final report

Project code: P.PSH.0843

Prepared by: Brett Wiskar
Wiley & Co Pty Ltd

Date published: 29 September 2017

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 1961
NORTH SYDNEY NSW 2059

Augmented Reality

(Investigate augmented vision technologies to improve subjective carcase assessment)

This is an MLA Donor Company funded project.

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Executive summary

Australia is one of the leading red meat producers in the world. The industry is keenly focussed on innovation and the delivery of new technology to drive efficiency and quality across the sector. This focus is in large part to ensure our future as a high value producer of red meat to the domestic and international markets.

Mixed reality is a term that spans the continuum between Augmented Reality and Virtual Reality. The global technology industry is pushing innovation in this area and bringing new and powerful solutions to market at great pace. Virtual Reality is targeted at the entertainment market but augmented reality is shaping up as a business and commercial set of tools. These tools have the capacity, as the name suggests, to augment the vision, knowledge, available information and tools that the user has at their disposal. This facilitates greater performance in terms of throughput and consistency of decision making by the user and is this area that is the focus of this project.

This project consists of two phases;

- A research phase reviewing and cataloguing relevant augmented reality projects, case studies and technology
- A proof of concept phase in which a prototype of an augmented reality application is developed for an AR head mounted display and tasked with reducing the subjectivity in MSA grading in a processing environment.

The current meat grading practices have led to distrust in the industry. MLA have stated that producers and feedlot operators are concerned about the precision of meat grading in Australia. Meat graders are not to blame. Humans are simply not built to repeatedly make objective judgements day in day out. In an American study of meat grading, it was found that 50% of meat samples were mis-graded in some way. In a 2003 study of meat grading in Australia as many as 70% of samples were mis-graded (Jang Ju Won et al, 2017).

The solution is objective measurement in an easy to use package. With augmented reality, it is possible to integrate the objective measurement capability of computer vision with the experience of meat graders. This will facilitate faster, more consistent and more precise meat grading while taking full advantage of the capabilities of meat graders.

The proof of concept developed is capable of directly discerning the colour of a meat sample, and count the area of the latissimus dorsi muscle and handsfree scanning of meat sample tickets. These features have been demonstrated on a Vuzix augmented reality headset as well as on various hand-held devices. The major challenges to deployment on a head mounted device are the lack of processing power and the heavy head mounted device itself.

Both the augmented reality market and the platform developed through this research show substantial potential. The successful demonstration of a meat grading application in conjunction with the continuing development of augmented reality solutions make it reasonable to expect augmented reality to play a substantial role in the meat industry in years to come.

Table of contents

1 Project overview

The project aimed to evaluate image processing software such as computer or robotic vision, which we have labelled Augmented Vision (AV), and Augmented Reality (AR) solutions against industry requirements. This was to demonstrate technology applied to improving the transparency and accuracy of the subjective measurement of MSA meat grading.

The project involved exploration of options for the design, development and implementation of technology systems targeted at providing support, monitoring and standardisation of MSA grading processes.

The project aimed to assess feasibility and, if possible, demonstrate a means of;

- Reducing subjectivity in existing industry grading systems
- Improving industry transparency and producer to processor trust
- Supporting the grading process through the identification of potential new technology

This research explored a variety of solutions including research into technologies such as:

- Vision and decision capture for post grading review, correction, adjustment, calibration and training purposes
- Augmented vision for real time decision support
- Smart vision systems with colour and edge detection capabilities

The outcome of the project can be summarised as delivering a prototype or proof of concept technology solution for demonstration to industry. This prototype will facilitate feedback and exhibit the feasibility of augmented reality and augmented vision systems in meat processing and grading applications.

2 Objectives

The project was comprised of two elements, a research project and a software prototyping project.

2.1 Research component objectives:

- To analyse and map the industry's current, subjective grading processes to identify the potential to reduce or eliminate subjectively from the grading process.
- Assessment, or identification of software and technology solutions capable of conducting part (or all) of this process to help reduce or eliminate that subjectivity.
- To assess current industrial Augmented Vision technology and forth-coming solutions that could drive improved subjectivity in meat processing (e.g. grading or other areas).

2.2 Prototype objectives:

- To develop a prototype of an Augmented Vision solution (to demonstrate the potential to display, capture, process, etc.) that illustrates how the use of such technology could reduce the subjectivity in the grading of meat in a production environment.
- To demonstrate this prototype to industry and gauge interest and demand for industry specific AV solutions.

3 Opportunity

Opportunities exist to increase the precision with which MLA's Meat Standards Australia (MSA) grading is conducted within the industry's meat processing facilities. These opportunities come in the form of reduction in subjectivity in the measurement of attributes that contribute to the grading score. It should be made clear that the MSA standard is not in question but the means of capturing the attributes and the subjective determination of these is the focus of this project.

Augmented Vision could offer decision support to workers in a number of industries and has already been deployed by companies such as Boeing, Lockheed Martin and DHL.

Decision assistance for meat graders may lead to improved outcomes for the meat industry. Increased precision has obvious benefits such as accuracy on a carcase by carcase basis and broader labour efficiencies but there are also subtle flow-on positive impacts to the industry and processors. Decision assistance is likely to bring about greater speed and decreased training periods for meat graders. In addition, decision support has the potential to normalize grading performance across shift duration, between graders, between facilities and across processor groups.

MLA have stated that producers and feedlot operators are concerned about the precision of meat grading. This precision is of specific concern to these groups as it affects their income. MLA has also stated that in their view, the implementation of OCM will directly and immediately address the concerns of producers (Ernst & Young, 2017). Thus, it is important that high quality OCM measures be implemented as soon as practical.

Globally, there is evidence from industry grading programs that human graded product does not compare favourably when objectively measured, raising concerns regarding the consistency of broad scale subjective measurement and assessment.

The method with which meat is graded in America is similar to that in Australia. Texas A&M University performed an investigation into the precision of meat grading in America, where it was found that the grade of 'choice' given by meat graders was found to be 70% of the total number of grades given. The same grade given by the computer vision was found to be 51% of the total number of grades given presenting a stark difference between the two methods of grading.

While it is obvious that American grading is not Australian grading, this is a close analogue of a conscientious, quality focused meat grading body. This comparable study found that substantial imprecision existed in the US industry's process.

4 Augmented reality technology

4.1 Components of an augmented reality system

An Augmented Reality system is most easily explained in terms of technologies with which the reader is already familiar. It is important to note little of the technology here is totally new. Indeed, the processors, cameras and display technologies used in AR have been widely available prior to the onset of AR popularization.

AR experiences can be categorised as follows:

- Handheld devices (smart phones)
- Spatial AR systems
- Head Mounted Devices
    - Smart Glasses
    - Smart Lens

The biggest change in Augmented Reality technology is the physical hardware format in which AR is experienced. This is best observed in the distinction between a handheld AR device and a Head Mounted Device (HMD). The industry is trending towards small, lightweight, Head Mounted Devices as opposed to handheld systems offering a number of advantages. Critically, the HMD is hands free, allowing the worker to focus on their work function and keep two hands on the designated task. This hands-free display and interaction is the true core of Augmented Reality's appeal.

This section shall discuss the primary technological components of AR systems.

The following components will be explored:

- cameras,
- processors and computing power,
- software, and
- display technology

4.1.1 Cameras

The camera technology used in augmented reality is almost identical to that used in handheld phones. The primary manufacturers of cameras for smartphones are Sharp, Sony, Toshiba, Omnivision and STMicroelectronics. The investment in this field has been substantial and compact cameras are a very mature technology. Interestingly, Apple does not manufacture cameras, instead relying on third party technology providers.

