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EXECUTIVE SUMMARY

Technology advancement and technology driven disruption is expected to experience exponential growth in the coming decades. Although Australian agriculture has a strong track record of technology integration, the speed of technology innovation makes the scanning and identification of high impact emerging technology a priority for Australian rural industries. This report responds to this priority, and presents the outcomes of a methodology to scan, synthesise and communicate technology trends and innovations that may impact Australian rural industries.

In this first iteration, a broad range of category and discrete technology types have been identified. Led by data mining and synthesis, and assisted by QUT experts and innovative individuals identified by RIRDC, a sub-set of these technologies has been refined. Presented in this report are the most highly rated technologies, positioned at the confluence and fringes of technology megatrends including the Internet of Things, big data, artificial intelligence and advanced sensors.

DIGITAL TWIN

A digital twin is a dynamic software model that represents a physical asset or process. Generated by sensors installed in physical assets and processes, a digital twin allows a user to view and act on real-time data remotely. Simulations can be run using a digital twin to predict asset or process failure. Increasing implementation of smart devices means that digital twins can potentially represent highly complex processes and be transformative in nearly all industries.
LOW POWER WIDE AREA NETWORKS

Low power wide area networks (LPWAN) support communication between sensors and smart devices. We have highlighted a type of LPWAN called LoRaWAN. LoRaWAN technology uses unlicensed radio frequencies and therefore can support the interoperability of smart devices and sensors without reliance on cellular networks. This positions LoRaWAN as a significant technology for supporting Internet of Things systems in remote locations.

HUMAN-MACHINE INTERFACES

Human-machine interfaces enable communication between humans and machines. We have highlighted three types of human machine interfaces. Natural language interfaces utilise sensory and non-sensory inputs such as touch, sight, and radar to facilitate communication between humans and machines. Conversational interfaces enable communication between humans and machines through spoken or written language. Wearable user interfaces allow communication between humans and machines through input collected from the user or environment such as fatigue and location. Innovative human-machine interfaces have the potential to remove complexity from interactions with machines, allowing unskilled workers with poor computer literacy to perform complex tasks.

SOLAR RETRANSMISSION

Solar retransmission is a patented technology for using satellite technology to capture and retransmit sunlight for use on Earth. The sunlight is captured in space and then retransmitted in frequency bands optimal for photosynthesis. This technology is viewed as an expansion on the capabilities of precision agriculture and sits alongside proposals for lunar-based solar energy and mineral collection.

PERSONAL ANALYTICS

Personal analytics technologies monitor personal activity and behaviour. Two implementations of personal analytics technologies are presented. Labour tracking leverages personal analytics technologies, such as wearable sensor devices, to track worker fatigue, stress, and movement. Smart contact lenses are an emerging personal analytics technology. Worn just like normal contact lenses, they are capable of monitoring biometric signals, as well as enhancing vision with augmented reality. Smart contact lenses represent the emergence of nanosensors for personal analytics and labour tracking. The innovation of unobtrusive wearable devices that use nanosensors is potentially transformative in a range of domains.

Successive iterations of the methodology will be employed in future reporting periods to supplement the already identified technologies. Findings will continue to be extrapolated to clearly communicate the transferability and subsequent impact of key emerging technologies for Australian rural industries.
INTRODUCTION

In this project, we are developing a scanning capability to assist the early detection, analysis and forecasting of issues and opportunities that may impact Australian rural industries. This will support rural industries and the range of supporting leaders and organisations to make sound policy and investment decisions that will position Australian rural industries well into the future.

Horizon Scan 1 worked toward the project aims by developing and then implementing a horizon scanning method comprising of interdisciplinary expertise, data mining and visualisation. This method was used to extract and synthesise potential issues and opportunities in the context of five broad focus areas representing the imperatives of Australian rural industries. The outcomes of Horizon Scan 1 were directed toward one of these focus areas, market and consumer preferences, and resulted in the identification of seven key trends.

Horizon Scan 2 incorporates learnings from Horizon Scan 1, and builds on the capabilities developed. Emphasis has been placed on revising the approach to accentuate trend discovery, evaluation and consolidation. Perhaps most significantly, Horizon Scan 2 adopts a refined scope, drawing on the previously identified megatrend of transformative technologies. The Rural Industries Futures Megatrends report outlined that transformative technologies will have significant impact on almost all facets of Australian rural and agriculture industries (Hajkowicz & Eady, 2015). While Australian agriculture has a track record for successful and timely adoption of technology, technology advancement and disruption is likely to experience exponential growth over the coming decades. The
speed at which this disruption occurs makes the timely identification of technologies and the analysis of their potential impact on Australian rural industries particularly important.

