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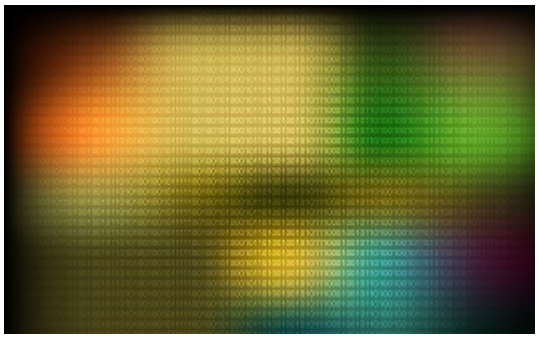


RESEARCH REPORT

EXECUTIVE SUMMARY

Computer Vision Technologies and Markets

Hardware and Software for Automotive, Sports and Entertainment, Consumer, Robotics and Machine Vision, Surveillance and Security, and Medical Markets

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SECTION 1

EXECUTIVE SUMMARY

1.1 INTRODUCTION

After being a research technology for the past few decades, computer vision has become commercialized in the past few years and is being deployed in a wide range of application markets including security and surveillance, automotive, consumer, industrial, medical, and entertainment, to name a few. A computer vision system captures images and then manipulates, changes, or enhances them for a given application. Each application requires a specialized adaption and enhancement to the computer vision algorithm, although several fundamental blocks of algorithms are common. During the course of Tractica's primary research for this report, all interviewees wholeheartedly agreed that intellectual property (IP) and technology play a big part in this sector. Most, if not all, companies interviewed either came from a university research team or had the backing of a prominent team of scientists.

During the interviews conducted for the report, it was also evident that getting computers to recognize objects just like humans still remains elusive and 100% accuracy and reliability is almost impossible. In some cases, such as industrial applications, by controlling the lighting conditions and placement of a camera, it is possible to obtain reliable results within an acceptable level of tolerance. In other cases, such as in automobiles, the camera is aided by additional sensors, such as laser and infrared, to obtain required accuracy.

New technologies like deep learning are evolving that promise to increase accuracy and reliability dramatically, but these technologies need more research before they can become mainstream. These technologies are modeled on a neural network and will allow the conversion of an image to text or speech. Deep learning will also enable the conversion of text or speech to image or video and the two together can enable tagging, searching, and indexing of a video or image just like text.

It was also evident during the research that the market is wide open to new entrants and technology as of early 2015. The market is awash in startups and small companies trying to ride the wave of hype. In fact, vertical markets like security and surveillance are already starting to become overcrowded, with some 80 companies offering facial recognition software. These companies will have to work hard to come up with innovative business models and differentiation in the long run to survive.

Established players, such as Google and Microsoft, are also trying their best to monetize computer vision technology. Google, Microsoft, Nvidia, and other large players have already established research labs focusing on computer vision. Research papers that break previous records are published in conferences on a quarterly basis and the technology ramp up is rapid. Overall, a huge amount of optimism exists in the industry and everyone is banking on huge growth in the future.

Chip vendors are also actively promoting the technology by providing development platforms and software. Nvidia, for example, offers the DRIVE PX platform for automotive vision applications, whereas Qualcomm has introduced a platform called Zeroth that is targeted toward neural network applications. Intel is an active participant in Open Source Computer Vision (OpenCV), a software library of general-purpose computer vision software libraries. An independent software consortium called the Khronos Group is releasing a platform called OpenVX.

The degree to which computer vision technology is being adopted depends hugely on the application. Applications like machine vision and gaming are leading the way where market traction is already occurring. Other applications, such as security and surveillance, are just starting to emerge.

The value provided by applications, coupled with innovation in business models, will dictate the growth of the market over the next 10 years. Marketing buzz from large companies will also play a large part in adopting technologies like virtual reality (VR).

Overall, Tractica remains bullish on the state of the computer vision market and feels that the technology will see widespread adoption in the near future.