The cameras in Augmented Reality headsets are typically 1.5 Mega-Pixels (MP), similar cameras in smart phones are on the order of 5-10 MP. A resolution of 1.5 MP is sufficient for feature recognition and image processing and as far as the size of units go it is a fair trade off to fit the device onto a head mounted device.

4.1.2 Processing hardware

The processing hardware in augmented reality is similar to that of older (pre-2013) telephones. The Vuzix M300 has an Intel atom micro-processor that can process at 200MHz. The Microsoft Hololens processes at 1GHz. If this is compared to the latest in smartphone technology, the Google Pixel processes at over 2GHz. In other words, the smart phone processes 20 times as quickly as the Vuzix headset. This is one of the limiting aspects of some of the augmented reality smart glasses (like Vuzix) currently on the market.

In the next few years, as technology progresses and processors become more compact it can be expected that smart glasses will become capable of much more complex tasks and their usefulness are expected to increase accordingly.

4.1.3 Information display

The display technology used in smart glasses is the aspect in which they vary most from smartphones. Smartphones are designed to be held at focal distance from the eye with reasonable pixel density and brightness. By contrast, the Head Mounted Augmented Reality Display must be immediately near the eye, and thus the eye cannot focus upon the display independently. For this, assistive magnifying lenses are used to bring the display into focus. This has been described as unhealthy by vision experts and should be treated with some caution [30].

The displays on smart glasses are necessarily much smaller than those on hand held devices but must still convey a large amount of information. To this end the displays used in HMDs must have a much higher pixel density. This challenge is being addressed by the manufacturers of AR devices however it represents a challenging area in which progress will be well received.

5 MSA grading

5.1 Procedures and possible improvements

All sectors of the meat supply chain have a vested interest in either; validating the quality of meat grading outcomes, or increasing the objectivity of grading outcomes.

Based on the value of increased objectivity or validation of the outcomes it is possible to identify the precise grading metrics most suited to processing by cameras and image processing software. The table below lists MSA grading tasks, the challenges or limitations of execution by an unassisted human operator, along with a brief explanation of the potential value or opportunity for Augmented Vision and AR solutions.

Evaluation task	**Challenges to the human operator**	**Comments on an AR solution**
Meat and fat colour	This visual inspection task is relatively simple however slight changes over the entire muscle or a sample part way between two colour options may prove unnecessarily challenging to a human operator. (Nollet et al, 2015)	An AR solution could precisely compare the colour of a meat sample and the swatch placed upon it as a guide. Of course, the reflectivity of the two samples must be considered for this to be precise, however this is a relatively minor challenge.
Eye muscle area	At present the eye muscle area is calculated using the MSA grid. The operator will count the number of squares filled and will then be forced to approximate the area of the partially filled segments, a process that necessarily introduces imprecision into the process.	Augmented reality would allow the operator to directly see the area of the muscle with greater precision, provided it is properly positioned relative to the camera. This way the imprecise measurement mechanism can be avoided.
Marbling	Marbling is likely the most challenging task for the meat grader. It involves limitless possible differentiations of marbling and the task must be performed via visual inspection only.	An AR software implementation in an HMD could narrow the marbling options allowing the grader to more easily determine the marbling in a sample and with a more advanced algorithm, the marbling score may be determined entirely independently of the operator. (Cheng, 2015)

Table 1- Meat grading processes and augmented reality potential

6 Augmented reality applications

6.1 Introduction

This section shall investigate the Augment Reality technology sector specific to the hardware and software providers and available solutions. This shall start by looking at industry-wide trends followed by a high-level review of many augmented reality applications to demonstrate the breadth of augmented reality capabilities. Following this, several augmented reality applications shall be investigated in greater depth to explore the challenges, benefits and business case for AR in industrial applications.

6.2 Industry overview

A study by the University of Pisa investigated the applications of augmented reality in industry. The study found that the industrial plant sector features heavily as does inspection (Anna Syberfeldt et al, 2017). These are the categories directly relevant to the project, this finding serves to assure the reader that the current application of augmented reality is not only feasible but well founded.

Author Jon Peddie states in his work “Augmented Reality. Where We Will All Live”

“Augmented reality is such a complex, wide ranging topic, it’s difficult to organize all it encompasses in a logical outlined way.” (Peddie, 2017)

Thus, it is important to note any subdivision of AR shall be imperfect. For the purposes of this section the following categories shall be used.

1. Hands-free manuals and context relevant information
2. Augmented senses and head-up analytics
3. Remote mentoring
4. Mixed reality simulations

It is important to note these categories shall necessarily overlap in some capacity, however these serve as a reasonable structure for wholly analysing the relevant applications of AR in industry.

6.3 High level review of applications

This section shall quickly introduce many applications of AR to give the reader a sense of the market as is and the capabilities of consumer products.

6.3.1 Category 1: Handsfree Manuals and Context Based Information

This group of AR applications is defined by making observations about the surrounds and sourcing information from the internet or an on-board database for presentation to the user. This is different to category two which provides new information which is not available on the internet.

Leaders in category one are Wikitude and Junaio. These are low level augmentation apps which typically run on smartphones and provide information to the user according to the environment they are in.

Another application in this category is the world lens dictionary, this allows the user to translate written text into their native language. This technology is still developing however it has been demonstrated on a smartphone.

The infinity augmented reality app uses facial recognition software to look up individuals and provide the user with relevant information. Typically, this takes the form of a Facebook profile. It is important to note that this approach is far from practical as current AR hardware is less than subtle. It is possible that future hardware solutions will be sufficiently subtle or widely used that this app may be normal.

Finally, for the group of context based information enhancement there is the Volkswagen MARTA (Mobile Augmented Reality Technical Assistance). This technology aids the user in performing simple maintenance such as oil and coolant changes.

6.3.2 Category 2: Augmented Senses and Head-up Analytics

The second category of AR applications provides information to the user that requires recognition and analysis of the current situation. The on-board analysis is the differentiating factor between this and the previous category.

The first example in category 2 is the recon jet for runners and cyclists. This AR solution doesn't interact with the context but provides information to user regarding their heartrate, speed and other relevant physical information.

The BMW HUD (Heads Up Display) is an example of a more advanced situated analytics application. This AR uses visual algorithms to recognize objects on the road and through overlaid visuals provides useful information to the driver. This serves to make pedestrians more obvious as well as tell the driver the time and distance to the car in front in case of slowing.

A particularly interesting and advanced application of AR is the liver explorer, this application is best understood through video. The video (https://www.youtube.com/watch?v=PWRLF8-CPlQ) provides a clear overview of the functionality of this app.

6.3.3 Category 3: Remote Mentoring

Category 3 describes AR applications that permit virtual interaction between a remote mentor and the person on site. This has been applied to surgery, maintenance and teaching. This application of AR allows experts to easily interact with challenging problems from a remote location with minimal delay and cost.

The first example of category 3 is the tele-mentoring approach developed by Purdue University which allows a surgeon to instruct another using a "transparent" display, this overlays the instructions onto the patient and allows instant audio feedback between the instructor and the operating surgeon.

This approach has found applications mainly for field medics needing instructions in war situations and for remote surgeons.

Category three shall be further explored in the detailed case study section later in this document through the Lockheed Martin project.

6.3.4 Category 4: Mixed Reality Simulations

The fourth and final category is mixed reality for the perception of virtual objects.

This application has seen widespread application in the consumer goods sector as well as inspection and maintenance.

Major furniture manufacturer and retailer, Ikea, has deployed a mixed reality platform for people to try out furniture in their homes before purchasing.

The Ikea application is relatively low tech compared to what is possible in terms of mixed reality. A Japanese hacker has successfully created a virtual representation of their favourite animated pop star using low cost motion sensors and headset.