In each of the reports produced during this project, we look to supplement the knowledge base already established in the Rural Industries Futures Megatrends report, and subsequent technology factsheets developed by RIRDC. Specifically, we will target emerging technologies that are impacting a range of industries in an international context. This report represents the first iteration of this direction. Given the shift in scope and revision of methodology, the following section presents a brief outline of the approach used for Horizon Scan 2 before presenting the technologies identified during this reporting period.
This project employs a concurrent phase, iterative methodology to:

1. scan and extract data from a variety of sources;
2. synthesise this information to identify potential trends and innovations for further investigation;
3. and, communicate these issues through visualisations.

Implementation of each respective project phase, led by data mining, synthesis, and visualisation, occurs across three interactive streams: Discovery; Evaluation; and, Consolidation. These streams are continuous over the course of the project requiring different inputs from each project phase. The inputs from each phase, and their interactivity is represented in Figure 1. A more detailed description of this approach is included in the Appendix: Approach and Project Streams.

**DISCOVERY**

Implementing data mining and human synthesis, the discovery stream focused on scanning selected data sources, including twitter, patent databases, industry and market reports, and technology news media. The confluence of data mining and synthesis outputs in the discovery stream resulted in a list of emerging technologies for further investigation in the subsequent evaluation and elaboration streams.
EVALUATION
Leveraging QUT experts and innovative farmers identified by RIRDC, the evaluation stream focused on filtering the signals identified in the discovery stream. This was achieved using online surveys in which experts were asked to rate the potential impact that a broad range of emerging technologies will have on Australian rural industries. This process has assisted us to narrow the scope of technologies we have presented in this report, and that will be included on the watchlist for monitoring throughout future reporting periods.

CONSOLIDATION
The consolidation stream focused on further investigating and monitoring technologies on the initial watchlist. This involved a detailed analysis of the technologies’ potential impact for Australian rural industries and developing a rationale for why they should be monitored. Both data mining and synthesis are essential for this stream to receive input from a broad range of data, and gain the requisite detail. Visualisation is used to draw together and present inputs from data mining, synthesis, and evaluations provided by experts.
RESULTS

FIGURE 2. VISUALISATION OF DISCOVERY STREAM OUTPUT
For Horizon Scan 2, we present results for one cycle of each the discovery, evaluation and synthesis streams. Data mining and synthesis outputs from the discovery stream have led to the identification of a broad range of technologies. These identified technologies can be classified as either category technologies or discrete technologies.

Category technologies describe broad classifications of technology, while discrete technologies describe specific implementations of technology, and they are generally related to one or more category technology. Examples of the relationship between category and discrete technologies is shown in Figure 2, which is a visualisation of a segment of the discovery stream outcome. Category technologies, such as Internet of Things, sensors and networks are represented by large nodes. These large category technology nodes share many connections with discrete technologies, which are represented by the smaller nodes.

The category and discrete technologies identified during the discovery phase form the initial pool from which we have selected technologies for evaluation and consolidation. For the Horizon Scan 2 reporting period, a range of discrete and category technologies were selected for further investigation. The remaining pool of technologies will be investigated in successive cycles of the methodology. Moreover, as the project continues, successive cycles of the discovery stream will identify and introduce new technologies for further evaluation. Select technologies that are evaluated to have high potential impact will be monitored to track their development over the course of the project.
A digital twin is a dynamic software model of a physical thing or system (Cearley, Walker, & Burke, 2016). It is connected to and uses data from sensors that are installed in the physical object or system that is being represented (Feuer & Weissman, 2016). In addition to using data from sensors integrated in physical things, digital twins can integrate contextual data, including metadata, condition or state data such as location and temperature, event data, and analytics in the form of algorithms and rules (Cearley et al., 2016). By utilising this data, a digital twin can represent the structure, context and behaviour of a physical thing or system in digital space.

**APPLICATION**

Digital twins provide an interface that allows a user to understand past and present operation of a thing or system (Feuer & Weissman, 2016), and then respond to any changes as necessary (Cearley et al., 2016). As data is collected over time, the application of a digital twin becomes more powerful and allows for greater intelligence within a system. For example, data collected over time can be used to monitor equipment and predict part failure, thus enabling a shift from a preventative maintenance model to condition-based asset management (Cearley et al., 2016). Beyond this, a digital twin can be used to virtually simulate, make predictions about, validate, and optimise an entire production system’s future operations (Feuer & Weissman, 2016; Volkmann, 2016).

Digital twins have typically been used in high-value asset industries, such as manufacturing and transportation (Velosa, Schulte, & Lheureux, 2016). However, the very idea of a digital twin and its capabilities is shifting with the advancement of the Internet of Things space. Offering the ability to digitise physical space, a digital twin provides a bridge between the physical and the digital world (Volkmann, 2016). General Electric is driving digital twin innovation, and has created a digital interface for managing a wind farm. The interface represents digital equivalents of each wind turbine in the wind farm, and provides various information about the operating environment and conditions of the wind turbines. Controls are also present on the interface that allow configurations to be made to optimise performance (Lund et al., 2016).

