively helps with overall platform performance if the computer vision software shares resources with other applications.

Upgrading the hardware requires a holistic view to ensure that compute, storage, and networking are all addressed. Tackling just one part of the solution risks creating bottlenecks elsewhere in the system design. Often, it is possible to use a general-purpose compute platform with appropriate software optimizations, without requiring accelerators to achieve the necessary performance. Using general-purpose processors means you can share your AI platform with other applications, and it's easier to maintain than having dedicated accelerators in the solution.

For more demanding applications, accelerators can play an important role in enabling real-time image processing.

Properly tiered storage will be part of the solution, enabling current data to be stored in faster storage media, such as Intel® Optane™ persistent memory. Meanwhile, archives can reside on slower media, such as solid state drives (SSDs). This enables you to strike a balance between cost and performance, while ensuring live data is available on media fast enough to support your application.

In practice, many solutions will require a combination of hardware and software optimizations.

In implementing computer vision solutions, there are a number of best practices that you can follow:

- **Design for the edge:** While some edge locations will be able to support servers, many will have limited space available. Consider the power, thermal dissipation and physical space available for the computer vision equipment. You may need to work with lower-powered edge solutions, and scale your application accordingly. For example, you might choose to analyze frames less frequently in an analytics application, to reduce the load on the processor. You may prefer to use SSDs, even if you don't need their speed, because SSDs offer a far greater storage density than hard drives.
- **Work with a trusted solution provider:** Although solutions for integrating video analytics already exist, these have often been oversold in the past, with excessive false positives and a high management cost. By working with your system integrator (SI) and technologies from a trusted IT vendor, like Intel, you can adopt validated and proven technology, reducing your risk.
- **Run a pilot project:** It's only when you use a solution that you can truly see what it's capable of. As a first step, you can train and test the AI model using real data. Measure its performance on different architecture options, so you can

strike a balance between cost and performance. This stage can be completed in the lab. As far as possible, though, you should also seek to replicate the runtime conditions in a pilot project using your target hardware platform. If you can work at one of the edge locations, within their space, power and thermal constraints, you'll get a fuller picture of any issues. This will help you mitigate them before attempting a roll-out at scale.

- **Use high-quality software:** The effectiveness of your computer vision solution will depend on the software stack you are using. In many cases, you can accelerate your deployment by using a solution built on top of proven AI frameworks, such as TensorFlow. Ensure you're using a software stack that is engineered for enterprise use, and has been proven in edge deployments. Your software needs to have security built in, to ensure visual data is protected.
- **Model the total cost of ownership (TCO):** Cost modeling can be difficult for projects that span a number of edge locations. There are often externalities that can be hard to incorporate in the cost model, such as the cost of technical support. It may be desirable to use SSDs instead of hard drives, because SSDs are considerably more reliable, even if they cost more up front. Using a more reliable option can cut the number of site visits required, with a dramatic impact on TCO.
- **Bridge the talent gap:** As video applications take off quickly, you may find you need fast access to new knowledge and skills. It may be difficult to hire experienced people, but your SI can help plug the gap by providing the expertise you need. Training resources are also available from Intel and other organizations.

## Solution Overview

Intel provides an end-to-end computer vision portfolio that you can use to build and optimize your solution. The first step is to develop and optimize your software. You may choose to work with an SI to do this, who can take the lead. Whether you take this approach, or build your own, it's important to have visibility of what the solution should include.

You can use the [Intel Distribution of OpenVINO toolkit](#) to optimize an existing trained AI model. Over 100 validated models are available from common software frameworks such as TensorFlow, Caffe and MXNet. The OpenVINO toolkit converts the model into an intermediate representation (IR) file, including making optimizations where possible. When the inference engine runs the IR file, it can deploy it using whatever hardware resources are available. This makes it easy to build solutions that run across FPGAs and other accelerators without maintaining separate code bases.