1.2 MARKET AND TRENDS

The best analogy to describe the computer vision market would be of a star rookie quarterback who won a championship for his team and is expected to win many more championships. In essence, computer vision is aiding numerous applications that are very promising and promises to revolutionize the way we do things today. But other than some success in gaming, automotive, and industrial applications, the market is still lacking the numbers that one would expect. The technology has been around in some form since the 1980s and has found applications in niche areas, but widespread adoption has been hampered by several technical and business issues as explained in subsequent sections.

The computer vision market is primarily driven by the application requirement. Although the basic technology (such as identifying an object in an image or video) remains the same across the board, the way the information is used varies in different applications. For example, technology to track a person could be used to identify a potential terrorist's movement in an airport, whereas the same technology could be used to track a buyer's behavior in a shopping mall.

The nature of the application, and whether it is targeted toward businesses or consumers, plays a big part in deciding the pricing and, therefore, the overall market. Applications developed for business-to-business (B2B) use are priced differently from the applications developed for business-to-consumer (B2C) use. In addition, the type of industry may also force a variance in the business model. Tractica's interviewees in the security and surveillance industry noted that the business models for the same surveillance system for an airport and a mall are very different. Government agencies prefer to make a lump sum payment upfront and have the system installed, whereas the retail market prefers a minimal investment and a monthly services model.

Tractica considers computer vision to be a horizontal market, as the applications are widespread across different application segments. We have segmented it into six verticals: automotive, sports and entertainment, consumer and mobile, robotics and machine vision, medical, and security and surveillance. Computer vision industry verticals are full of buzzwords that are generating lots of press coverage today. Phrases like "drone-based surveillance," "self-guiding robots," or "self-driving car" have become topics of choice in many technology magazines and development is being followed closely.

Each vertical has its own drivers and challenges. Each vertical also has its own ecosystem that supports the computer vision application and, although the technology is the same, different pricing requirements may dictate a completely different solution.

Table 1.1 Vertical Markets for Computer Vision

Market	Major Buyers	Description
Automotive	Consumers	Applications related to car and other vehicles. These include Advanced Driver Assistance System (ADAS), autonomous vehicles, etc.
Sports and Entertainment	Studios, content producers	Computer vision-based technologies and effects used in sports, movies, and TV content
Consumer and Mobile	Consumers, enterprises	This vertical includes applications based on consumer and mobile devices, such as smartphones, tablets, and digital cameras; biometrics, virtual reality, and character recognition are some examples
Robotics and Machine Vision	Factories, manufacturing facilities	This vertical includes applications that are primarily targeted toward industrial automation; these include parts inspection system, self-guiding drones
Medical	Hospitals	In this vertical, computer vision systems are used to extract 3D images
Security and Surveillance	Government, retail chains, malls	Applications that are based on the live camera feed from places of interest to national security

(Source: Tractica)

The automotive vertical consists of technology used in cars, trucks, and other automobiles. The industry is starting to emerge and many computer vision-based systems are already in place. A self-parking system developed by Mercedes is one application of computer vision technology and has been around for some time. Google's self-driving car, which has been licensed in the state of Nevada, is generating quite a bit of buzz. Audi has also announced its own plans for a self-driving car.

The sports and entertainment vertical has been using computer vision techniques for a long time. Science fiction movies have used computer vision-based effects since the 1970s. However, the extent to which effects blend into the surroundings has improved drastically in recent years and the result is a more realistic video.

The consumer and mobile vertical has emerged in the last 5 years and has a wide range of applications based on computer vision technology. Gaming technology, such as Microsoft's Kinect, has used computer vision extensively. The growth of smartphones and tablets with onboard cameras has spawned numerous computer vision-based applications. Newer technologies like virtual reality (VR) that draw from computer vision fundamentals are promising to give rise to a whole new market segment within the consumer and mobile vertical.

Machine vision is one of the more mature verticals in the computer vision market. Camera-based systems used for defect detection have been around for a long time. Historical systems were good at repetitive, well-defined tasks. Newer products in machine vision can be trained to do different tasks. Robots that are movable and include cameras promise to open up a whole new range of applications in this vertical.

The medical vertical has also been using computer vision techniques for some time, but they have become more prominent within the industry in recent years. A 3D extraction of a baby's facial features using ultrasound is made possible by computer vision technology and it has been fewer than 5 years since such a feature was introduced.