**FORECAST**

In the coming years, sensors and ‘intelligence’ will increasingly be present in common assets such as buildings, cars, and consumer products, and digital twins will exist for potentially billions of these things. Given this, digital twins have the potential to represent complex networks and systems, and to impact nearly all industries (Cearley et al., 2016).
DIGITAL TWIN

Digital twin technology is at the confluence of advanced sensor technology, big data, and the Internet of Things. With assets in the real world represented by digital twins, it is possible for a user to monitor and control assets remotely. Over time, and with extensive data, digital twins have the potential to be transformative in many industries. They can be used to predict asset failure, or to simulate changes to a process before implementing them in the real world.

EXPERT OPINION

Experts were surveyed and asked to rate the impact of digital twin technology on a 5-point scale. On average, responses show that the capabilities offered by digital twin technology were perceived to have high impact for Australian rural industries. Particularly highly rated were the capabilities to view real-time data on the working condition of equipment, and to predict and monitor the conditions under which equipment might fail.

INNOVATION TRENDS

Digital twin technology is driven by General Electric and Siemens. Digital twin innovation is likely to expand with the growth of the Internet of Things.

Digital twin technology has the potential to be implemented in agricultural processes to monitor equipment status, such as part wear and power input/output, and to test and facilitate optimal system performance.
LOW POWER WIDE AREA NETWORKS

Low power wireless area networks (LPWAN) support low bandwidth communication between sensors and smart devices (Velosa et al., 2016). Various LPWAN technologies are available and in development, including LoRa, Sigfox, Weightless, Ingenu RPMA, EC-GSM and NB-IoT. Due to the low bandwidth and subsequent low data transfer of LPWANs, connected devices can be deployed across large areas and powered for several years on a single battery (Adelantado et al., 2017).

APPLICATION

Applications enabled by LPWANs depend on device data transfer needs and the size of the area in which they operate. Commercial LPWANs support the largest areas. The subscription service, Sigfox, has stations around the world that support up to a 50km range. NB-IoT and EC-GSM leverage existing licensed mobile network bands and will offer coverage similar to cellular networks (Wixted et al., 2017). Use cases for such networks include geotracking of vehicles and communication with geographically dispersed assets, such as oil pumps and pipelines (Velosa et al., 2016). Other technologies, such as LoRa, use unlicensed ISM bands, and can therefore be used to set up private networks that are independent of a network operator (Velosa et al., 2016). This is an important capability for applications such as agriculture which might be situated in areas not serviced by reliable wireless connectivity.

LoRaWANs are created by gateways which relay messages between devices and a central network server. Gateways have a range up to 15km in unobstructed environments and several gateways can be deployed to cover a greater distance. LoRa technology facilitates bi-directional communication and can support thousands of devices with maximum data transfer of 27 kbps. It is best suited to applications that receive and send a reduced number of regular or irregular messages. This makes it an attractive option for applications such as agriculture, leak detection, and environmental control. LoRaWANs are not suitable for industrial automation or critical infrastructure that require real-time data transfer and monitoring (Adelantado et al., 2017).

FORECAST

LoRa has a strong community in urban Europe, however, is less established in other parts of the world. As an immature market, the LPWAN landscape is likely to change with the roll-out of commercial networks and an increasing uptake of Internet of Things for business and consumer applications. While commercial technologies are likely to dominate the market, smaller players such as LoRa are likely to be persistent to support specific applications.
**LoRaWAN**

LoRaWAN, and other LPWAN technology is a response to the growing Internet of Things. LoRaWAN technology is capable of providing low power, wide area networks for thousands of connected smart things. Of particular utility is that private LoRaWANs can be setup independent of network carriers. This enables it to be used for applications in remote contexts, such as agriculture, that do not have reliable wireless internet coverage.

**EXPERT OPINION**

Experts were surveyed and asked to rate the impact of LoRaWAN technology on a 5-point scale. On average, responses show that there is a strong interest in smart things, and the Internet of Things in Australian rural industries. Low power and inexpensive networks that are not reliant on complex local infrastructure were perceived to have high impact by participants.

Seamless interoperability among smart things without the need for complex local infrastructure

Inexpensive, low power networking of connected smart things without the need for broadband or mobile internet

**INNOVATION TRENDS**

Map showing the key centres for LoRaWAN networks and number of gateways established in each location.

