TI's processors leading the way in embedded analytics

Mark Nadeski
Marketing Manager
Texas Instruments

Overview

This white paper explains how TI is enabling the needed analytic systems across a variety of application areas including surveillance, automotive and industrial inspection with programmable, software-compatible processors that scale from power- and size-constrained embedded systems all the way to purpose-built high-performance compute servers.

TI DSPs and analytics

"Analytics" is a popular buzzword these days and is often cited as the way to solve many challenging problems ranging from optimizing manufacturing and retail sales, to winning a presidential race, to keeping one's possessions and loved ones safe. There is no shortage to the situations where analytics can be applied and, consequently, seemingly no end to the variety of analytic algorithms that exist.

Texas Instruments (TI) has been innovating in embedded analytics for over 20 years with a long history in many analytics-heavy application spaces including security and surveillance, automotive vision, industrial and factory automation, military and defense and various consumer applications. TI's digital signal processor (DSP) technology is ideal to run the computational functions that make up the heart of analytic algorithms. With an expanding portfolio of high-performance DSPs and heterogeneous system on chips (SoCs), TI now provides a programmable platform that can scale from size- and power-constrained systems all the way to high-performance, purpose-built compute servers, allowing code reuse and development efficiencies across the entire range of platforms.

Analytics everywhere

The world of analytics is all around us. To find a good example of where analytics are used, one needs to look no further than their car. Automotive vehicles are one of the best examples of intelligent analytic systems. Advanced driver assistance systems (ADAS) are becoming commonplace in today's vehicles and have extended capabilities that include lane departure warnings, blind spot detection, parking assist, adaptive cruise control and collision detection and avoidance.

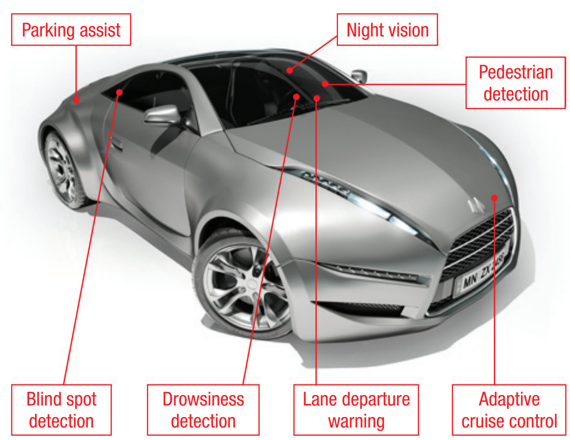

Figure 1: Advanced Driver Assistance Systems (ADAS) are enabled by embedded analytics.

Other examples of analytics are security and surveillance cameras which are becoming increasingly smarter; capable of running algorithms like trip zone detection, motion detection, people counting and tamper detection all within the camera itself. The cameras are increasingly connected back to networked video recorders (NVRs) running even more advanced analytic algorithms like facial recognition, object identification and optical character recognition (OCR). TI's TMS320C665x multicore DSPs help developers quickly add advanced analytics to their video surveillance cameras and bring more intelligence to the edge.

Even items that don't run analytics themselves are often built by systems or shipped through systems that rely on analytics. Machine vision systems help assemble and inspect items on the factory floor. Optical inspection systems run analytic algorithms looking for defects in everything from silicon wafers to sheets of glass to rolls of paper. Fruit and vegetables are similarly inspected by machine vision algorithms and are sorted based on size, color, defects and other criteria. Products are warehoused and shipped through complex inventory and shipping systems relying on bar code readers and scanners. Visual inspection systems are even used to ensure that there are enough chocolate chips in certain cookies. TI's DSPs are at the heart of many of these systems, running the analytic algorithms either directly at the camera, at the scanner or inside a "vision box" that processes data gathered from multiple sources.

These are just a few examples of embedded analytics; the space where the solution is often necessarily constrained by power and size limitations and cost is a key care-about. At the other end of the analytics spectrum lays another arena where "big data" lives and massive number crunching is done in server farms and in the cloud. The analytics here attempt to make sense of data sets so large that it becomes difficult to process with traditional data processing applications. In this space, the applications are larger and targeted areas consist of business informatics, genomics, biomedicine, seismic geology, climate change, metrology and Internet searches. These application areas lie primarily in the space of high-performance computing, traditionally far beyond the world of embedded processing and the domain of the DSP. But even in this space, power is becoming a concern and the utilization of DSPs can significantly lower the power footprint for purpose-built servers.