This user was able to go on an AR date and a walk with the pop star. It was also possible to interact with the pop star through a "touch" of her tie or hair.

This example may appear to lack commercial application. However, it is a strong case study of market engagement and virtual interaction opportunities created by AR. One day, it may be possible to go on virtual dates with virtual companions or other people remotely. This hints at future of connection with the help of augmented reality.

Finally, a virtual supermarket in China exists totally in "unused" space. These supermarkets exist in train stations or otherwise, there is nothing to be seen for the naked eye however, with an AR device one can navigate a supermarket and perform their shopping which shall be shipped to their door.

7 Detailed investigations

This section shall investigate a selection of Augmented Reality applications in greater depth. Areas of interest shall be:

1. The way the process was previously performed
2. The new AR process
3. The AR hardware solution
4. The benefits of implementing AR
5. The risks associated with the application

The applications that shall be investigated are:

1. Danish pork trimming with Cogent
2. Aircraft wiring harness assembly with Boeing
3. Order picking with DHL
4. Aircraft assembly with Lockheed martin

7.1 Danish pork trimming with Cogent

The first case study was performed by Cogent research in Norway. This study examined the productivity and percentage effectiveness of meat trimming processes performed by three groups of workers. The workers were untrained in the use of AR however they were trained meat processing staff. The study used a CT scan to determine the amount of lean meat in each meat sample. The study examined the helpfulness of augmented reality in the extraction of lean meat from these samples. There were three groups: the first received only oral instruction, the second had a computer monitor to guide them and the third had an AR headset. The group given only oral commands represents the control group. In the past, this task has been performed by trained operators working only by eye.

This displays the cutting instructions and the fat content of the meat for the worker more clearly than by eye. The findings of this study are shown below.

Support modality	Production capacity (arb units)	Yield by starting mass %
Oral	15	53
Computer monitor	12	64
Head mounted device	7	64

Table 2 - Support modalities and meat trimming outcomes (Lars Bager Christensen et al, 2016)

As can be seen from the results, the Augmented Reality group performed poorly in the capacity parameter, this was explained by the operators. The operators stated that the display was too unstable and that the tracking algorithm was not sufficiently stable for the analysis to work properly.

The augmented reality headset used in this application was the Vuzix m100 headset and the software used was the Junaio platform.

It can be concluded from this work that the application of AR in meat packing is still in its early stages but the technology shows that precision can be increased and with sufficiently smooth integration there is no reason high speed couldn't be achieved.

7.2 Aircraft wiring harness assembly with Boeing

Boeing, in conjunction with Skylight has implemented a Google Glass based system for assembling airplane wiring harnesses [26]. This is an exceedingly intricate and complex process which cannot be memorized by an operator. In addition to the complexity, there is extremely low margin for error as with everything in the aviation industry.

A Boeing electrical technician stated, "there's no margin for error, you can't pull over the plane if something goes wrong" (Boeing, 2015)

The way this was done in the past was initially dominated by 'phonebooks' of wiring diagrams and then laptops. But these approaches have two significant issues:

1. The operator must constantly look away from their work
2. The operator must take their hands off the work to update the book or laptop

The use of AR headsets has fixed both challenges. The heads-up display means the worker never needs to look away while the voice activation means their hands stay on the work.

These changes made a substantial improvement to the rate and quality of work produced. According to Boeing, this has reduced production time by 25% and decreased errors by 50%. From this case study, it is clear that category one applications of AR have the potential to increase workflow and reduce errors in everyday industrial and manufacturing operations.

It is relevant to note that this solution used the Google Glass 1 and existed prior to the announcement of the google glass 2 which was made public in July 2017.

For further information about this project, the reader is encouraged to follow the link below.

https://upskill.io/landing/upskill-and-boeing/

7.3 Order picking with DHL

The task in question is the picking of parcels in warehouses for global logistics industry leader DHL [26]. This task has typically been performed by workers with hand held laser scanners and paper picking lists. The picking process has been described as cumbersome and disruptive by workers. Moreover, the process has been challenging for new workers who require expensive and time-consuming training (DHL, 2017).

This process has been improved by the implementation of augmented reality. This gives pickers all available information in a head up display which updates as they work. This includes the package they are looking for, the place to find it and the place to put it on the trolley. In addition, the system allows workers to scan barcodes without the need for a handheld scanner.

The hardware solutions used in this case were a combination of Google Glass and the Vuzix m100 headsets. While the software used was the xPick software by Ubimax.

This application of augmented reality has been well received by workers and has provided a 25% increase in efficiency and reduced error rates. It is possible to conclude from this case study that applications of augmented reality can make workers more effective and less error prone simply by presenting information clearly (Holger Glocknerm et al, 2016).

7.4 Aircraft assembly with Lockheed martin

Typically, the task of assembling fighter jets has been only for the most experienced and highly trained technicians. This is due to the highly technical nature of the work and the low margin for error therein. The training process to prepare a technician for this task is expensive and can take years. The need for highly trained technicians leaves the assembly line open to disruption, especially during holiday periods (Lockheed Martin, 2014).

Recently, Lockheed has implemented an augmented reality system to address these challenges. The system is based on Epson Moverio BT-200 glasses with NGRAIN software. This solution shows an overlay of each component on the aircraft as it is assembled. This application is similar to the Boeing case study in that there is an instruction manual however in this case there is also remote mentoring. It is also important to note that this task is different in nature to assembling wiring harnesses and requires a greater degree of visual instruction.

The result of these systems is a marked improvement in precision and speed. Specifically, there was a 30% increase in speed and an increase of precision to 96%. Additionally, Lockheed reported shortened training periods for technicians further reducing costs (Philipp Rauschnabel et al, 2016).

8 The Augmented Reality Market

This section shall investigate the size of the market, the major players and the development trends of both. In addition, hardware solutions shall be introduced.

8.1 Product Positioning

Mixed Reality (the term given to the combined Augmented and Virtual Reality sector) is expected to be the next big wave in wearable technology. Technology giants such as Apple, Google, Facebook, and Microsoft are all undertaking substantial development and investment projects. The development and release of solutions from these players to their respective market is likely to dramatically expand the acceptance of AR solutions and the knowledge of this technology in the broader population. This year's Consumer Electronics Show and Mobile World Congress witnessed the market potential for AR and VR with a shift of attention to these products (G Dini & M. Dalle Mura, 2015).

8.2 Market Development

AR smartglasses first hit the market in 2013 when IT companies including Google and Vuzix came out with "Developer Editions" or 1st generation products. Due to technology and cost limitations at the time, these products were mainly used to raise awareness and gather feedback. As these companies specifically target enterprise users, they also devoted much time to creating custom applications for their products. By 2015, they were still in the process of perfecting their AR technology and seeking competent partners in hardware and software development. Shipments of smartglasses were, therefore, relatively modest, with an annual shipment volume of less than 100,000 units.

2016 turned out to be a promising year for AR. There were sales record of around 300,000 units as well as a large number of new products and start-ups entering the market. With these groups working on the technology, development is accelerating. It is predicted that the market will reach 10.6 million units by 2020 [29].

The CAGR (Compound Annual Growth Rate) of the AR market has held strong at 80% for some time and this is expected to remain steady or increase in coming years.

It is expected that the AR industry will largely be supported by enterprise users through this period as opposed to individual users. Primary areas for this development are commercial, marketing, education and retail.

These markets will show the greatest need for AR application and end devices over the next few years. These industries will also be the focus of AR companies for years to come.

A number of sales predictions have been found and tabulated below. Note that the vertical axis is logarithmic and so the top line produced by augmentedreality.org is 10 to 100 times as optimistic as the others. It is suggested that this is not a realistic outcome.

