ANNEXES A-7

IMMERSIVE MEDIA AND ADVANCED INTERFACES: IDENTIFYING OPPORTUNITIES THROUGH PATENT ANALYTICS

National Research Foundation
Prime Minister's Office
Singapore

IPOS
Intellectual Property
Office of Singapore

This patent analytics report is commissioned by the National Research Foundation (NRF) Singapore and produced by the Technology Foresighting Unit of the Intellectual Property Office of Singapore (IPOS), with the support of the Info-communications Media Development Authority (IMDA).

Intellectual Property Notice

Disclaimer

The information, analysis, and opinions (the "Content") contained herein are based on information reasonably available and accessible as of the date of the analysis. While IPOS endeavours to ensure that the Content is correct as of the date of the analysis, IPOS does not warrant the accuracy or completeness of the Content. The Content in this report does not constitute any legal, business or financial advice and nothing contained herein shall be construed as such. Neither IPOS nor any of its affiliates shall be liable for any claims, expenses or liabilities which may arise from this report.

CONTENTS

NATIONAL RESEARCH FOUNDATION
PRIME MINISTER'S OFFICE
SINGAPORE

IPOS
INTELLECTUAL PROPERTY
OFFICE OF SINGAPORE

1 KEY FINDINGS

1.1 Gear up! Immersive media technologies to be next generation of media platform

Innovations in immersive media have garnered increasing interest in the past decade with a record-high of more than 8000 inventions in 2017 while registering a growth of 27.0% p.a. in the period of 2013-2017. This intense innovation output has been fuelled by advancements in key enabling technologies, such as media capture devices, sensors, display solutions as well as data transmission and processing methods, which contribute to delivering media with highly realistic contents and an immersive touch.

The strong growth and high interest in innovation scene, as supported by patent data, correlate well with the optimistic market prospects estimated to be worth at least half a trillion by 2025 and is a testament to immersive media's potential as the next generation of media platform. Furthermore, technology giants such as Seiko Epson, Microsoft, Samsung, Sony and LG are spearheading innovation in all immersive media domains, including virtual reality (VR), augmented reality (AR), media creation/display, media capture, and human-computer interaction (HCI), signifying their vested interest and intent to mould the direction of immersive media technologies. As such, stakeholders should maintain a vigilant watch on technological advances and determine the level of immersive media adoption into their businesses to achieve maximum operational efficiency and/or users/customers satisfaction, so as to maintain business relevancy and advantage.

1.2 Look out! AR head mount displays a highly competitive area

AR wearables have attracted a significant amount of interest from AR stakeholders, with notable emphasis in head-mount displays (HMD) which comprised more than 85% of inventions of the wearable devices domain. Being the current major gateway to an AR experience, technology giants, such as Epson and Microsoft, are eyeing the AR HMD space and dominating the innovation arena with their large patent portfolios and the mass market with their AR HMD products.

Despite the availability of numerous products, innovation activity in improving AR wearables is still robustly ongoing at a rapid growth of 36.2% p.a. in the recent 5 years. Further investigation revealed a high proportion of innovative efforts relate to AR HMD technical components. These immense innovation efforts have been aimed at overcoming current AR HMD limitations in portability, field of view, rendering speed and manufacturing costs. In light of the on-going vigorous innovation efforts by lead players and their aggressive ring-fencing strategies, as evident from their large patent portfolio sizes, it would be challenging for players with limited expertise to enter the congested AR HMD market.

1.3 Team up! Forging partnerships with AR HMD leaders for industrial deployment

Innovation in HMD deployment is still at its initial stage, with a relatively low overall number of inventions. However, interest is rapidly growing in the recent five years, as shown by the fast annual growth of 37.3% in the period of 2013-2017. The potential deployment across multiple industries, particularly in information & communication media, logistics, retail, finance, healthcare and education, will refresh the digital media scene, providing users with a new realism experience, combining real-time information feed with natural human-environment interaction, heightening users' immersion experience. Given the immense potential as the next digital delivery platform, an explosive growth in innovations relating to AR deployment, through the use of HMD, can be expected in the next three to five years.