Proposed uses of LoRaWAN technology in agriculture have been cattle tracking and soil quality monitoring. The application of LoRaWAN technology could extend to a variety of applications that use low power sensors and smart things.
HUMAN-MACHINE INTERFACES

This section provides a brief overview and forecast of human-machine interfaces. Three emerging human-machine interfaces are then discussed in further detail: Natural Language Interfaces, Conversational Systems, and Wearable User Interfaces.

A human-machine interface is a device or software that allows humans to operate machines and technology. They are a broad class of technology, covering common devices such as keyboard and mouse, and touch screen interfaces. Due to the ubiquitous nature of machines and technology in our lives, most people will have some experience with human-machine interfaces. As technology is becoming more sophisticated with the growth of the Internet of Things and artificial intelligence, our interactions are also changing. Human-machine interfaces are expanding to facilitate new methods of interaction, such as voice and gesture.
FORECAST

As the range of applications, and devices that people interact with grow, novel methods of human-machine interaction will increase in importance. It is believed that the next five years will see significant innovation in human-machine interfaces (Cearley et al., 2016). Billions of devices will implement zero-touch interfaces (Zimmermann et al., 2016). Instead they will rely on other human senses such as sight and smell, as well as sensory channels that extend beyond human senses, such as radar (Cearley et al., 2016).

Innovation of human-machine interfaces will be present across various industries, and will be potentially transformative in industries relying on complex interactions between humans and machines. With advanced human-machine interfaces, requirements for computer literacy will diminish and smarter machines will make it easier for humans to handle unfamiliar or complex situations (Brant & Austin, 2016). For instance, devices and machines that have no visual interface, but that can carry out complex tasks based on simple commands given by human workers.

As the number of connected devices grow, human-machine interfaces will also facilitate ambient experiences. This is where machines and computerised devices can recognise contextual information and then adapt experiences and actions as users passively move through different locations or perform different tasks (Goertz & Reinhart, 2016).
NATURAL LANGUAGE INTERFACES

Natural language interfaces facilitate interactions between humans and machines using a range of input and output types, including sight, sound, touch, smell and radar. These various interaction modalities are used to build a ‘conversation’ between the human and machine to create an immersive, continuous and contextual experience (Cearley et al., 2016). As technology advances in the areas of mobile computing, wearables and the Internet of Things, zero-touch interactions between humans and machines will become increasingly prevalent (Zimmermann et al., 2016).

APPLICATION

The most differentiated applications facilitated by natural language interfaces will make use of voice, ambient technology, biometrics, facial recognition, ‘sensored’ environments, movements and gestures. Combining these technologies will allow for natural and personalised interactions (Zimmermann et al., 2016). Interactions will be able to be performed in multi-step sequences, and across multiple devices, systems and machines. This will allow machines to understand user needs based on the tasks they are performing as they move from place to place, and from data collected from previous tasks (Cearley et al., 2016). The user will also be able to interact with the systems in meaningful ways to instruct new actions (Brant & Austin, 2016).

These capabilities are demonstrated in the patent, mobile systems and methods of supporting natural language human-machine interactions (Weider et al., 2016). The functionality specified is for speech-based and non-speech-based interfaces for telematics applications. Context, prior information, domain knowledge and user data are used to create an environment for users to submit requests in a variety of domain applications. The interface then responds to these requests in natural language. Extensive profile information is stored for each user, thereby improving the capability to reliably and accurately determine the context of the request and present expected results.
CONVERSATIONAL INTERFACES

A conversational interface is a type of natural language interface which enables interactions between a machine and a human to occur through spoken or written language (Cearley et al., 2016). Well-established natural language interfaces include digital assistants present on mobile devices and speaker products such as Google's Assistant, Amazon's Alexa, Apple's Siri and Microsoft's Cortana.

APPLICATION

Mainstream applications of conversational interfaces are still relatively primitive, allowing people to ask basic questions or give basic commands (Brant & Austin, 2016) such as make a phone call, set an alarm or schedule an appointment. Examples of this are virtual assistants on smart phones and smart watches, and more recently on dedicated hardware for the home, such as Amazon's Echo speaker, and Google's Home speaker. These capabilities are also reflected in recent patents. For example, a patent for an intelligent automated assistant is used to facilitate conversational natural language interactions between a human and a computer on various platforms, including web and mobile. These interactions are used to request various information or to request actions be performed (Gruber et al., 2017). Similarly, technologies for conversational interfaces for system control provides conversational control of a home automation system. Based on spoken input, the computing device provides text response to the user and performs the command given (Uppala et al., 2016). Interactions with conversational interfaces can also be used to carry out very complex tasks. For example, collecting oral testimony from crime witnesses which then results in the complex result of the creation of a suspect's image (Cearley et al., 2016).