Security and surveillance is yet another emerging vertical. Numerous systems are available that can grab a feed from a camera and detect objects, such as faces, humans, animals, cars, etc. Of all the verticals, this one has lowest barrier to entry, as many of the algorithms used are common and a system can easily be built upon it.

Given the breadth of the computer vision market, it is not surprising that a large number of companies are participating in this market. Tractica has considered over 100 companies in researching the market for this report and believes that another 100 companies easily exist. Most of the companies cater to niche markets and the field is dominated by startups that have been active in the business for fewer than 3 years. Some are generating revenue, but most are trying for Series B funding.

1.3 Business Models

1.3.1 Software as a Service

The software as a service (SaaS) licensing model involves payment on a monthly basis for software usage. This model is most popular with cloud- or web-based applications. The advantages of such a model are very low upfront costs and the fact that the user pays on a monthly basis. Very often, it is possible to cancel the subscription at any time with no penalties.

In the context of computer vision, this model is popular in the security and surveillance market where retail chains, in particular, prefer a subscription model, as opposed to an upfront, one-time payment. This model is also popular in the consumer vertical for certain high-value smartphone applications. For example, a VR application designed for a museum utilizes a SaaS model so the updates are always available.

1.3.2 Technology Licensing and Royalty

The technology licensing model involves licensing costs, followed by per unit royalties per units of hardware shipped. This model is popular with processor IP companies, such as ARM, which charges a one-time licensing fee and then collects royalties as chips based on ARM shipments. This model has seen limited traction in other industries though.

In the computer vision industry, this is popular with companies that make platforms that could be used to develop applications. One example is Wikitude, which makes a complete platform that runs on a smartphone or a hardware reference board. Wikitude licenses the technology to enterprises or mobile developers who, in turn, develop applications using it. When the application is sold via mobile stores or another means, they pay royalties on sales to Wikitude.

1.3.3 One-time Payment

One-time payment requires paying an upfront fee for a device. Most of the hardware industry follows a one-time payment model. Often, there is a support contract or warranty contract that supplements the one-time payment. Support contracts kick in after the warranty period expires and provide warranty for the specified duration.

Most verticals that require the sale of hardware fall under this business model. The machine and robotics, medical, and automotive verticals typically involve the sale of a device that is offered at a fixed price. Manufacturers also charge for support and warranty to supplement the one-time payment. Several consumer and gaming devices also use this business model.

1.3.4 Pay-as-You-Go and Services

Pay-as-you-go involves payment for services or products on an as-needed basis. The device may be sold at a minimal or zero price and could involve payment as and when used. Mobile service providers use this type of business model and it is popular with people who travel or have an intermittent need for a mobile phone.

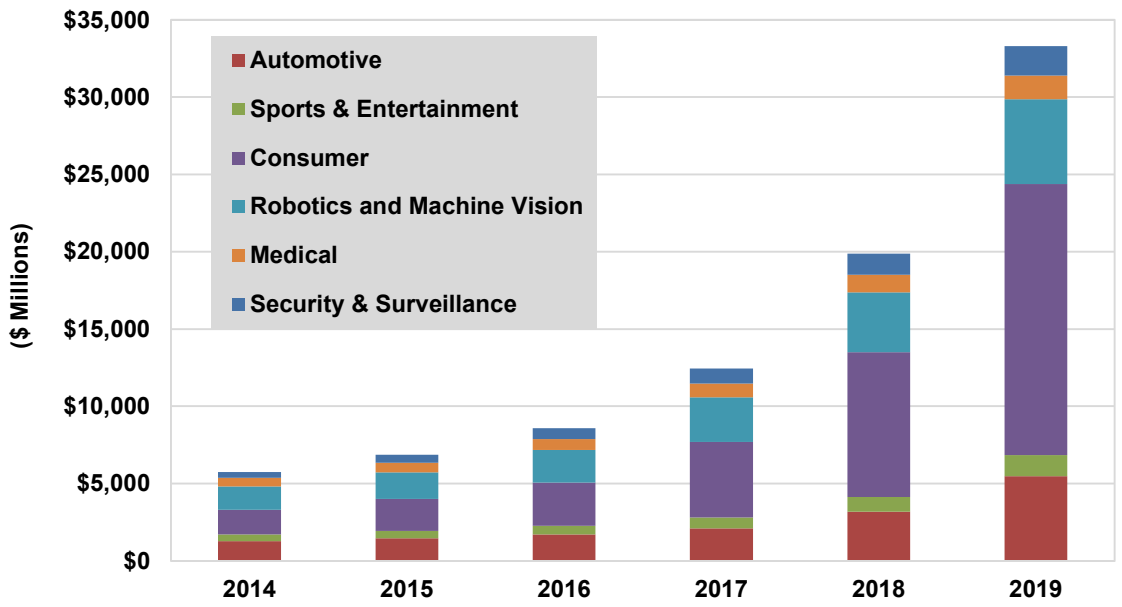
Within the computer vision market, the sports and entertainment vertical employs this type of business model. Sports applications often require the installation of equipment and the computer vision application may be deployed for a particular tournament. Once the tournament is finished, the application provider may choose to leave the equipment installed in anticipation of the next event.