Given adoption of AR is still in its nascency, and that leading AR-HMD developers are actively seeking collaborations to bring AR technology into various industries, AR industrial deployment represents an area of opportunity for service providers and info-communication media solution providers to upgrade their existing content delivery medium and gain a competitive edge over their counterparts. Specifically, though these stakeholders may not possess adequate expertise in AR HMD technologies, they can forge strategic partnerships with the leading players in AR HMD by bringing in their domain expertise as a strong value proposition and establish themselves to be the forerunners in their respective industries through AR deployment.

1.4 Move in! Wide-open space in occlusion with R&D potential

Representing the biggest and most elusive piece of AR technology to enable a truly immersive experience, occlusion enables the ability to hide virtual image behind a real-life object to preserve the line of sight rule, allowing a more realistic AR scene. As such, it is not surprising that occlusion-related innovations have registered fast growth in the last five years and attracted high commercial interest from AR players.

Compared to inventions in the other high commercial interest areas, occlusion-related inventions are more closely related to fundamental scientific research. This indicates that this area is still largely at an early development stage and hence not immediately available for large scale commercial exploitation and deployment. With top applicants in this area owning small patent portfolios, the lack of technology ring-fencing by industry players gives new players greater opportunity to establish a first-mover advantage in occlusion and thus generates impetus for immediate entry into this sub-domain.

2 INTRODUCTION

The past century has witnessed various revolutions in the use of computers. This was initiated during the mainframe era in the 1960s where one computer was shared among multiple users for a specific use and has now reached the current mobility era where one user would interact with several computers, such as personal laptop and mobile devices, simultaneously. The interaction between human and machines has also evolved from command line interfaces, involving typing and clicking, to current touch-and-swipe graphical interfaces. The constant push towards a human-centric design and a natural-user "intuitive interface" would bring us to the cusp of a next major revolution towards a digital ubiquity utilising immersive media technologies.

Immersive media aims to bring sensory excitement to the user. Through digital immersion, users can experience moments that are not yet physically possible, such as an ordinary man experiencing space travel or witnessing a historical event. Immersive media can be seamlessly integrated into numerous aspects of our lives, ranging from personal entertainment to industrial applications by engaging users beyond the static 2D displays. These technologies include 360-degree media, virtual reality and augmented reality, each providing different immersion levels.

In this report, a detailed analysis of patent inventions relating to immersive media and related human-machine interactions has been provided based on the worldwide patent applications published in the period from 2008-2017. The analysis has covered various aspects of the immersive media technologies, namely human-computer interaction (HCI) methods deployed in immersive media technologies, media capture and media creation/display solutions, and innovations to specifically realise virtual reality (VR) and augmented reality (AR) (Exhibit 1) [a]. In particular, this report further examines the AR domain and its various related technologies. As patent data represents an important source of information on scientific and technological advancements in the present knowledge-based economy, analysis of immersive media related technologies allows us to have a better idea of the technology trends, the respective domains and areas of innovation opportunities.

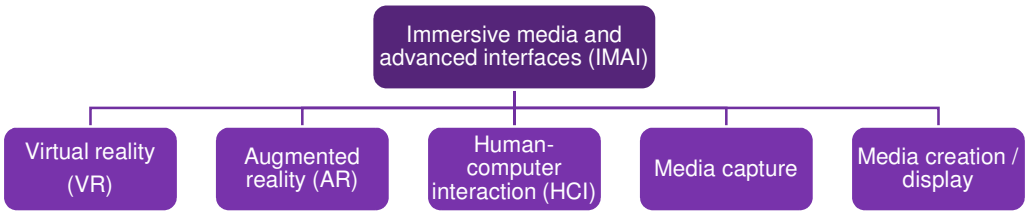


Exhibit 1: Scope of the patent analytics study

[a] The technology segmentation was derived with input from the Info-communications Media Development Authority (IMDA) of Singapore.