In the last year, consumer applications of conversational interfaces have diversified and spread to a variety of market segments (Crist, 2017). These include, but are not limited to, televisions, fridges, robots, headphones, alarm clocks, automobiles (VW, Ford), security systems, and lighting (Crist, 2017; Kastrenakes, 2017). A large part of this diversification can be credited to Amazon's decision to open its technology platform to other vendors (Pierce, 2017). As the capabilities of conversational interfaces expand, they will offer increasingly seamless and continuous interactions across different products and devices in industry sectors as diverse as finance, retail, healthcare and automotive (Bisht, 2016).
WEARABLE USER INTERFACES

Wearable user interfaces (WUIs) facilitate bidirectional communication between a user and a computerised device. Communication can be passive or active. Passive communication is where a wearable device picks up information from a user, technology or context without direct input. This information can then be transmitted to other devices or to the user directly. Active communication occurs where a user directly interacts with the wearable device to issue commands or communicate with other technologies and systems (Ghubril & Prentice, 2014).

APPLICATION

Current commercial applications of WUIs, such as smart watches and fitness trackers are viewed to be marginally useful. The proliferation of Internet of Things devices will lead to increasingly useful applications of WUIs, such as the ability to simultaneously control a number of connected smart home devices (Ghubril & Prentice, 2014; Goertz & Reinhart, 2016).

The most significant application of WUIs is in complex environments where users receive and must be aware of simultaneous inputs from competing sources. In this use case, WUIs are applied to reduce physical and cognitive workload. They can parse information from peripheral devices and present it to the user, or they might be able to facilitate simplified or automatic communication with peripheral devices. In military operations, novel WUIs have been proposed to provide sensory enhancements for the identification of critical features in an environment, and to aid navigation and communication (Laarni et al., 2009). In the context of surgery, a patent for a wearable user interface for use with ocular surgical console proposes a wearable device in communication with a surgical console that simultaneously displays the surgical viewing area and peripheral data relating to the surgery. This allows the surgeon to check settings and other information without needing to pause the surgery to move their gaze (Yacono, 2014).

Other innovations are for directly controlling external computerised devices. A patent for a method and apparatus for a gesture controlled interface for wearable devices specifies a flexible device worn on the body comprising of sensors for detecting bio-electrical signals and gestures. Triangulating inputs from each range of sensors allows discriminations to be made between different gestures, subsequently allowing for the control of a computerised device (Wagner, Langer, & Dahan, 2016).
HUMAN-MACHINE INTERFACES

NATURAL LANGUAGE INTERFACES • CONVERSATIONAL INTERFACES • WEARABLE USER INTERFACES

Human-machine interfaces provide the means for humans and machines to communicate. With increasingly sophisticated technology and the growth of artificial intelligence, novel interfaces that accept input from various sensory channels will allow for unprecedented levels of communication between humans and machines.

EXPERT OPINION

Experts were surveyed and asked to rate the impact of human-machine interface technologies on a 5-point scale. On average, responses show that human-machine interfaces have potential impact for addressing skill shortages in rural workers, allowing unskilled workers to operate complex equipment. Interfaces that allow verbal communication between humans and machines were perceived to have higher impact than communication via electronic wearable devices.

INNOVATION TRENDS

Analysis of number of patents published by country identifies the USA as the main innovator of human-machine interfaces.

Analysis of number of patents published per year shows that innovation of natural language interfaces and conversational interfaces has occurred for several years, with peaks in 2014 and 2016. Innovation of wearable user interfaces has been less extensive, but more recent between 2014-2017.
Aerospace technology plays an important role in precision agriculture. High resolution, remote sensing imagery can be obtained at near real-time (e.g., planet.com) to provide invaluable information about crop yield variability. This can be used to generate yield maps in-season and to assist after-season management (Yang, Everitt, Du, Luo, & Chanussot, 2013).

Beyond commercial services, there are even greater aspirations for how to leverage the resources of space. Companies such as Planetary Resources (plantaryresources.com) aim to unlock the solar system's economy by mining asteroids for important elements. The feasibility of such operations is highlighted by NASA's Asteroid Redirect Mission in 2020. This mission aims to retrieve a multi-ton boulder from a near-Earth asteroid, and redirect it to a stable orbit closer to Earth where samples will be taken (NASA, 2015). Further, an area of sustained interest for aerospace technology is lunar-based solar power. Various schemes have been proposed to capture solar energy in space and beam it down to Earth for use (Bullis, 2009; Dorminy, 2017a, 2017b).

**APPLICATION**

With potential impact and application for agriculture, a patent has recently been published specifying a system for capturing and retransmitting solar energy for reinforcing photosynthesis (Laine & Parrot, 2015). The technology comprises of a satellite with two optical assemblies; the first for collecting sunlight, and the second for retransmitting sunlight. The optical assembly for retransmission has a controllable orientation, meaning that it could be positioned to retransmit sunlight to specific and modifiable locations on Earth. Further, by transferring light through the optical assemblies only light in specified frequency bands that are optimal for photosynthesis are retransmitted.