The promise of analytics

Analytic algorithms aim to discover meaningful relationships and patterns in data allowing systems to either provide relevant information to facilitate making a decision or to actually make an intelligent decision. They do this through extensive computation utilizing the most current methods in computer science, statistics and mathematics.

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The use of advanced analytics promises to enable amazing things straight out of science fiction with the list of exciting possibilities including things like autonomous vehicles, secure identification, truly personalized shopping and advertising, smart cities, natural resource management, disease prevention, the creation of a self-sustaining planet, etc. As processing technology continues to progress and algorithm development further advances, these future applications become closer to reality.

The advancement of analytics has progressed so far that many times it's hard to determine if the technology depicted in movies and television actually exists, is a futuristic vision or just a convenient way to move the plot along. Chances are it is a combination of all three with some of the capabilities existing today but the overall technology likely not in a state to be usable as depicted on screen.

Analytics in today's world

The promise for the use of analytics will always outpace reality. For example: in the security and surveillance world analytics promise a future of automated surveillance where cameras are not only able to recognize and identify perpetrators of illegal activities, but can actually detect impending threats with sufficient notice to allow the prevention of such activities. In reality, initial "smart cameras" overpromised and under-delivered on their capabilities to work in a real-world environment doing things like motion detection, creating a backlash against analytics in the security industry. Thanks to the improvements in processing capabilities (as well as the sensor technology) in the cameras and improved robustness of the software,

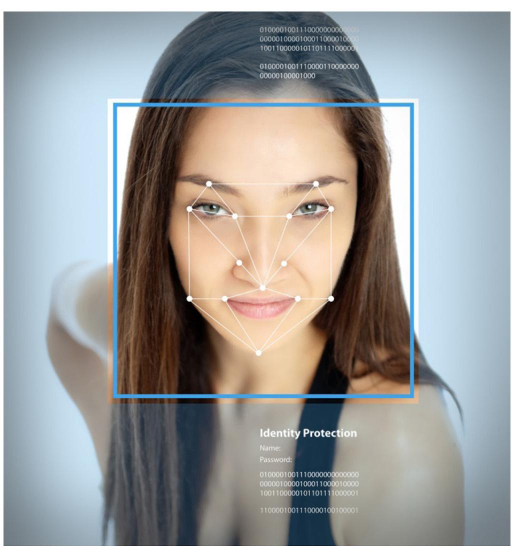


Figure 2: Face recognition is an example of a biometric application enabled by analytics.

analytics are becoming common place as the short comings of the initial automated surveillance technology are rapidly being surmounted.

While it is clear that the technology has come a long way, it is apparent that the solution still needs to be advanced. When the safety of public events and venues are at stake, it is nearly impossible for humans monitoring the situation to watch all areas and be able to recognize threatening behavioral patterns or incidents. With the use of analytics algorithms, cameras will be able to pick up on things such as people loitering and objects being left behind, allowing preventative measures to take place to ensure the safety of the public before a potential security breach actually takes place.

While technology exists that can improve these types of dangerous situations, it is not deployed on the scale where it can be utilized in most open, public situations. Targeted areas which are more controlled and considered greater than average security risks (airports, government agencies, banks, etc.) are able to better make use of advanced technology. In most of these cases, the environment is at least somewhat controlled, reducing various factors like weather, lighting changes and partially hidden faces that limit the accuracy of analytic algorithms. Also, in these targeted cases, generally a single entity is responsible for managing the entire system: for example a private security company at a bank. This company would have the capability of controlling the entire system.

In a controlled environment, even a loosely controlled environment, analytics-based systems are making tremendous progress. Take for example the number of automated toll roads that are now operating based on cameras running license plate recognition algorithms to identify the vehicle. Similarly intelligent traffic systems (ITS) are being developed that are able to do much more than fine vehicles that run red lights or exceed the posted speed limits. These systems can recognize stalled or abandoned vehicles, detect accidents and monitor and adjust traffic patterns. These ITS systems can be enhanced through the use of DSPs, off-loading the compute-intensive analytic algorithms and improving the response time and system power consumption.

Data and what it can do

Buoyed by wireless technologies for connecting things getting cheaper, more reliable and low power enough to be useful, more and more devices will be connected each year as the Internet of Things (IoT) finally begins to become visible in everyday lives. This loosely defined segment of technology can be thought of as adding connected sensors communicating data. Everything from wearables to smart meters to the infamous connected toaster will be adding data to the massive traffic from smart phones, tablets, laptops and computers. While each data point from these connected devices, or even a single stream of data, isn't typically very helpful, aggregating data across large subsets produces enough information where analytics can be used to make all kinds of useful conclusions.