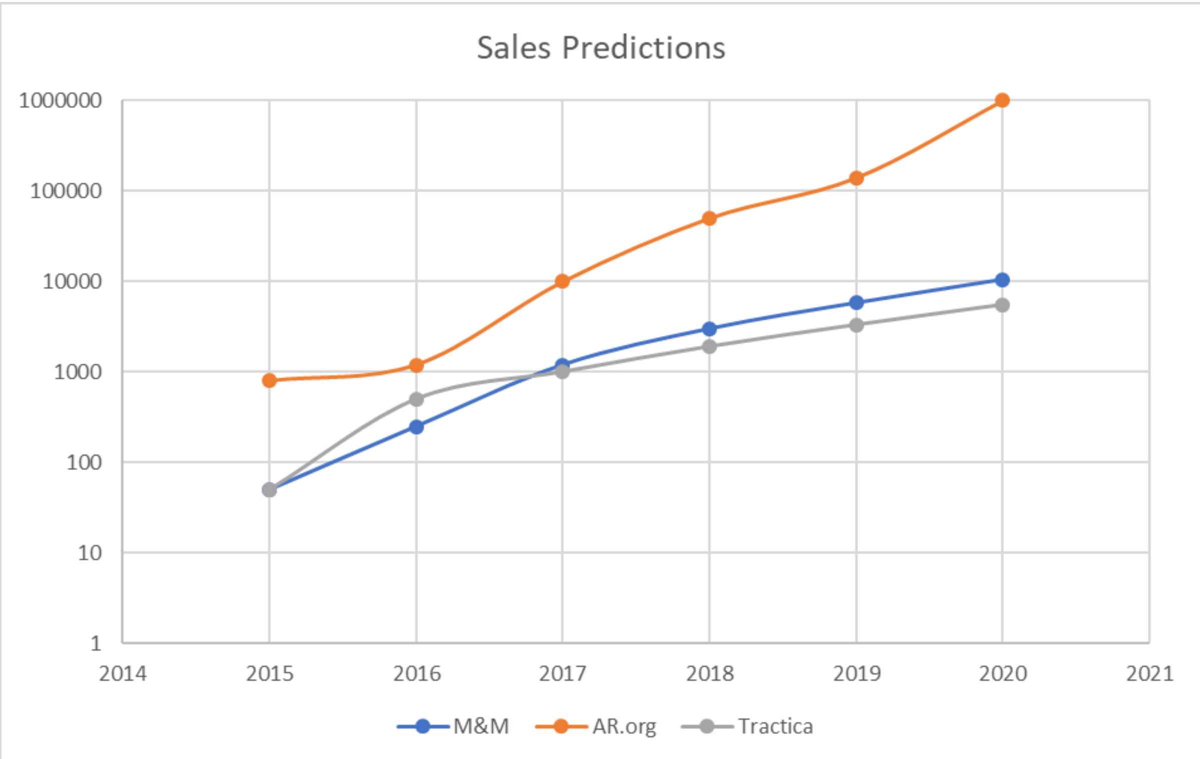


Figure 1 Augmented reality sales predictions from different sources (R. Hsu, 2016) , (O. Inbar, 2015) , (Tractica, 2017)

8.3 Development of the AR industry

8.3.1 Key vendors in the AR industry

Besides Google, which has stirred the industry with the launch of Glass, there are two other market groups that have played important roles in the development of AR technology. The first includes consumer electronics companies such as Japan's Epson and Sony. These companies are already equipped with key optical and lens technology facilitating the launch of AR products in 2014 and 2015. The second group includes start-ups that were established considering the potential rise of AR. These start-ups, including Vuzix, ODG and Kopin. Each have technical teams that are specialized in specific technologies such as display, military or projection. These technologies can be used in AR application.

The table below presents the most notable augmented reality platforms and relevant details [29].

Company	**Industry**	**Product Name**	**Release Month**	**Price (USD)**	**Description**
Epson	PC Peripherals	Moverio BT-200	May 2014	$ 700.00	Enhanced features in accessories, lens and controllers; works out-of-the-box with most Android apps
Google	Internet	Google Glass	May 2014	$ 1,500.00	Comes with built-in GPS, camera and speakers; discontinued in January 2015
Microsoft	Software	HoloLens	March 2016	$ 3,000.00	Features a Microsoft Holographic Processing Unit; made first available for developers and enterprise users
Sony	Consumer Electronics	Smart Eyeglass	March 2015	$ 840.00	Needs to connect with a compatible smartphone; targeted at enterprise users
Vuzix	Start-up	M100	December 2012	$ 999.99	Entered AR market in 2010; received investment from Intel (who also acquired Recon) in 2015

Table 3 Analysis of key AR vendors and their solutions MIC April 2016 [29]

8.3.2 Development of key players

8.3.2.1 Google

Google have played a key role in sparking public interest in AR. Google deployed a developer's edition glass in 2012. The Glass was then publicly released in 2013. Most recently the Glass 2 was released in July 2017.

In 2015 Google publicly ended production of the glass leading to widespread discussion and concern. The recent move to deploy the Glass 2 has given the market greater assurance as the largest of players is still in the game.

The Google Glass 2 will be directly targeted at enterprise users as opposed to SME or individuals. It was stated in the public release that DHL, Lockheed Martin and Boeing would all be using the Glass 2. The "google glass at work" represents a group of professional apps specific to the industry sector. The Google Glass 2 has greater transmission and processor performance. Additionally, the screen is larger and has a hinge. The hinge allows the user to move the eye piece in to a position suitable to them (Hofmann, 2017).

Google has been seeking hardware partners for Project Tango. Announced in 2014, Project Tango is a platform that aims to perform 3D mapping and indoor navigation with sensors and cameras by integrating motion tracking, depth perception, and area learning. Through partnerships with Android device manufacturers and developers, Project Tango is building its AR technology and application to run on all kinds of Android devices. In May 2015, Google started selling the software development kit for US$512, and in 2016, partnered with Lenovo to showcase the prototype of Project Tango device at MWC.

8.3.2.2 Microsoft

Microsoft's Windows Holographic platform made its debut at the announcement of Windows 10 which took place in early 2015. Using HoloStudio to design a quadcopter, Microsoft displayed how a HoloLens-wearing man used nothing but his fingers and virtual components to build the machine and then, with a 3D-printing machine, brought the prototype of his creation into the real world. Microsoft officially released HoloLens a year later at both CES and MWC 2016. Available by application to developers in the United States and Canada, HoloLens started shipping in March 2016.

Microsoft is taking a product development strategy similar to Google's smartglasses with HoloLens. That is, HoloLens is only made first available by application to developers in certain areas. On one hand, this strategy can help Microsoft monitor shipment of the product and to maintain flexibility of product improvement as well as control costs. On the other, Microsoft will be able to enrich the content and application of HoloLens in the developer community and reduce the risk of unfulfilled expectations, while identifying the most lucrative markets to target.

As the performance of Microsoft's Windows Phone is not yet up to par with Android and iOS, the announcement of HoloLens at the Windows 10 event reveals Microsoft's ambition to regain its past glory in the market by catching onto the wearable technology trend. Following the release of Surface, Microsoft has started shifting its focus to HoloLens and to involve more developers with its cloud tools and Windows Holographic Platform API. There is also a good chance that the new

Windows 10 will be coming to all devices running the OS (i.e. Xbox), which will further enhance customer experiences and enable a Microsoft ecosystem.