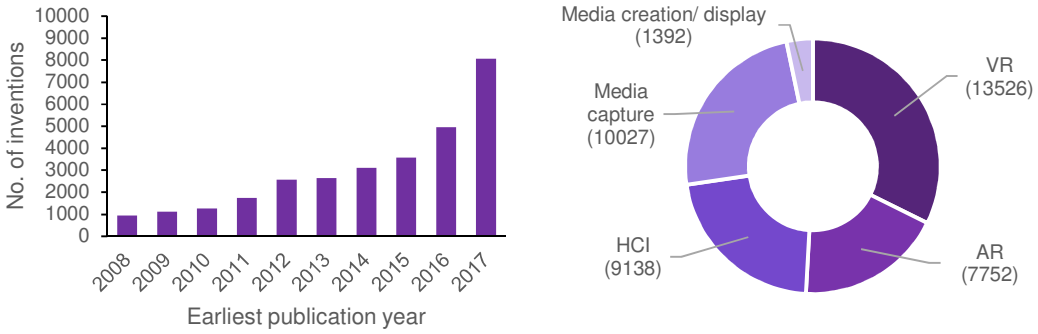
3 OVERALL TRENDS

3.1 Global Publication Trends

Approximately 30,000 inventions [b] relating to immersive media technologies have been published worldwide in the surveyed period 2008-2017 [c] (Exhibit 2), with an annual growth of 27.0% over the last five years, significantly higher than the average growth in global patent filings of 8.3% in the same period [1]. The rapid growth of immersive media innovation activity has been fuelled by advancements in various enabling technologies such as media capture devices such as real-time cameras, sensors in the detection of user's state and recognising surrounding environments, display devices as well as data transmission and processing such as 4G communication and cloud services. With the advancements in these core technologies, immersive technologies are a step closer towards delivering their promise of providing a naturally intuitive interface between human and machines through seamless incorporation in numerous applications including entertainment, education, healthcare and enterprises.

Market estimates are suggesting an enormous growth potential in immersive media related industries. In fact, the VR/AR market alone is expected to reach $95 billion to $569 billion by 2021 to 2025 [2] [3] [4]. Hence, with the continuous high growth of innovation activities and bright market prospects, immersive media innovations are expected to continue their rapid growth in the near future.

The innovative efforts, fuelled by market demand, would accelerate the evolution of businesses that immersive media bring about. With directions spearheaded by technological giants such as Microsoft, Samsung and Sony (see Sections 3.2 – 3.5), stakeholders should review their business strategies to determine the optimal level of immersive media adoption so as to achieve maximum operational efficiency and/or users/customers satisfaction



*Numbers in parenthesis represent the total number of inventions published in 2008-2017.

Exhibit 2: Worldwide innovation trend (left) and distribution of technology domains (right) of immersive media and advanced interfaces.

[b] Number of inventions is calculated based on the number of unique DPWI patent families (see Appendix A: methodology). Note that an invention can be counted in multiple technology domains as the invention can involve different technological aspects.
[c] Data collected on 30 September 2018. Note that some patent publications in 2017 have yet to be classified. Thus, these publications were not retrieved by the search queries using patent classification.

3.2 Virtual Reality (VR) and Augmented Reality (AR)

Amongst the different domains of immersive media technologies studied in this report, VR- and AR-related innovations account for more than 50% of the entire dataset (Exhibit 2 (right), Exhibit 3 and Exhibit 4). In particular, VR technology not only has the highest number of inventions (>13000), but also the fastest annual growth of up to 46.7% over the last five years.