It is usage of this aggregate data that will fuel projects like smart cities where real-time data from cameras and sensors will be aggregated at a command center and be used to develop smarter solutions for traffic management, emergency response systems, smart street lighting, video surveillance of public spaces, efficient sanitation solutions, real-time location capabilities and optimizing various city planning activities like determining the best locations for new businesses.

Figure 3: Real-time data will be used to develop "smart cities" improving everything from traffic flow to city planning.

Analytics will also shape the way businesses operate as companies attempt to predict customer behavior and actions. Consumers are already generating an overwhelming amount of data through multiple channels such as voice, email, text messages, web usage, social media posts, videos, credit card usage and assorted cell phone apps. Much of the interaction data is especially problematic because most of it is unstructured and requires advanced analytics that can automatically access and extract insights from them. Solutions to problems of all shapes and sizes will increasingly leverage analytics to glean patterns from the vast amount of data available. Even the race for the next President of the United States may come down to which political party better utilizes analytics. During Obama's 2012 re-election campaign, analysts used uplift modeling, a form of predictive analytics also known as persuasion modeling, to identify individuals who are likely to be positively influenced by ads, mailings, phone calls and various outreach efforts. A set of predictive models were developed using a matrix of political, demographic and household data that applied a score to every voter in all the battleground states to determine who is a "persuadable." The models optimized how Obama's campaign spent their money and "guided every door knock and every phone call in the final weeks of the campaign[1]."

The data tsunami

The world is rapidly filling up with data. The 2014 edition of Cisco's popular industry report[2] on networking traffic states that in 2014 the world used more than half as much web data as was used in the entire history of the world prior to that year. The predictions for the coming increase in data are staggering but are certainly believable. In addition to the increase in the sheer amount of connected devices, there's the constant demand to watch and upload seemingly-always-increasing-in-resolution video. Cisco's report estimates that by 2018 nearly a million minutes of video content will cross the network every second.

Data generation is simply going to outpace the ability and economics of storage solutions.

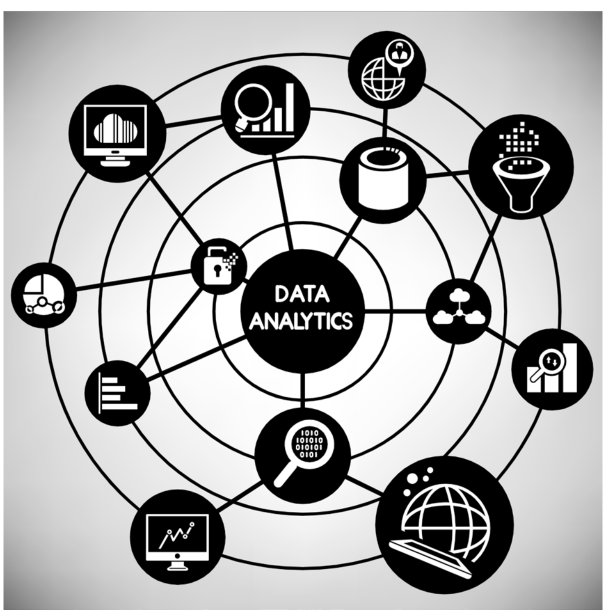


Figure 4: Advanced data analytics can extract insight from the unstructured data that surrounds us.

As more and more data is generated, the storage and processing of that data becomes a paramount challenge for industries and businesses of all sizes. Not only will analytics be able to glean insights from all this data, but analytics will also be a key tool in shouldering the burden of the data onslaught.

Edge analytics

The idea of storing all the data being generated will not be practical in our advancing connected world. Data generation is simply going to outpace the ability and economics of storage solutions. Instead, it will be necessary to run analytics to extract value from the data in real time and to determine which data potentially has value and should be saved, possibly for later processing. In order for analytics to be run as data is ingested by the system, a processor must be placed at the point of data entry or generation. This is often referred to as processing at the edge. In such a system, data is stored after it is processed rather than before and the saved data may only be a small subset of the data stream. In this way, requirements for system bandwidth, central processing and storage are all reduced.

A good example of edge processing is a surveillance system utilizing multiple cameras and a central processing box or networked video recorder. Having a processor running analytics in the camera, at the edge of the system, enables the capability of identifying certain events in real time and sending accompanying metadata of the event to the central processing system as it simultaneously receives the video. This saves the central processing system from running the same analytics on the individual camera feeds, freeing up the central processor to run higher level analytics, increasing the capabilities of the system. It also reduces the overall data traffic in the system as the camera can send reduced-resolution video during times in which no event takes place.