8.3.2.3 Key Issues

The reason Google Glass was unable to penetrate the market in 2013 is largely due to its price of $1,500 USD. By early 2016, however, the price of smartglasses, including those from Sony, Epson, Atheer, and Glassup, had dropped down to between $500 USD to $1,000 USD. At this price, AR companies are able to attract their main target customers, the early adopters and/or particular enterprise users, which they draw through exhibitions, YouTube ads and beta tester reports.

As for other customers, such as mainstream enterprise users and individual consumers, pricing is not the only factor that matters. AR companies also need to consider their different needs for smartglasses. For example, regardless of retail, medical, or education industry, enterprise users place high importance on product practicality and reliability. They have certain conditions that must be met, such as stable connection, easy interaction and visual quality. On the other hand, they care less for product design or visually-appealing apps. By contrast, individual consumers wear smartglasses to be tech-savvy and chic, so they have a stronger preference for brand names and product design. They also tend to consider whether smartglasses can provide additional features on top of their smartphones or other wearable devices.

There are certain standards that all AR companies should meet, such as pricing, design (size and weight), and battery life. However, for other features, enterprise users and individual consumers have different preferences that should be considered by AR companies when making decisions for development priorities and target markets.

8.3.2.4 Conclusion

This report has explored a wide variety of AR applications and shown the state of the art in this technology. Following this some, relevant case studies were investigated to give a deeper understanding of the advantages of AR in different applications, chief among these were ~25% effectiveness gains for Boeing and UGL.

9 MSA Grading Process**

The aim of MSA grading is to assure consumers that a cut of beef will eat to the quality shown on an MSA label when cooked by the method shown. This simple description system can form a basis for retail pricing and generate product confidence.

The program was developed using more than 100,000 consumers, across seven countries, who taste-tested some 700,000 beef samples to define the traits of a cut of red meat that affect eating quality.

Metrics collected at the point of grading are processed using the MSA model to determine a grade for the carcase and the cuts from the specific animal. The grade paired against eight recognised cooking methods the system can accurately predict the eating quality outcomes of individual beef cuts.

9.1 How is the MSA score calculated?

The MSA score, out of 100, is calculated by adding a percentage of the individual consumer scores for each sensory component as follows:

- Tenderness 40%
- Juiciness 10%
- Flavour 20%
- Overall liking 30%

These percentages have been established from statistical analysis and provide the best relationship between the data collected from the consumer research score sheets.

9.2 How are the MSA grade standards set?

The MSA score that forms the cut-off point between each grade is also set from analysis of the consumer test data.

The calculated MSA score is compared statistically to the box ticked and the optimum division points become the grade boundaries. A safety margin is included at the low end of good everyday MSA 3 to reduce the risk of any MSA product being unsatisfactory.

The MSA model, which calculates the grading outcome for each carcase, is downloaded into a data capture unit (DCU). This is a small hand-held computer that the MSA accredited grader uses to record the information from each individual carcase during grading.

9.3 How carcases are graded

Each carcase is identified with a carcase ticket and the following information is recorded in the DCU:

- Body number and lot number – cattle from individual vendors will be kept in separate lots.
- Carcase weight – important in determining weight for maturity.
- Sex – male or female.
- Tropical breed content – recorded from the MSA vendor declaration. The hump height is measured to determine the most accurate eating quality grade outcome.
- Hanging method – determined as being either Achilles hang or tenderstretch.
- Ossification – measured to determine carcase maturity.
- Marbling – using both the MSA and AUS-MEAT measurement systems.
- Rib fat – a minimum of 3mm is required, measured at the AUS-MEAT standard site, to ensure that the carcase has adequate fat cover to protect the carcase during the chilling process. Overall fat cover is also assessed including any hide puller damage. A primal that has an area greater than 10cm x 10cm affected by hidepuller damage will be ineligible for MSA.
- pH and temperature – pH is measured using a pH meter and must be below 5.71. Temperature should be below 12˚C according to the AUS-MEAT standards.
- Meat colour – recorded using AUS-MEAT standard meat colour chips in a range of 1A (very pale) to 7 (very dark purple). As it is important to ensure that consumers are satisfied with the visual appearance, meat colours in the range of 1B to 3 are accepted depending on the abattoir or brand specification.

Other measurements that do not impact on eating quality can be taken at the customers' request, including:

- Eye muscle area (EMA) – measured in square cm using an AUS-MEAT grid.
- Fat colour – recorded using AUS-MEAT chips from 0 (white) to 9 (yellow).

The carcase is given a grade code of 0 if all the specifications are met and the cuts can grade under MSA.

If the carcase does not meet all the specifications it is given a grade code that indicates which of the specifications were not met.

For more specific information on the MSA grading process and attributes please refer to MLA's document "Tips and Tools – Meat Standards Australia" (MSA15)

** The material on MSA Grading Process is sourced from MLA documentation.

10 Prototype Project

Following the initial phase of researching and assessing the Augmented Reality software and hardware landscape, the MSA grading processes, this project progressed to exploring the specifics of how to apply AR to improving the quality and consistency of MSA grading.

10.1 MSA Industry Research

Plant visits were conducted to Australian Country Choice at Colmslie and to Teys Australia's facility at Beenleigh (both in Queensland). During these visits, grading processes were observed. Accredited grading staff and plant operations managers were spoken with regarding the grading process.

In addition to the above, meetings were conducted with:

- Ian King, CEO of Aus-Meat who are responsible for establishing and maintaining agreed national industry Standards for Meat Production and Processing across the industry.
- Janine Lau, Research & Development and Integrity Manager - Meat Standards Australia, MLA

10.2 MSA Grading steps suitable for inclusion in the prototype

During research activities such as:

- Industry meetings,
- Facility tours
- Grading staff interviews
- The review of the MSA instructional material (documents, videos, grading aids and literature)

Several opportunities were identified for Augmented Reality and Computer Vision to provide decision support in MSA grading.

These opportunities then informed the prototype or proof of concept project that has been incorporated into phase 2 of this project.

10.3 What is in the prototype

The Project Team reviewed the MSA grading steps and identified elements that could be described as one or more of the following:

- Subjective
- Time consuming
- Subject to inaccuracy (through factors such as fatigue, human error, inconsistent training etc)
- Able to be automated with the projected time and budget based on potential AR hardware available,

In addition to these the element could be partially or fully fulfilled by computer vision software and incorporated into an Augment Reality industry solution.

This list included;

- Bar-code scanning
    - Body number and lot number
    - Carcase weight
    - Sex
- Marbling – using both the MSA and AUS-MEAT measurement systems.
- Rib fat
- pH and temperature
- Meat colour
- Eye muscle area (EMA)
- Fat colour

From this list of potential aspects of grading that could be incorporated into the proof of concept solution.

- These items were;
- Colour grading of meat
- Colour grading of fat
- Reading of barcodes from carcase tickets
- Measurement of square centimetres of latissimus dorsi muscle

10.4 Selected and purchased hardware

The team selected two AR hardware devices based on market research. These devices needed to have a number of characteristics including;

- A common and accessible operating system and application development environment
- A market of skilled developers able to execute solutions on the platform (or similar hardware using the same operating system)
- Appropriate technical capacity including
    - Camera (resolution)
    - Battery life
    - Processor capacity
    - Utility and wearability
- Potentially most importantly, a legitimate product roadmap and market access moving forward.

From the research and the criteria for hardware selection the decision was made to purchase a Hololens from Microsoft and an M300 device from Vuzix.

10.4.1 Hololens

The literature review identified the Microsoft HoloLens as one of the leading products on the market. It is exceedingly capable in terms of processing capacity. The HoloLens is however expensive and challenging to develop on. With a price tag of US$4,000 it was determined that the HoloLens was more powerful and expensive than was needed for this project.