The Intel Distribution of OpenVINO toolkit includes the Intel® Deep Learning Deployment Toolkit (Intel® DLDT) with a model optimizer and inference engine, computer vision functions, and optimized libraries for OpenCV and OpenVX, to enhance traditional computer vision applications.

The Intel Distribution of OpenVINO toolkit is free to download. To help train your team and kickstart your projects, Intel provides a number of reference implementations for a variety of applications. These include smart retail analytics, a network video recorder, store aisle monitor, store traffic monitor, safety gear detector,

and intruder detector. Code for these implementations is available for download.

Using the OpenVINO toolkit opens up a world of hardware choices. It enables you to use a single code base and let OpenVINO take care of optimizing your solution for the available execution hardware at runtime. This can be done whether using CPU, FPGA, Integrated GPU, or video processing unit (VPU).

Looking at CPUs, Intel offers a range of processors so you can balance performance against power consumption. This is important when hosting video applications at the edge (see Figure 1). You can run the same software at the edge as you do in the data center. This helps streamline your software development pipeline with consistent tools and languages across all your deployment locations. For low-power applications at the edge, you can use an Intel Atom® or Intel® Core™ processor.

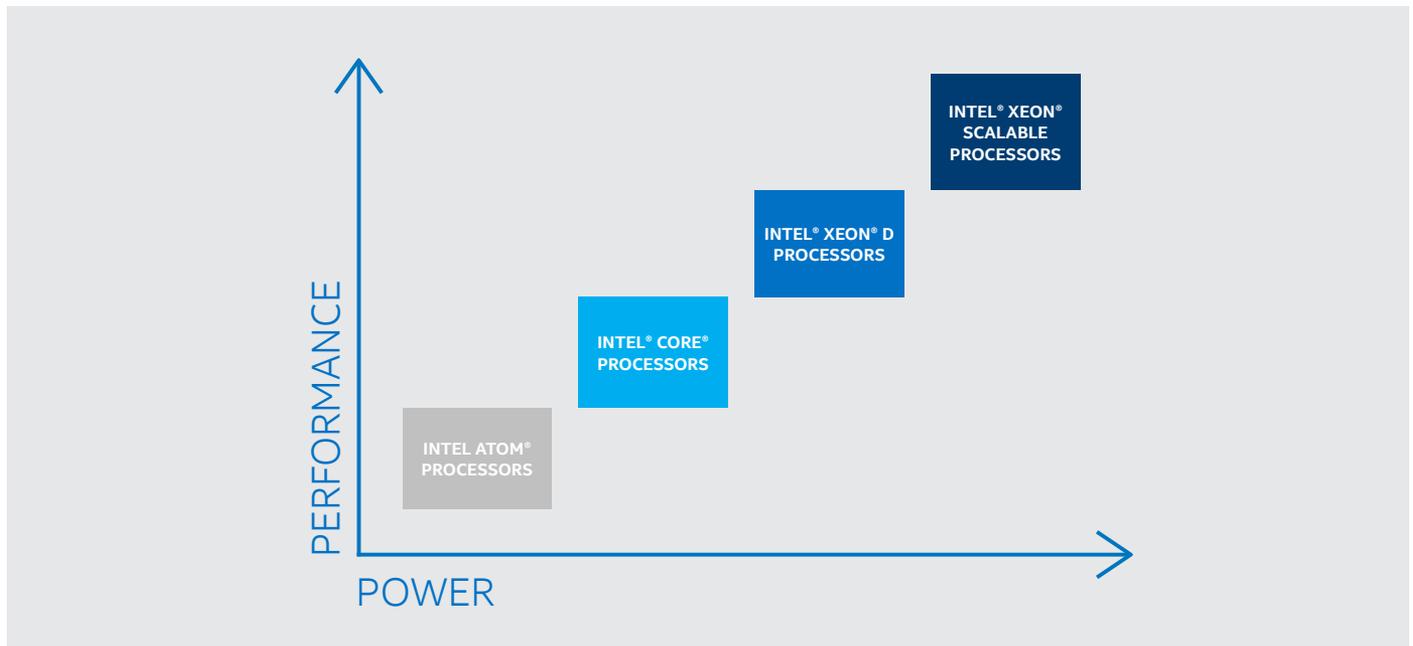
For more demanding applications where power is less of a constraint, choose Intel® Xeon® processors. The Intel® Xeon® Scalable processor includes support for reduced precision (INT8) data, which can help to increase data processing speed. It also includes Intel® Deep Learning Boost (Intel® DL Boost), which adds a new instruction to accelerate deep learning inference. The Intel Xeon Scalable processor includes support for Intel Optane persistent memory. This technology adds an affordable high-performance and high-capacity memory tier in the storage hierarchy.