VR and AR are slated to be the next computing platforms [5], and predicted to be adopted by 20% of large enterprises by 2019 [6]. Markets pertaining to these technologies have also reported positive estimates ranging from $95 billion to $569 billion by 2021 to 2025 [2] [3] [4], boosted by intensive investment activities such as Facebook's $2 billion acquisition of Oculus [7], and Google's $542 million and $794 million investments into Magic Leap [5].

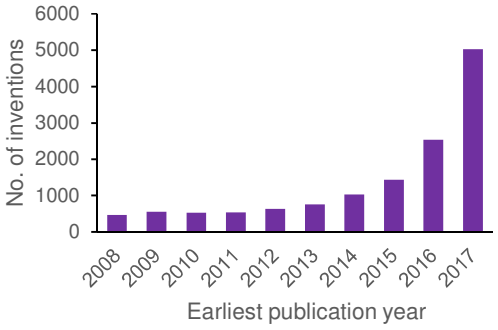


Exhibit 3: Worldwide publication trend of VR

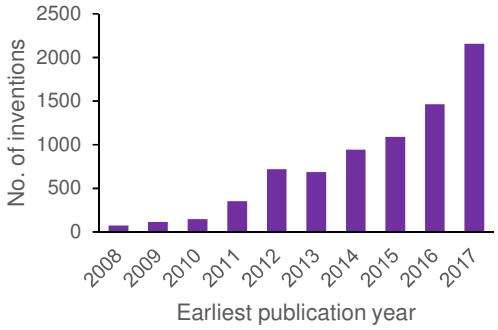


Exhibit 4: Worldwide publication trend of AR

Top applicants (VR)	No. of inventions
Sony Corp	567
Microsoft Corp	416
Google Inc	362
Samsung Electronics	285
LG Electronics	267
Brother Kogyo Inc	246
Canon Inc	215
Oculus VR LLC	212
LETV Holding Beijing Co Ltd	186
Colopl Inc	167

Table 1: Top applicants of VR

Top applicants (AR)	No. of inventions
Seiko Epson Corp	528
Microsoft Corp	350
Magic Leap Inc	147
Samsung Electronics	136
Canon Inc	131
Sony Corp	127
LG Electronics	113
Electronics and Telecommunications Research Institute (ETRI), Korea	108
Osterhout Design Group	88
Qualcomm Inc	88

Table 2: Top applicants of AR

In contrast to the 1980s-1990s when VR and AR first emerged and failed to meet market expectations due to poor graphics/processing and high costs, current digital reality technologies are supported by advancements in technologies enabling more sensitive user detection, faster data processing and transmission and higher display resolution. Moreover, technology giants with vested interest in head mount displays/devices (HMDs), are ramping up efforts in innovation to lead the frontier towards a truly immersive experience. This is evident from the list of the top innovators in the VR and AR domains (Table 1 and Table 2), where most of them are multinational corporations (MNCs) well-established in consumer electronics devices and digital platforms. In order to win a place in the VR/AR market, these leading players have strived to develop their own HMD products. Various products, such as Sony's PlayStation VR, Google Cardboard, Samsung Gear VR, Epson's Moverio, Microsoft's HoloLens and Magic Leap's Magic Leap One, are already available in the market.

Given that top leading players have amassed large patent portfolios (Table 1 and Table 2), major stakeholders are putting in efforts to protect their establishment in the VR/AR industries, making these two domains highly competitive.

3.3 Human-Computer Interaction in Immersive Media

Human-computer interaction (HCI) aims to enable naturally intuitive user inputs to the immersive media platforms. Specifically, these naturally intuitive inputs include (1) tracking of different physical aspects of users, such as the movement of head or eye and their gestures, speech or brain waves, to control the platform and (2) tangible interfaces such as haptic control/feedback and sensory stimulations.

In the past decade, more than 9000 inventions relating to HCI in immersive media has been published (Exhibit 5). As the push towards digital ubiquity would mean a user interaction with an increasing number of computers, naturally intuitive inputs would streamline the human-computer interactions and greatly improve the efficiency, thus leading to an enhanced immersive media experience.