10.4.2 Vuzix

Vuzix is one of the most well-known of the AR HMD start-ups. With some success in the M100, the company moved on to the M300 second generation headset. In terms of value for money this is one of the best headsets on the market. In addition to this good value, the M300 also has the favourable attribute of operating in the android environment. Developing for android is relatively well explored and facilitates quick turnaround between app ideas and finished products. It is for these reasons that the M300 was selected as the development platform for this project.

10.5 Initial Product Assessment

The **Microsoft Hololens** proved to be a high-quality product with some limitations. The Hololens is a new product in market and consists of a full goggle transparent lens, like a ski goggle. The device has a limited battery life and upon first use it is apparent that the field of view is quite restricted.

Since the purchase of the Hololens for this project Microsoft have announced the next generation of the Hololens will be released and shipped in 2019. This means a 4-year period between the development of the hardware and software for the version purchased and the following generation product. This a considerable time window in which technology evolves and progresses and it is a safe assumption that the quality, usability and versatility of the 2019 second generation Hololens will be dramatically improved.

The **Vuzix M300** was a lightweight, flexibly mounted unit with some efficient OEM utilities including camera functions, image gallery, internet browsers and bar code scanning. The battery life was as expected and the light construction of the unit provided the impression that this unit could be practically used in industrial settings.

10.6 Prototype Hardware Selection

Following the initial review of the product and exploration of each item's feature-set it was determined that the Vuzix M300 would be the most appropriate device for use in the development of a prototype. This was due, largely, to its lightweight, unobtrusive form factor meaning incorporating it into the required equipment of a meat grader would be practical. Additionally, the Vuzix has the capacity to be continually charged from an external battery pack (in the operator's pocket) via micro-USB cable.

10.6.1 Features for inclusion

The features selected for development were;

- barcode data reading,
- calibrated colour grading (meat only), and
- dynamic eye muscle area finding and calculation

10.6.2 Prototype development

These features were to be developed using an Android operating system on the Vuzix M300 device.

Readers may be familiar with this operating system as the same system as used on Android mobile smart phone and is the competing phone platform to Apple's iPhone (iOS). Android has approximately 88% of the Global Smart Phone operating system market and in Australia represent 52.3%. Users with Smartphones from Samsung, HTC, LG, Google, Huawei, Sony and Motorola are using Android as their operating system whether they know it or not.

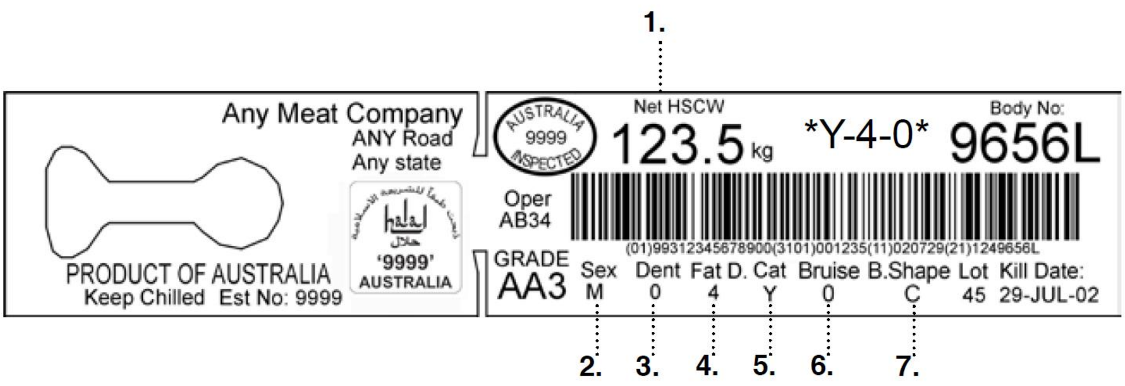
The market penetration of this operating system means skilled development resources are comparatively common and cost effective.

The prototyping project embarked upon an agile process working to develop features using the Vuzix M300 as the base hardware. This was done through working against a backlog of technical issues and features to be addressed.

10.6.3 Outcomes and Qualitative Assessment

This section shall show screenshots and a brief discussion of the steps involved in grading meat with the app as currently developed. The operations were performed on a smart phone however they could be performed on a head mounted device provided sufficient processing power.

The project sought to customise pre-existing barcode scanning functionality with the device to accommodate standard carcase tags. This functionality would read the data from the barcodes and display it to the user. The industry standard carcase tag including barcode and associated data is picture below.



AUS-MEAT slaughter floor language characteristics

1. Hot Standard Carcase Weight (HSCW)
2. Sex (male/female)
3. Dentition
4. P8 fat depth (mm)
5. Category (sex and dentition)
6. Bruise score
7. Butt shape

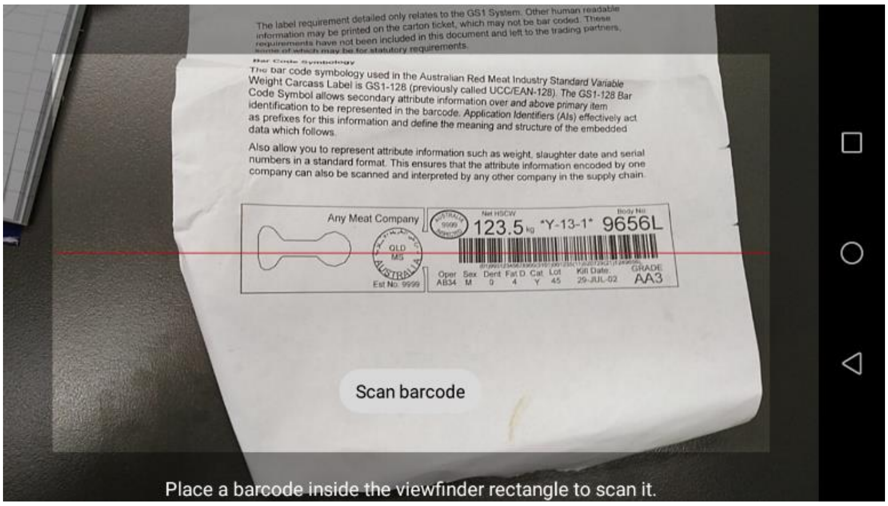
* Aus-Meat Ltd - Handbook of Australian Beef Processing

Aus-Meat MSA Grading Chips

MLA’s YouTube video of MSA Grading Beef.

10.6.4 Scanning the barcode (Step 1)

This step is rather simple. A user simply positions the barcode in the proper spot and it will scan accordingly. On the Vuzix unit a user hears a 'beep' when the barcode has scanned successfully. The device displays the data from the barcode before the user is then able to either, rescan or move forward to the next feature.

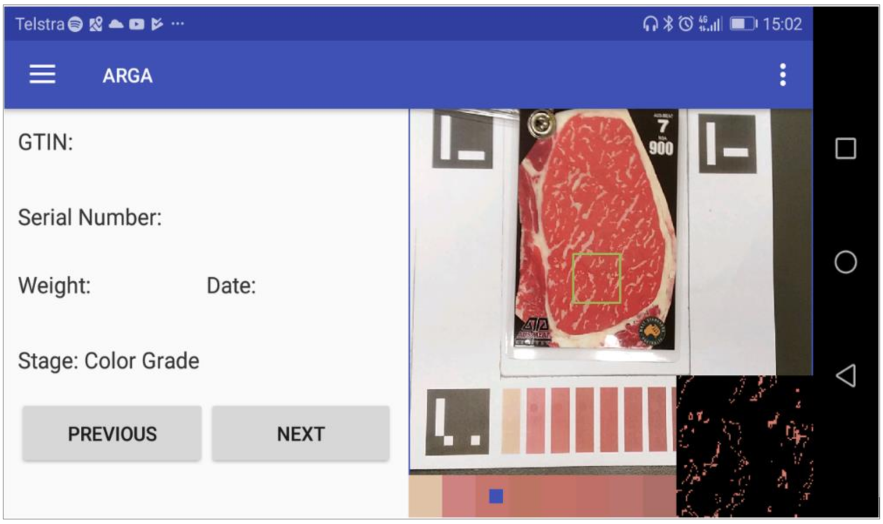


10.6.5 Grading colour (Step 2)

In this step, the colour is graded using a 'jig' as a control which allows the computer to, not only, position the meat properly but compensate for colour lighting conditions.