Alternatively, FPGAs enable you to reprogram the circuitry of the accelerator to run your application. [Intel® Programmable Acceleration Cards \(Intel® PACs\)](#) enable you to connect a pre-validated FPGA board to an Intel Xeon processor-based server, using PCI Express (PCIe). Acceleration cards are available based on the Intel® Arria® 10 GX FPGA, or the Intel® Stratix® 10 SX FPGA for more demanding applications. In the past, programming FPGAs required highly specialist skills. Now, Intel has made FPGAs more accessible by creating the [Intel® Acceleration Stack for Intel® Xeon® CPU with FPGAs](#). It provides a standard software stack for FPGAs that enables you to reuse accelerator code. It also lets you use optimized libraries and frameworks to take advantage of the FPGA without any custom programming. One of the strengths of FPGAs is that they can accommodate future innovations in computer vision, because their circuitry can be reprogrammed after shipping.

Intel has also created reference designs for accelerator cards for vision applications, which your SI may take advantage of. The Intel® Vision Accelerator Designs provide power-efficient deep neural network inference for video analytics and computer vision applications. They can be used in edge servers, network video recorders and edge appliances. The cards are designed to work with the OpenVINO toolkit, so you can easily accelerate applications using them.

There are reference designs for two cards:

- The [Intel® Vision Accelerator Design with Intel® Movidius™ VPUs](#) incorporates specialized processors designed to deliver high-performance machine vision at ultra-low power. It offers excellent computer vision and deep learning performance per watt per dollar and helps to drive scalability for well-defined deep learning workloads. It excels in camera and network video recorder applications



**Figure 1.** Intel offers a range of processors, so you can choose the right one for the power budget and performance requirements at the edge.

that have power, size and cost constraints. It is also good for mainstream deep learning topologies that can be optimized into an ASIC. There is a range of interfaces: PCIe, Mini PCIe, M.2/Key E. This reference design supports up to 16 video streams per device (depending on frame rate and algorithm complexity), with a batch size of up to 4. Power consumption is typically less than 2W.

- The **Intel® Vision Accelerator Design with Intel® Arria® 10 FPGA** is an alternative option when you need to run compute-intensive networks such as VGG or ResNet-101. It is configured for edge servers, including network video recorders, gateways, and video analytics servers. This reference design offers high performance, low latency, and consistent power consumption (typically around 35W for Intel® Arria® 10 1150 device). Because it is based on an FPGA, the card has dynamic flexibility for custom or new workloads. This accelerator can be connected over PCIe and aggregates between 3 and 32 video streams per device, with batch sizes of up to 144. Various precision options (FP16/11/9) are also supported to balance speed and accuracy. The card offers especially strong performance in low-batch sizes for mission-critical applications and enables a deep learning network that supports more than 2 million parameters. You can buy a branded version of Intel Vision Accelerator Design with Intel Arria 10 FPGA from [IEI Integration Corp.](#)

To develop your software with OpenVINO toolkit, you can use Intel® System Studio. It includes analyzers, compilers and libraries to help you to implement efficient code and improve performance and power efficiency. Using hardware-assisted tracing, it can help you identify memory leaks and

poorly performing code, so you can optimize it. System-wide debuggers and analyzers help you to enhance system stability. Intel System Studio helps you to develop IoT applications faster with access to cloud connectors and over 400 sensors, and easy-to-use code wizards and samples.