Services have been popular with startups as a means of generating revenue. While the application matures for a full hand-off to users, startups often engage their resources on a services basis to prove the technology and application.

1.4 Market Forecast

Tractica forecasts that the computer vision market will grow from $5.7 billion in 2014 to $33.3 billion by 2019 at a compound annual growth rate (CAGR) of 42%. The consumer and machine vision and robotics segments are the two largest application markets today, accounting for $1.58 and $1.52 billion respectively, as of the end of 2014. Tractica anticipates that the consumer market will experience a CAGR of 61.8% between 2014 and 2019, representing the highest growth rate among all the segments, and growing to reach $17.5 billion by 2019. Robotics and machine vision will be the second largest application market, accounting for $5.49 billion in 2019 with a 5-year CAGR of 29.2%.

Chart 1.1 Computer Vision Revenue by Vertical Market, World Markets: 2014-2019



(Source: Tractica)

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SCOPE OF STUDY

This report focuses on market dynamics and opportunities surrounding computer vision technologies across six vertical markets including automotive, sports and entertainment, consumer, robotics and machine vision, medical, and security and surveillance. Computer vision-based systems primarily rely on cameras as primary sensors. They may also use supplementary sensors such as IR or radar to extract the relevant information. For purposes of this report, only systems that predominantly use cameras as a means to extract information are included in the market definition. Systems that depend entirely on non-camera based sensors are excluded. The study includes market sizing and forecasts for computer vision hardware and software during the period from 2014 to 2019, segmented by world region and application market.