**PREDICTION**

The aerospace industry is growing rapidly. In north America, the aerospace and defence industry grew by 4.4% in 2016 to $365 billion. It is expected to reach $421 billion by the end of 2021. Even faster growth is expected in the Asia-Pacific with the sector growing 10.9% in 2016 to reach $272 billion. While much of this value is generated through government contracts, the number of new private companies being created in the commercial aerospace industry is increasing (Singh, 2014). Although the concepts of lunar mining and solar retransmission are ideas ahead of their time, continued commercial interest and innovation make them difficult to ignore.
SOLAR RETRANSMISSION

The use of satellites and the imagery they capture is an important asset for precision agriculture. Although ahead of its time, the notion of using satellites to capture solar energy and retransmit it to Earth represents an iteration of a persistent interest in utilising space-based resources for applications on Earth. This proposed innovation sits in the context of active work in the areas of lunar-based mining and solar energy.

EXPERT OPINION

Experts were surveyed and asked to rate the impact of satellite imagery and solar retransmission technology on a 5-point scale. On average, responses demonstrate the value of satellite imagery for agricultural applications. Although perceived to have lesser impact, the capabilities of proposed solar retransmission satellites were of interest to survey participants. The ability to control and optimise sunlight exposure and growing conditions for crops was perceived to have particular impact.

INNOVATION TRENDS

The below diagram provides a visual representation of the proposed solar retransmission system in the patent, a system for capturing and retransmitting solar energy for reinforcing photosynthesis (Laine & Parrot, 2015).
PERSONAL ANALYTICS

This section presents an overview and forecast for personal analytics technology. Two emerging personal tracking technologies are then discussed: Labour Tracking, and Smart Contact Lenses.

The term personal analytics describes technologies and practices that are used to monitor personal activities and behaviours. Personal analytics is also referred to as personal informatics and quantified self (Lupton, 2016). One of the most obvious types of personal analytics occurs via fitness trackers and smart watch devices, such as Fitbit and Apple Watch. These products are usually positioned as technologies that facilitate self-improvement and a healthier lifestyle. They propose to do this by monitoring and providing feedback on variables such as calories burned, distance and speed travelled, sedentary vs active time, and sleep quality. Users are then expected to interpret and act on this data in meaningful ways (Delgado, 2015; Lupton, 2016).

Personal analytics technology has received great interest for tracking workers in hazardous environments such as factories and job sites. In such contexts, the application of personal analytics technology is aimed at reducing accidents, improving worker accountability, identifying worker fraud, and optimising work efficiency (Scism, 2016). Personal analytics technologies are also viewed as important for tracking individuals with special needs such as the elderly and hospital patients (Janwadkar, Bhavar, & Kolte, 2016).

FORECAST

Big data is becoming an increasingly sought after and valuable resource for businesses. Customer insights data can provide highly profitable forms of knowledge to inform changes to business strategy and operations (Lupton, 2016). With personal analytics technology, it is possible to generate similar insights about the behaviours of human resources to create safer work environments and optimised operations (Ghubril & Prentice, 2014; Zimmermann et al., 2016). Such capabilities are believed to have application in a range of industries including healthcare, agriculture, and security and policing (Lupton, 2016). Personal analytics technologies will offer particular benefit for industries where workers perform jobs alone, in hazardous conditions, and where there is the potential to harm others. In 2020, it is expected that 50% of employees in isolated and hazardous working conditions, such as heavy machinery operation, will be monitored by wearable personal analytics technology (Zimmermann et al., 2016).
LABOUR TRACKING

Labour tracking is the application of personal analytics technologies and practices to the tracking and monitoring of human resources in workplace contexts. Methods for labour tracking are diverse. They range from camera surveillance systems that monitor task efficiency, to sensor enabled wearable devices that can track biometric inputs including fatigue and heart rate (O’Connor, 2016). With the development of the Industrial Internet of Things, innovation of labour tracking is being driven by the convergence of big data analytics and low-cost sensing (Intel, 2015). Workers connected by intelligent sensor devices and big data analytics are not only safer, but measures can be implemented to increase worker and operations efficiency (O’Connor, 2016; Scism, 2016).

APPLICATION

Labour tracking has significant applications in industries that are hazardous (Scism, 2016), require workers to perform tasks in remote or isolated locations (Zimmermann et al., 2016), and that require high standards of accountability (Scism, 2016). In such contexts, labour tracking technologies include simple wearable devices, such as fitness trackers that provide feedback to an individual and an organisation. On a more complex level, labour tracking solutions can simultaneously measure biometrics as well as environmental data. For instance, a “combination of skin temperature, raised heart rate, and no movement patterns for several minutes could mean a person is suffering from heat stress” (O’Connor, 2016).