The top players in this domain are mainly entities with commercially available immersive platforms, such as VR or AR HMDs (Table 3). Indeed, the innovations in this domain mainly involve the development and integration of user interaction techniques into VR/AR HMDs.

The global market for overall HCI technologies is expected to grow significantly due to high penetration of computers across multiple facets of lifestyles with market estimates of $33.05 billion by 2025 and $1.72 billion by 2022 for gesture and brain-computer interface, respectively [8] [9]. Therefore, with the potential of taking immersive experience to the next level, innovation pertaining to HCI deployed in immersive media is expected to observe a continuous fast growth.

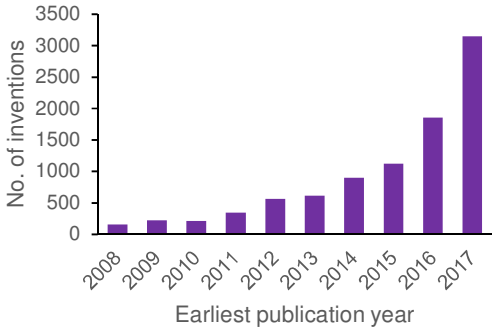


Exhibit 5: Worldwide publication trend of human-computer interaction

Top applicants (human-computer interaction)	No. of inventions
Sony Corp	414
Microsoft Corp	406
Samsung Electronics	233
LG Electronics	190
Google Inc	184
Seiko Epson Corp	172
Magic Leap Inc	172
Colopl Inc	132
Oculus VR LLC	125
Electronics and Telecommunications Research Institute (ETRI), Korea	110

Table 3: Top applicants of human-computer interaction

3.4 Media Capture

Capturing of contents for immersive media relates to inventions involving devices or techniques with the ability to capture or process contents, such as images, videos and audio, into 360-degree or 3D formats. Besides cameras, recorders and scanners, inventions of this domain will also include techniques for encoding/decoding immersive media content and light-field capturing methods.

Despite a relatively high number of approximately 10000 published inventions in 2008-2017, the annual growth in the recent five years was only 4.9% per annum (Exhibit 6). This is in stark contrast to the other four domains which observed growths of at least 27.3%. Key innovators in the media capture domains comprise Samsung, Sony, LG, Panasonic and Fujifilm, all of whom are well-established MNCs in manufacturing digital camera and video capturing devices (Table 4), suggesting that existing digital photo and video technologies form the current technological backbone for content capture tailored for immersive media.

While most innovations on media capture are centred on existing digital photo and video technologies, there have been newer and more exciting solutions that provide enhanced quality of captured content. Light-field capturing technology, for example, allows variable focal control after image acquisition and thus an enhanced immersive experience. Innovations in this area are led by Canon, Technicolor SA and Samsung, and have experienced fast growth of 21.3% from 2013-2017 that stands out in the almost-stagnant media capture domain. The market attention has been exemplified by reported interest from Google in acquiring light-field-focused technology company, Lytro [10]. Going forward, it would be interesting to see how light field capturing technology or similar technologies, which are capable of capturing multi-dimensional information, would evolve and how they would be deployed in downstream applications.

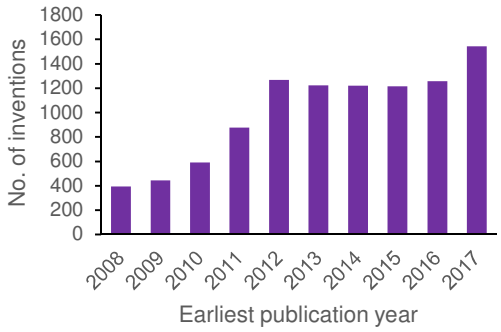


Exhibit 6: Worldwide publication trend of media capture

Top applicants (media capture)	No. of inventions
Samsung Electronics	308
Sony Corp	232
Panasonic Corp	221
Fuji Film Co Ltd	219
Canon Inc	205
LG Electronics	205
Ricoh Corp	187
Technicolor SA	114
Electronics and Telecommunications Research Institute (ETRI), Korea	100
Siemens AG	94