SOURCES AND METHODOLOGY

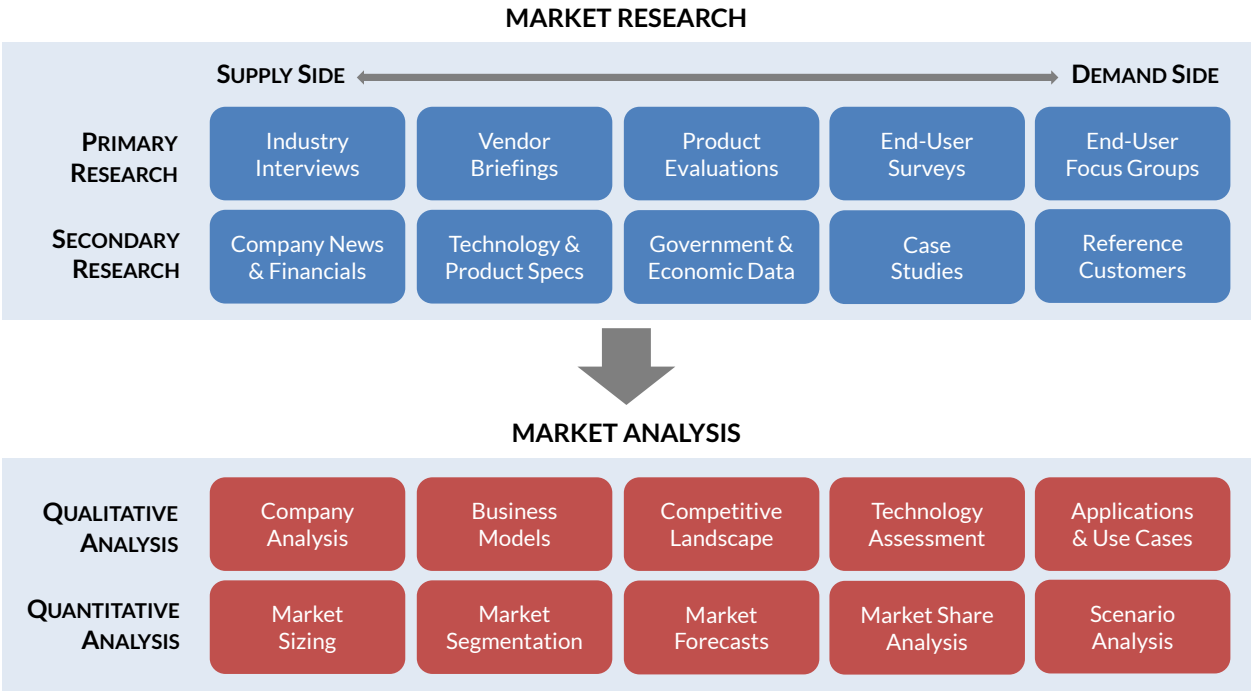
Tractica is an independent market research firm that provides industry participants and stakeholders with an objective, unbiased view of market dynamics and business opportunities within its coverage areas. The firm's industry analysts are dedicated to presenting clear and actionable analysis to support business planning initiatives and go-to-market strategies, utilizing rigorous market research methodologies and without regard for technology hype or special interests including Tractica's own client relationships. Within its market analysis, Tractica strives to offer conclusions and recommendations that reflect the most likely path of industry development, even when those views may be contrarian.

The basis of Tractica's analysis is primary research collected from a variety of sources including industry interviews, vendor briefings, product demonstrations, and quantitative and qualitative market research focused on consumer and business end-users. Industry analysts conduct interviews with representative groups of executives, technology practitioners, sales and marketing professionals, industry association personnel, government representatives, investors, consultants, and other industry stakeholders. Analysts are diligent in pursuing interviews with representatives from every part of the value chain in an effort to gain a comprehensive view of current market activity and future plans. Within the firm's surveys and focus groups, respondent samples are carefully selected to ensure that they provide the most accurate possible view of demand dynamics within consumer and business markets, utilizing balanced and representative samples where appropriate and careful screening and qualification criteria in cases where the research topic requires a more targeted group of respondents.

Tractica's primary research is supplemented by the review and analysis of all secondary information available on the topic being studied, including company news and financial information, technology specifications, product attributes, government and economic data, industry reports and databases from third-party sources, case studies, and reference customers. As applicable, all secondary research sources are appropriately cited within the firm's publications.

All of Tractica's research reports and other publications are carefully reviewed and scrutinized by the firm's senior management team in an effort to ensure that research methodology is sound, all information provided is accurate, analyst assumptions are carefully documented, and conclusions are well-supported by facts. Tractica is highly responsive to feedback from industry participants and, in the event errors in the firm's research are identified and verified, such errors are corrected promptly.

Chart 10.1 Tractica Research Methodology



(Source: Tractica)

NOTES

CAGR refers to compound annual growth rate, using the formula:

CAGR = (End Year Value ÷ Start Year Value)$^{(1/steps)}$ – 1.

CAGRs presented in the tables are for the entire timeframe in the title. Where data for fewer years are given, the CAGR is for the range presented. Where relevant, CAGRs for shorter timeframes may be given as well.

Figures are based on the best estimates available at the time of calculation. Annual revenues, shipments, and sales are based on end-of-year figures unless otherwise noted. All values are expressed in year 2015 U.S. dollars unless otherwise noted. Percentages may not add up to 100 due to rounding.

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