TI's DSP solutions are ideal for adding analytics to edge processing in these types of surveillance and security systems as well as a growing number of other edge-processing applications like industrial inspection, access control, driver's assistance systems and currency machines. DSPs meet all the needs of running-edge analytics including processing mathematically intensive analytic algorithms in real time, providing high-bandwidth connectivity and having power consumption low enough so that it can fit into power- and size-constrained enclosures.

Real-time processing: Analytics algorithms are based on a myriad of mathematical, statistical, signal and image-processing techniques and as a result are inherently mathematically intensive in nature. The DSP architecture is optimized for processing these types of algorithms in real time. This can be a somewhat relative term that varies based on the needs of the application. Generally it means responding to inputs before the opportunity window to take action is gone. Most edge-analytics systems have a tight constraint on latency, meaning the processing must be done in a fixed amount of time in order for the system to function. In a biometrics system like a fingerprint access control application, real time might mean identifying the person within a second so the delay does not become noticeable or annoying. In an ADAS system being used for collision detection, processing and response time is obviously bounded significantly tighter. In both scenarios, TI's DSPs provide the real-time, deterministic processing required of analytics systems.

High bandwidth connectivity: Many edge-analytics applications involve high data throughput. Huge amounts of data are brought into the system from sensors, cameras, microphones and other input devices and need to have processed output passed onto the rest of the system just as quickly. TI offers a rich, diverse portfolio of processors with high-speed peripherals, connectivity, hierarchical memory organization, advanced direct memory access (DMA) controllers and wide memory interfaces that are ideal for analytic systems.

Low power: Many applications of edge analytics are mobile or deeply embedded systems that are dealing with small enclosures and running off limited power sources. Low power consumption and minimal heat generation are often must-have requirements. Many processors are capable of running analytics, but the architecture of the DSP makes it the most power efficient at doing so. TI's DSPs lead the industry in the amount of programmable processing per Watt at the performance levels required of edge-analytics applications. The capability of TI's processors to provide high-performance analytic processing at low power is enabling the emergence of many edge analytics systems.

High-performance analytics processing

For those that run the massive data centers that house hundreds of thousands of square feet filled with servers storing and sorting data, the data tsunami becomes an issue in not only growing the capacity for storage but in cooling the equipment. It was estimated that last year information-communications-technologies (ICT) used 1500

Figure 5: Power consumption of data centers is a growing concern as cooling infrastructure increases in cost.

terawatt-hours of power, or about 10 percent of the world's total electricity generated, with a single data center potentially consuming more power than a medium-size town.[3] Cooling infrastructure is very expensive and every Watt of processing that can be saved by the facility is a Watt less of waste heat that must be removed.

As the need for analytics grows, designers of the next wave of server hardware recognize that analytics applications will perform better and more economically if the specialized processing needs of analytics are addressed with targeted, rather than general-purpose, processors and server elements.

The same architectural advantages of the DSP that gives it the best power efficiency in the industry for edge analytics can be carried over to the world of high-performance computing. Traditionally DSPs did not have the computational horsepower to be considered in this space, but with the release of the high-performance multicore TMS320C6678 and the 66AK2Hx SoCs, TI is enabling analytics servers to be optimized to save power and cost.

These SoCs are designed for analytic use cases with the right mix of processing elements, chip-level interconnects and elements like network processing and switching that balance performance and cost for analytics applications in a way that general processing solutions do not. For the analytic tasks these are designed to do, these processors are best-in-class in terms of performance throughput and power efficiency.

Both the TMS320C6678 and the 66AK2H12 multicore SoCs feature eight C66x DSP cores with the 66AK2Hx device including an additional four ARM® Cortex®-A15 processors providing the perfect blend of RISC and DSP processing. They both include a rich set of high-speed connectivity options yielding plenty of flexibility in deployments ranging from PCIe-based extensions to server racks in a data center. Additional processing nodes can be employed as needed through the use of multiple Ethernet interfaces that enable connectivity to cluster switches in a data center.

Hewlett Packard is embracing the idea of purpose-built servers with the HP Moonshot server that promises to deliver breakthrough efficiency and scale. The HP Moonshot servers are designed and tailored for specific workloads to deliver optimum performance.