## Use Cases

Many companies are building computer vision and video analytics solutions based on Intel® technologies. Here are some examples:

- In Outdu's real-time video analytics solution, cameras with built-in AI locally analyze visitors who walk into a site. The cameras deliver deep insights that lead to greater understanding of visitor behavior. Outdu's video analytics solution incorporates the Intel Distribution of OpenVINO toolkit for optimized speed, performance, and scalability. To enable inference at 60 frames per second (FPS), an Intel® Neural Compute Stick can be added.
- Intel and Philips used servers powered by Intel Xeon Scalable processors to perform deep learning inference on patients' X-rays and computed tomography (CT) scans. The companies tested two healthcare use cases for deep learning inference models. One was on X-rays of bones for bone-age-prediction modeling, and the other on CT scans of lungs for lung segmentation. The OpenVINO toolkit and other optimizations, along with efficient multi-core processing from Intel Xeon Scalable processors, delivered compelling results. Philips achieved a speed improvement of 188.1x for the bone-age-prediction model, and a 37.7x speed improvement for the lung-segmentation model over the baseline measurements<sup>3</sup>.

<sup>3</sup> Intel® Xeon® Platinum 8168 processor at 2.70 GHz, Intel® Hyper-Threading Technology (Intel® HT Technology) disabled; BIOS version SE5C6 20.86B.0D.01.0010.072020182008; system memory 192 GB, 2,666 MHz; Intel® Turbo Boost Technology enabled; Intel® SSDSC2CW240A3; Ubuntu® 18.04.1 LTS (GNU/Linux 4.15.0-29-generic x86\_64\*); Keras\* 2.1.1; TensorFlow\* 1.2.1; OpenVINO™ Toolkit 2018 R2; Intel Math Kernel Library for Deep Neural Networks (Intel® MKL-DNN) v0.14; Bone-Age-Prediction Model 299x299x3 .png images; Lung-Segmentation Model 512x512 .dcm images. The baseline shows zero optimizations. The optimized data used the same system configuration, in conjunction with the noted optimizations. Performance results are based on testing as of August 2018 and may not reflect all publicly available security updates. See configuration disclosure for details. No product can be absolutely secure.

See backup for configuration details. For more complete information about performance and benchmark results, visit [www.intel.com/benchmarks](http://www.intel.com/benchmarks).

Refer to <https://software.intel.com/articles/optimization-notice> for more information regarding performance and optimization choices in Intel software products.

- Improving traffic counts in retail environments—ranging from small shops to megastores—is vital in maintaining proper inventory levels and managing staff. Advantech's UShop EIS AI system uses AI video analysis technology, including gateways with Intel Core processors and the new Intel Vision Accelerator Design products. The solution anonymously detects human heads and bodies, enabling more precise staff allocation and merchandise adjustment. The Advantech system uses the Intel Vision Accelerator Design with Intel Movidius VPU to generate heatmaps and perform traffic pattern analysis. This helps identify how shoppers walk around the store, information that aids retailers in proper merchandise placement in near-real time. The Intel technology also interprets shopper behavior (such as gestures or reaching for a product). This can be combined with RFID data to identify which items are picked up and purchased versus which items are picked up and put back down. In this way, retailers can glean further insight into customers' preferences and behaviors.

Learn more about these use cases and others in the Developer Success Stories library.

## Conclusion

Organizations implementing computer vision solutions need a foundation of dependable technologies from a reliable vendor. Intel provides a range of technologies that are optimized for computer vision and deep learning in video environments, and available from trusted suppliers. Using these technologies, you can work with your SI and Intel's ecosystem to deliver video-based solutions that are tailored to meet your organization's needs. When building new, resilient business models and processes, those who use innovative technologies like computer vision and AI can create a solid foundation for long-term success.



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