Table 4: Top applicants of media capture

3.5 Media Creation/Display

Conventional screen displays remain inadequate for a truly immersive experience for audiences, who are always seeking stimulating visuals via novel display or presentation solutions. These novel solutions include 360-degree presentations, ultra-high definition displays, holograms, 3D volumetric projections and variable focal displays, which are covered in this domain. For this domain, there were more than 1000 inventions published worldwide in 2008-2017 with an annual growth rate of 28.6% (Exhibit 7).

Interestingly, while immersive media users long for 3D display solutions, patent data revealed that innovation activities have been more focused on improving resolution of 2D displays. Unsurprisingly, this domain's leading players are major manufacturers of televisions and screen displays (Table 5).

High definition videos and TV programs, in comparison to those in the standard definition formats, have already provided us with sharper and more vivid images, allowing for an enhanced visual experience. With the mainstream adoption of ultra-high definition (UHD) or 4K displays, the number of inventions specific to 4K- and 8K/16K-UHD has been on the rise (Appendix C Exhibit 20 and Table 16). Among them, 4K-UHD inventions are mostly directed to signal transmission, indicating a shift of focus towards broadcasting solutions and an adoption of the 4K-UHD display as a mainstream broadcast medium while 8K/16K-UHD inventions are still focused on improving their core display technology (Exhibit 8). However, with various major TV manufacturers introducing their 8K-UHD products into the consumer market [11], the creation and adoption of such UHD contents is imminent.

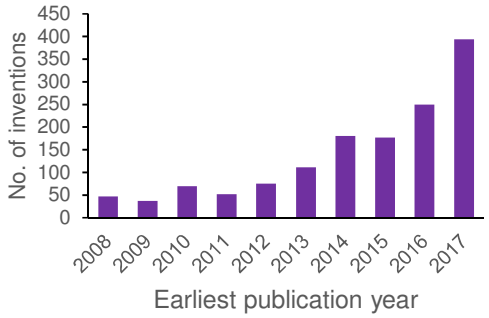


Exhibit 7: Worldwide publication trend of media creation/display

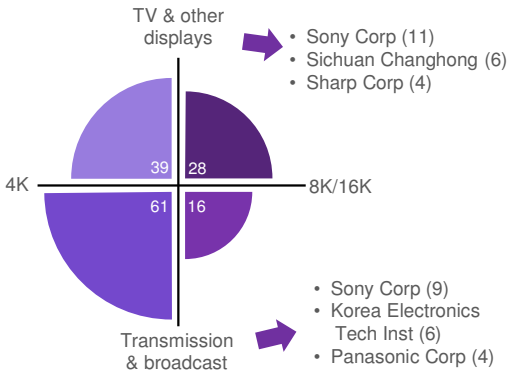


Exhibit 8: Focus areas of 4K and 8K/16K UHD-related inventions and corresponding top applicants

Top applicants (media creation/display)	No. of inventions
Toshiba Corp	100
LG Electronics	90
Samsung Electronics	67
ETRI, Korea	67
Sony Corp	61
Microsoft Corp	44
Korea Electronics Technology Inst	25
Nippon Hoso Kyokai Corp	23
Canon Inc	21
Thalmic Labs Inc	13

Table 5: Top applicants of media creation/display

Major manufacturers of televisions and screen displays are consistently putting in effort to create novel display solutions while improving conventional screen displays. Such efforts result in continual redefinition of industrial standards in display and content technologies, making it necessary for immersive media creators to keep abreast of the developments in this arena.