The ProLiant m800 cartridges from HP are powered by TI's 66AK2Hx processor using TI's KeyStone™ II architecture running in HP's Moonshot server

Figure 6: The HP ProLiant m800 cartridges running in HP's Moonshot server platform are powered by TI's processors to deliver breakthrough efficiency and scale.

platform. The unique advantages to aid in real-time processing makes the 66AK2Hx SoC ideally suited for this type of application. There are three main advantages that TI's DSPs bring to the HP Moonshot server platform. First, C66x DSP cores have great signal-processing performance as well as very low latency response times and can receive, process and return packet data very quickly. Secondly, an integrated I/O fabric utilizing sRIO moves data quickly and with low latency. This sRIO I/O fabric provides 10× lower hop-to-hop latency than Ethernet I/O. Lastly, the 66AK2Hx SoC provides additional KeyStone II architecture elements such as the Multicore Navigator and TeraNet which further enable low latency data movement within and across devices. TI is proud to be a hardware partner in the HP Moonshot Program that looks to improve upon the energy, space, cost and complexity of traditional servers.

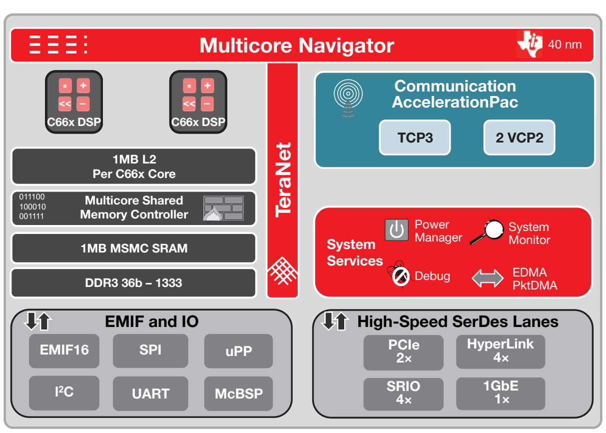
Scalability

TI's solutions for edge analytics and high-performance analytics are both based on TI's innovative KeyStone architecture and share the same processing elements, chip infrastructure, software development environment and tools. This provides an incredibly scalable solution where development investment can be leveraged and reused across platforms.

Both based on TI's KeyStone architecture, they provide a scalable solution from adding analytics in a smart camera all the way to embedded high-performance compute systems. (Pictures not to scale.) For example, the C66x DSP core that can be used to add analytics to a smart camera in a security system is the same DSP core running higher-level analytics on multiple camera inputs in the networked video recorder. Algorithms can run on both platforms with minimal additional development time. Analytics that are developed on the TMS320C6655 DSP with a single C66x DSP core can be scaled up and reused on the TMS320C6678 DSP with eight C66x DSP cores, providing complete software and development reuse.

Conclusion

TI has been in embedded analytics for over 20 years with real-time processing solutions in security and surveillance, automotive vision, industrial and factory automation, military and defense and various



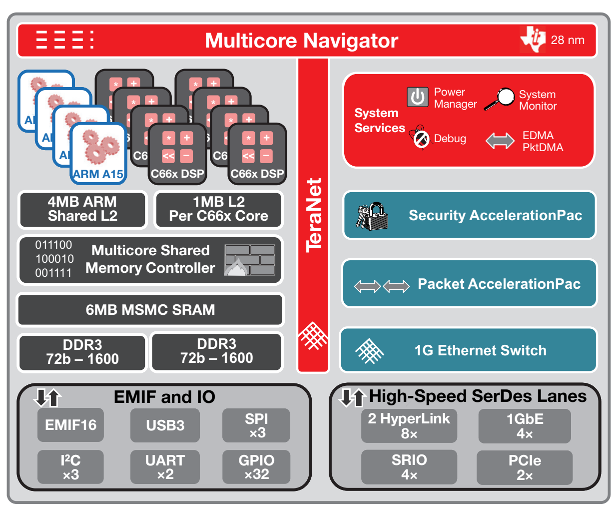


Figure 7: Block diagrams of TI's C6657 (left) and 66AK2H12 (right) SoCs.

consumer applications. Analytics are becoming increasingly important as a way to uncover meaningful information and find patterns in the vast amount of data now available. TI's DSP processors will enable edge analytics, which will be a key tool in managing the data tsunami. TI's high-performance multicore SoCs will bring power efficiency to purpose-built analytics servers. TI's family of code-compatible KeyStone devices provides a scalable processing solution for all sizes of analytics applications.

Sources

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2. **Cisco Visual Networking Index: Forecast and Methodology, 2013–2018**
3. **The surprisingly large energy footprint of the digital economy [update]**

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