Current labour tracking systems include Vandrico’s (vandrico.com) smart helmet wearable device used to monitor miners. This device clips on to standard helmets and provides 3D real-time location tracking, and hands-free communication to workers via visual cues. A recent patent (Daniel, 2017), provides a system for managing teams and assets based on geofencing principles. Members of a team are equipped with wireless tracking devices that establish a virtual perimeter based on the location of individuals. It is possible to specify maximum distance between members and send/receive alerts when this is exceeded. Such technology has potential in critical environments, or in jobs where specific relationships between workers and equipment is required. For example, to maintain efficiency, or to reduce asset shrinkage.
SMART CONTACT LENSES

Smart contact lenses are technology embedded contact lenses that are capable of sensing various biometric signals, as well as providing enhanced functionality such as augmented reality. Worn in the same manner as regular contact lenses, smart contact lenses can offer unobtrusive monitoring of individuals, as well as provide significant visual enhancements. Smart contact lenses represents a broader trend of nanosensor wearables, that incorporate sensors that range from millimetre to nanometre scale (Garcia-Martinez, 2016). At this scale, sensors can fit in discrete and unobtrusive personal analytics devices.

APPLICATION

Notable applications of smart contact lenses come from two giants of the tech industry; Google and Samsung. Google, in partnership with pharmaceutical company Novartis, announced that it is working on a smart contact lens that measures blood-glucose levels for people with diabetes (King, 2014). Samsung, on the other hand, has recently filed a patent for a smart contact lens featuring a screen for use in augmented reality applications (Samsung Electronics Co Ltd, 2016). It is argued that this will provides a more natural augmented reality experience than larger head mounted displays (Chowdhry, 2016). Samsung is not alone in developing display integrated smart contact lenses. A patent specifying a smart contact lens with embedded display and image focusing system was recently published (Shtukater & Raayonnova, 2017). This technology claims to monitor a person’s head movement and gaze direction, which could be particularly useful for evaluating worker vigilance and fatigue.

The capabilities of smart contact lenses emphasise the potential application of nano-scale personal tracking devices. While smart contact lenses won’t be appropriate for all people and industries, the development of discrete nanosensor tracking devices in other form factors will have significant impact. Examples might be discrete and disposable patches worn on the skin to detect fluctuations in temperature or environmental contaminants. For this purpose, some of the most advanced nanosensors to date have been ‘manufactured’ using synthetic biology and the modification of single-celled organisms (Garcia-Martinez, 2016). Known as biosensors, these nano-scale biological sensors are customisable to detect various types of chemical and biometric targets, such as skin conductivity, pH, and temperature (Edwards et al, 2013).
PERSONAL ANALYTICS

LABOUR TRACKING • SMART CONTACT LENSES

The use of personal analytics technologies has gained increasing interest in work contexts to improve worker safety and increase operations efficiency. Advancements in wearable and nonosensor technology is driving innovation in unobtrusive personal analytics technology.

EXPERT OPINION

Experts were surveyed and asked to rate the impact of personal analytics technologies on a 5-point scale. On average, personal analytics technologies are perceived to have greatest impact for the purpose of monitoring workers. The ability to track worker location to increase productivity and safety, and to monitor stress and fatigue were highly rated. Comparatively, communication of this data to health professionals was perceived to have less impact.

INNOVATION TRENDS

Analysis of patents published by country identifies the USA as the main innovator of labour tracking and smart contact lens technology. However, innovation has occurred in Europe and Asia.

Analysis of number of patents published per year shows that innovation of labour tracking technology has steadily increased over the last several years. Innovation of smart contact lenses began in 2014 and has increased in 2016 and 2017.
CONCLUSION

This report represents the first iteration in a revised horizon scanning scope. This revised scope was initiated by the learnings gained from Horizon Scan 1, and targets the early detection of emerging and transformative technologies that have potential impact for Australian rural industries. Identification of technologies having impact internationally and beyond the rural industries was highlighted as having particular value. To meet the aims of the revised scope, our approach incorporates data mining, synthesis, industry experts and visualisation across three interactive streams: discovery, evaluation, and consolidation. The progression and interactivity of these streams has been designed to detect emerging technologies across a broad range of domains, to understand the value and potential of these technologies, and then extrapolate findings to present their significance for Australian rural industries. The success of this approach is evident in the outcomes that have been produced and discussed in this report.