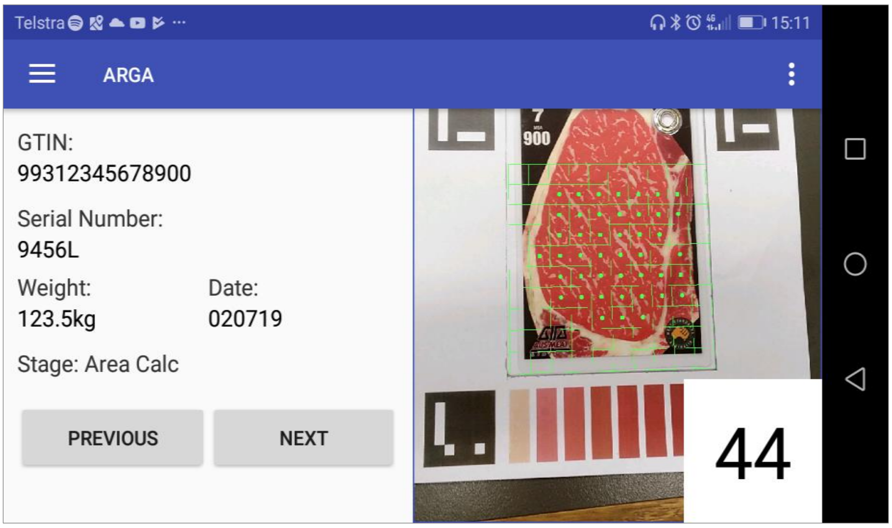
In a similar way, the graders current place a calibrated colour chip next to the meat to allow comparison the Jig incorporates all grading colours and compensate for ambient light conditions by having the grader place these colours next to the meat to be graded. This allows for the meat colour to be assessed in consistent lighting conditions.

In the image below it can be seen that the system has selected the third colour option in this frame according to the area within the green square. This 3rd colour option is denoted by the blue square displayed on the colours across the bottom of the interface.



10.6.6 Counting Area (Step 3)

For this step, the app superimposes a grid upon the meat surface and counts the number of squares completely filled in. One can see that in the example above there were 44 square centimetres filled in.



10.6.7 Learnings

10.6.8 Hardware Limitations

Unfortunately, during the prototype development project it was determined that the Vuzix M300 lacked processing power required to provide a consistent and rich user experience.

This inadequacy manifested in the device 'running hot' when processing images and video in real time. This could be counteracted by modifying the software to revert to capturing a still image for processing (grading) instead of using a video feed when running on lower specification Android hardware.

The user experience also was less than ideal and would likely be problematic in a fast-paced manufacturing/processing environment.

The Vuzix hardware proved to be running 24 to 36 months behind the contemporary Android smart-phone handsets. This provides an indication that the technology roadmap will mature in the time to come. Assuming this to be the case it is fair to anticipate that a robust, cost-effective Vuzix or similar Android base HMDs will be available in the medium term. This would open this type of device to broad scale industrial and processing applications.

10.6.9 Inconsistent Industry Grading Operations

It became apparent through the project that MSA grading was not performed consistently throughout the industry. Factors including,

- Animal carcase size (length and weight)
- volume of animals being processed
- Facility layout
- Process task design

Mean that there is not a consistent implementation of a productise solution that would allow wholesale, industry wide adoption.

This variability limits the short-term opportunity to design and deliver a software solution that would automate the grading process either as an augmentation or a fully automated solution.

NOTE: this in no way is indicative of or is intended as commentary on the consistency of grading outcomes in the industry.

10.6.10 Future Opportunities

It is clear from the process undertaken in this project there are opportunities to enhance the outcomes and consistency of grading across industry. Augmented Reality and, more specifically, Automated Vision has been shown to be capable of standardising a number of the more subjective elements of attribute assessment in MSA grading. Attributes such as colour, area and marbling lend themselves to software assistance measurement.

Future opportunities for application of technology include;

1. **MSA Grading and Artificial Intelligence** (AI and machine learning) – using computer vision systems and artificial intelligence to assess meat through image capture and the process to more accurately determine the eating quality in line with appropriate data points.
2. **Parasite Detection via Artificial Intelligence** (AI and machine learning) – using fixed cameras, computer vision systems and artificial intelligence to assess the viscera table process in the red meat industry. This would leverage technology similar to that used in medical imaging to detect cancer or cell abnormalities to identify and visually detect specific
3. **Real time vision feed of MSA grading** to provide transparency to the producers mitigating conflict and disagreement between parts of the supply chain.
4. **Use of robotics to assess and record MSA grading attributes** like temperature and pH while capturing high resolution images that would allow standardised grading across industry.
5. **Eating Quality and Artificial Intelligence (AI and machine learning)** – using fixed cameras, computer vision systems and artificial intelligence to integrate with future MSA eating quality research to develop greater correlation between attributes like marbling and eating quality.

11 Conclusion

An investigation was conducted into the applicability of augmented reality systems to aid meat grading according to the MSA grading standard. There were two key parts of the investigation:

- A desktop review of relevant literature, and
- development of a proof-of-concept prototype application.

It was determined, with further development, computer vision systems will be able to accurately grade meat and reduce human subjectivity. This conclusion has been made based on the app's success in grading meat colour and area under controlled conditions. Furthermore, the objectivity and repeatable accuracy of an automated system may lead to increased transparency and promote greater trust between producers, processors and retailers.

This finding implies the potential to deploy the system effectively and widely in a relatively short timeframe. Based on the effectiveness of augmented reality systems in other industrial settings and the success of the prototype, we suggest that this system may be an effective aid for meat grading in an industrial setting in the next 3 to 5 years.

Finally, it was found that head-mounted augmented reality (hardware) devices were inadequate in their current state of development, given the processing loads placed upon the system. These could be replaced by hand-held devices with more substantial processing power. This finding was based on the outcome that the application ran smoothly on a high-end handheld device, whilst running poorly on the VUZIX m300 headset.

It is important to note that the meat grading app, in its current state of development, is a proof of concept. The prototype application functions as evidence that an augmented reality and computer vision software project is possible but cannot function effectively in an industrial setting using the trialled hardware. The app at this stage is capable of grading colour and muscle area in a controlled environment. Both of these features require further development such that they may operate in a robust, accurate and precise fashion in a less controlled industrial setting.

In addition to further development of the prototype system it is clear that a technology solution that would aid the human graders and lead to a hybrid between the operator and a computer solution would require some task redesign and a change to the physical environment in the processing facility. This might include additional lighting, hardware, camera, display solutions and external processing units.

Further such a solution could lead to a dramatic increase in transparency across the industry, allowing producers to see their meat at the point of grading on an animal by animal basis.