4 AR - THE NEW VIRTUAL REAL

4.1 Overall Trends

AR technology allows its users to see virtual information in their physical environment through a physical device such as a display or a pair of glasses. This enables the user to actually "see" and not just imagine if a certain object is to be present. Riding on this ability, AR could be applied in countless scenarios, where the applications can range from individual to enterprise levels and from entertainment to national defence areas. Recognition of AR's potential is evident from the fast growth in related innovation activities at 27.3% in the last five years (Exhibit 4). The market size of AR technology is forecasted to overtake the VR industry (US$ 34.08 billion) and to reach US$ 60.55 billion by 2023 [12].

The United States, Korea and Japan have been the traditional powerhouses in the AR domain and have been producing a higher number of inventions compared to other countries especially from 2008 to

Invention origin	Earliest publication year										Total
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
U.S.	9	19	14	54	134	200	346	391	463	646	2276
China	5	10	16	20	45	78	90	151	333	791	1539
Korea	17	28	33	116	205	105	171	188	200	266	1329
Japan	17	26	31	43	124	127	169	182	253	171	1143
Germany	4	4	4	8	6	8	12	14	30	32	122

Table 6: Publication trends of the top 5 countries of applicant origin

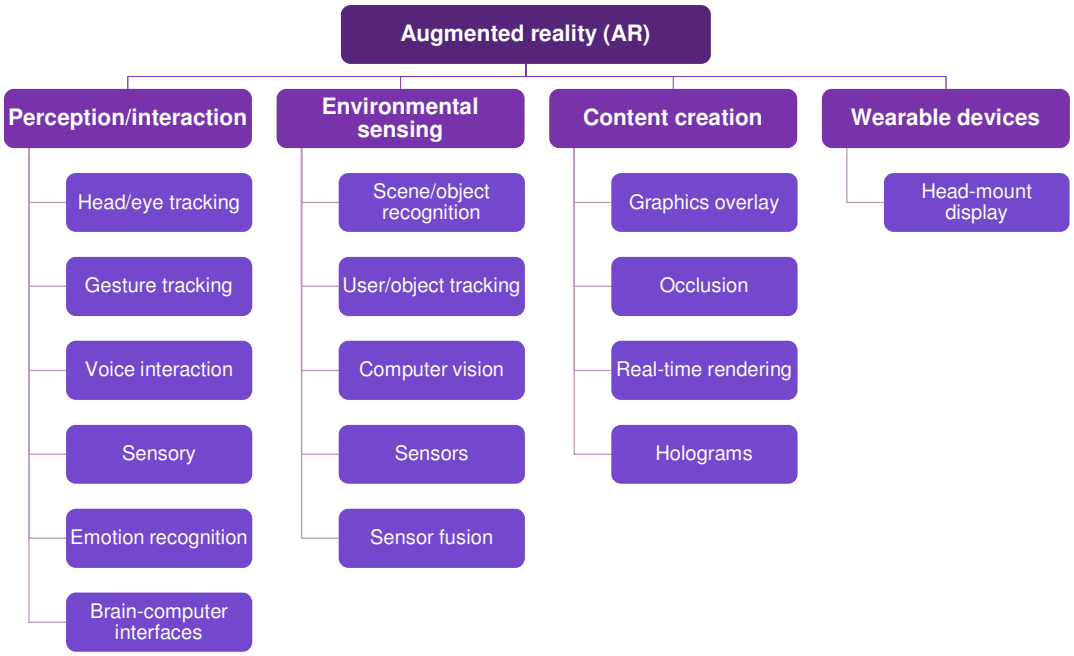


Exhibit 9: AR technology breakdown and its sub-domain classifications

2012 (Table 6). The early head start in this technology domain has allowed these countries to build a strong technological foundation and demonstrated a technology edge over other countries with their corporations leading the AR innovation scene. In the last five years, China has ramped up their capacity for innovation and has already outpaced the U.S. in terms of the number of published inventions in 2017. However, there is yet to be a large Chinese corporation which has emerged as a leader in the AR applicant list. Rather, the surge of patenting activity from China has been contributed mainly by hundreds of entities with smaller portfolios.