In this first iteration, category and discrete technology types have been identified in domains as diverse as information and communication technology, data analytics, genomics, artificial intelligence, and renewable energy. Through our evaluation stream, a sub-set of these technologies has been refined, leading to the 8 analysed and discussed in this report. These 8 represent various types of innovation and potential impact for Australian rural industries. For each of the technologies discussed in this report, we have attempted to clearly communicate the essential elements of the technology, current application areas, innovation trends, and an initial forecast for the continued development and significance of the technologies. This process has principally been
achieved through data mining of patent databases, and the synthesis of this and other data sources. Further, the capabilities of each technology have been recontextualised for Australian rural industries through engagement with industry experts, and in some cases through early stage scenarios.

The extent of technologies identified, and their refinement and synthesis has provided a demonstration of the utility of the discovery, evaluation and consolidation project streams. As this report represents one iteration of each of these streams, our aim for future reports is to build on the capabilities of each stream. Of particular importance in this respect is the further extrapolation of our findings to clearly communicate the transferability and subsequent impact of technologies for the Australian rural industries.

In the following reporting periods, we aim to implement multiple cycles of discovery, evaluation and consolidation. In each successive iteration of this process, we will:

- **Broaden our scanning scope to ensure coverage of technologies from a broad range of domains.**
- **Expand upon the already identified technologies, and evaluate their impact for Australian rural industries.**
- **Broaden data mining sources to strengthen the analysis of technology trends.**
- **Continue to monitor and develop knowledge of the technologies that have already been identified to have potential impact for Australian rural industries.**
- **Continue engagement with QUT and RIRDC experts to gain insights into the specific value and use cases of the identified technologies, and clearly communicate these evaluations in infographic and scenario visualisations.**
REFERENCES


Twitter. (2017). twitter.com


This project employs a concurrent phase, iterative methodology to:

1. scan and extract data from a variety of sources;
2. synthesise this information to identify potential trends and innovations for further investigation;
3. and, communicate these issues through visualisations.

Implementation of each respective project phase, led by data mining, synthesis, and visualisation, occurs across three interactive streams: Discovery; Evaluation; and, Consolidation. These streams are continuous over the course of the project requiring different inputs from each project phase. These inputs from each phase, and their interactivity is represented in Figure 3.
DISCOVERY
Discovery focused on scanning selected sources to extract relevant data and detect signals of emerging and transformative technologies. Data sources were strategically selected to ensure input from a diversity of domains within an international context. In this implementation of the discovery stream, sources included select twitter users, patent databases, industry and market reports, and technology news media. Scanning of these sources has employed data mining and synthesis concurrently:

- Data mining focused on scanning the twitter feeds of thought leaders and technology experts in a range of technology and industry domains. These were selected based on the recommendations of QUT experts working in relevant technology domains.
- Synthesis focused on scanning a broad range of technology news publishers, industry and market reports, and patent databases.

The confluence of data mining and synthesis outputs in the discovery stream resulted in a list of technologies for further investigation in the subsequent evaluation and elaboration streams.

EVALUATION
Evaluation focused on filtering the signals identified in the discovery stream. Its implementation leveraged expertise from QUT, and RIRDC through the provided list of innovative farmers, to assess the potential impact of a broad range of emerging technologies. This process used Delphi style surveys which are deployed in successive rounds.

The first round of surveys focused on evaluating a large volume of technologies identified in the discovery stream. This was achieved through presenting a series of simple statements that describe the functionality of a technology, and asking for a rating based on its perceived impact. From these ratings, a short-list of technologies was compiled for further investigation and ongoing monitoring. Successive survey rounds will present a lower volume of questions but will require increasingly qualitative responses. It is through this process that we will narrow the scope of technologies that will be included on the watchlist and that will be monitored throughout future reporting periods. As the evaluation stream progresses, we will develop an objective list of criteria to establish the possible scale of impact of each transformative technology. These criteria will then be re-introduced in successive discovery stages of the project to assist with filtering the large volume of data.
CONSOLIDATION

Consolidation focused on monitoring technologies on the initial watchlist, and providing a detailed analysis of their potential impact for Australian Rural Industries. This involved a detailed analysis of the technologies’ potential impact for Australian rural industries and developing a rationale for why they should be monitored. This elaboration stream utilises both data mining and synthesis to receive input from a broad range of data, and gain the requisite detail.

Data mining focuses on eliciting deeper analysis of the technologies identified and short-listed during the discovery and evaluation streams. Directed by specific technologies and related keywords, data mining targets social media feeds and patent databases. The outcome of this stage provides assessment of candidate technologies based on metrics such as trends over time, associated keywords and industries to identify the contexts in which the technology is active and where it is receiving innovation, and location. The data gained from this stage of data mining, and from the evaluation stream, feeds into and directs synthesis. With this direction, synthesis can focus on specific applications and implementations of the technology to better understand and communicate its potential impact for Australian rural industries. Visualisation is then used to bring together the inputs of synthesis and data mining, as well as inputs from the evaluation stream. This includes the development of infographics to communicate the watchlist issues and themes.