Next steps

With the current state of development in mind, it is possible to develop a plan for the next stages of the project:

1. The app must be developed to the point that it yields precise results reliably. This includes increasing the system's visual anchoring, optimization and refinement under sub-optimal lighting conditions. This process will need to include real life testing of the system under processing facility conditions.
2. The app may be augmented through the implementation of additional features. These features may include the recognition of marbling and rib fat. These features will increase the appeal of the app to industry, thus increasing uptake.
3. At some point in this process, the system will need to be scientifically evaluated through comparison with current meat grading practices. This will confirm that a computer vision-based approach is indeed superior to the current meat grading process, as well as uncover opportunities to further refine the system.
4. Should a commercial solution be developed in the future it's compliance with legislation and regulatory frameworks will need to be a significant part of the project scope to ensure that the solution is approved for use in industry.

Closing remarks

It has been demonstrated that a computer vision system has potential to significantly improve the meat grading process. It is recommended that this system be extended through the development of further features (collection of objectively assessed attributes) and to then be scientifically verified. Through a process of experimentation and refinement in a real-world setting, this system could become commercially viable.

12 Bibliography

Anna Syberfeldt et al, 2017. Augmented Reality Smart Glasses in the Smart Factory: Product Evaluation Guidelines and Review of Available Products. *IEEE Access.*

Android Central, 2016. *Wikitude.* [Online]
Available at: http://www.androidcentral.com/lg-and-wikitude-teamlaunch-3d-augmented-reality-browser
[Accessed 2017].

AREA, 2016. *proof of concept.* [Online]
Available at: https://image.slidesharecdn.com/findingthenicheawe2016areafiorentini-160729154212/95/christi-florentini-lockheed-martin-aeronautics-smartglasses-and-ar-in-aerospace-11-638.jpg?cb=1470095169
[Accessed 2017].

Augmented Reality Trends, 2014. *Infinity AR to Launch an App which fulfills Sci-fi Vision of AR.* [Online]
Available at: http://www.augmentedrealitytrends.com/augmented-reality/infinity-ar.html
[Accessed 2017].

Augmented Reality Trends, 2016. *augmented-reality-supermarkets-soon-to-be-introduced-in-china.* [Online]
Available at: http://www.augmentedrealitytrends.com/augmentedreality-retail/augmented-reality-supermarkets-soon-to-be-introduced-in-china.html

Boeing, 2015. *Google glass and skylight for assembly.* [Online]
Available at: http://www.boeing.com/features/2015/02/corp-google-glass-02-16-15.page

Boeriu, H., 2011. *Head-Up Display 2.0 – Augmented Reality.* [Online]
Available at: http://www.bmwblog.com/2011/10/07/head-up-display-2-0-augmented-reality/
[Accessed 2017].

Cheng, W. e. a., 2015. Marbling analysis for evaluating meat quality: Methods and techniques. *Comprehensive Reviews in Food Science and Food Safety,* pp. 523-535.

DHL, 2017. *DHL Supply Chain makes smart glasses new standard in logistics.* [Online]
Available at:
http://www.dhl.com/en/press/releases/releases_2017/all/logistics/dhl_supply_chain_makes_smart_glasses_new_standard_in_logistics.html

Ernst & Young, 2017. *independent review of the proposed installation of DEXA in AUS-MEAT registered processing facilities,* ampc.com.au https://www.ampc.com.au/uploads/pdf/independent-review/DEXA-Independent-Review-Issues-Paper-2-FINAL.pdf: AMPc.

FEEL DESAIN, 2013. *Recon Jet | Eyewear Gadget.* [Online]
Available at: http://www.feeldesain.com/recon-jet-the-ultimate-eyewear-gadget.html
[Accessed 2017].

foodlogistics.com, 2015. *Wearables/Augmented Reality Software Boost Order Picking 25%, Pilot Test Shows.* [Online]
Available at: http://www.foodlogistics.com/news/12053240/wearables-augmented-reality-software-boost-order-picking-25-pilot-test-shows
[Accessed 2017].

G Dini & M. Dalle Mura, 2015. Application of augmented reality techniques in through-life engineering services. *Procedia CIRP 38,* pp. 14-23.

Hodgkins, K., 2015. *Google Adding 'Word Lens' Camera Translation and Conversation Mode to Translate App.* [Online]
Available at: https://www.macrumors.com/2015/01/14/google-word-lens-ios-translate-app/
[Accessed 2017].

Hofmann, B. e. a., 2017. Smart-glasses: Exposing and elucidating the ethical issues. *Science and engineering ethics,* pp. 701-721.

Holger Glocknerm et al, 2016. *Augmented reality in logistics,* http://www.dhl.com/content/dam/downloads/g0/about_us/logistics_insights/csi_augmented_reality_report_290414.pdf: dhl.com.

Jang Ju Won et al, 2017. Exploring the Existence of Grader Bias in Beef Grading. *Journal of Agricultural and Applied Economics,* pp. 1-23.

Lars Bager Christensen et al, 2016. *Augmented reality in the slaughterhouse – a Future operation facility? ,* Aarhus: Cogent Research – Danish meat research institute .

Lockheed Martin, 2014. *Accelerating Augmented and Virtual Reality for Richer Visualization in Training.* [Online]
Available at: http://www.lockheedmartin.com.au/us/news/features/2014/141124-mst-visualizing-the-future.html

Mevis Fraunhofen, 2017. *liver explorer.* [Online]
Available at: https://i.ytimg.com/vi/PWRLF8-CPlQ/maxresdefault.jpg

Microsoft, 2016. *A new way to see your world.* [Online]
Available at: https://www.microsoft.com/en-us/hololens/hardware
[Accessed 2017].

Nollet et al, 2015. *Handbook of Food Analysis, -Two Volume Set.* Boston: CRC Press.

O. Inbar, 2015. *Smart Glasses Market Report 2015,* http://www.augmentedreality.org/smart-glasses-report: Augmentedreality.org.

Peddie, J., 2017. *Augmented Reality: Where We Will All Live.* s.l.:Springer.

Philipp Rauschnabel et al, 2016. Augmented reality smart glasses: An investigation of technology acceptance drivers. *International Journal of Technology Marketing,* pp. 123-148.

ppe.pl, 2017. *Hatsue Miku.* [Online]
Available at: http://www.ppe.pl/encyklopedia-5814-hatsune__miku__project_diva_f-m-51320-galeria.html

Purdue University Press, 2015. *remote mentoring.* [Online]
Available at: http://www.purdue.edu/newsroom/releases/2015/Q3/surgeons-may-get-remote-assistance-with-new-telementoring-system.html

R. Hsu, 2016. *Development trends of augmented reality smartglasses,* Los Angeles: Markets and Markets.

Recon Instruments, 2016. *recon jet.* [Online]
Available at: https://www.reconinstruments.com/products/jet

Sacco, A., 2016. *Google Glass takes flight at Boeing.* [Online]
Available at: https://www.cio.com/article/3095132/wearable-technology/google-glass-takes-flight-at-boeing.html
[Accessed 2017].

Tech.de, 2017. *Infinity Augmented Reality App.* [Online]
Available at: http://www.tech.de/news/schrecklicher-augmentedreality-trailer-auf-youtube-1002146.html

Tractica, 2017. *Smart Augmented Reality Glasses.* [Online]
Available at: https://www.tractica.com/research/smart-augmented-reality-glasses/

Volkswagen, 2016. *volkswagenag.* [Online]
Available at: https://www.volkswagenag.com/en/group/research/virtual-technologies.html
[Accessed 2017].

Vuzix, 2016. *M300 Smart Glasses.* [Online]
Available at: https://www.vuzix.com/Products/m300-smart-glasses
[Accessed 2017].

Welt.de, 2016. *IKEA VR app.* [Online]
Available at: http://www.welt.de/wirtschaft/webwelt/article119525750/ Ikea-App-projiziert-Moebel-in-die-eigene-Wohnung.html