The AR domain was further broken down into four technology sub-domains, namely perception/ interaction, environmental sensing, content creation and wearable devices (Exhibit 9, Exhibit 10,

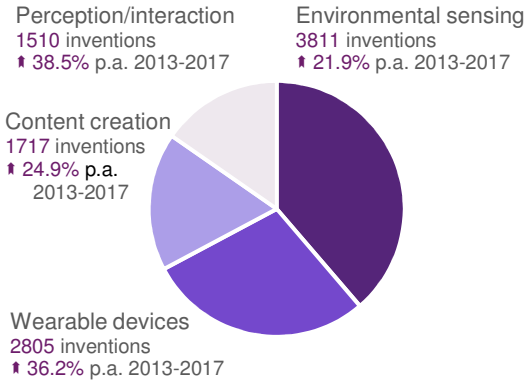


Exhibit 10: Technical sub-domain distribution of AR inventions

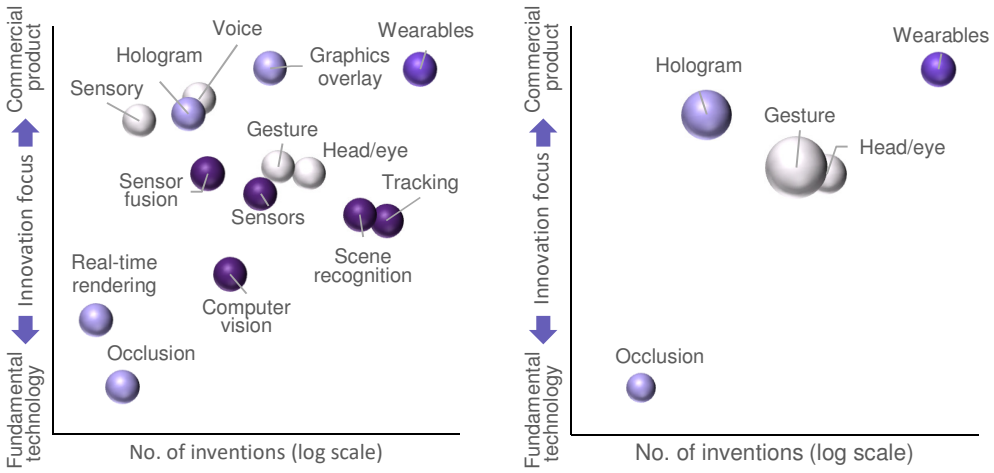


Exhibit 11: Innovation focus of different technical areas within AR technology (left) and five highlighted technical areas based on commercial interest (right). Bubble size reflect the relative commercial interest.*

* Innovation focus is a relative measure of whether an invention relates closer to fundamental research or to commercial exploitation. It provides a good indication to the commercial readiness of the product/method covered in the invention. For details, see Appendix A: Methodology.

Appendix C Exhibit 18, Exhibit 19 and Table 13) [d]. This chapter focuses on five specific areas, namely

[d] The AR technology breakdown and classifications were derived with input from IMDA, Singapore. Inventions related to simultaneous localization and mapping (SLAM) were included under the sub-domain of computer vision.

AR wearables, head/eye tracking, gesture tracking, hologram and AR occlusion based on commercial interest [e] (see Exhibit 11).

4.2 AR Wearables

The AR wearables sub-domain represents one of the largest sub-domains within the AR field, together with a high growth of 36.2% p.a. in the period from 2013-2017 (Exhibit 12). Within the AR wearables dataset, there are approximately 2400 inventions relating to head-mount displays (HMD) and about 400 inventions on other wearables such as smart watches or wristbands. The higher number of inventions relating to HMD is not surprising as AR HMD has been viewed as a gateway to an immersive experience. Numerous players, such as Epson, Microsoft and Osterhout, have demonstrated an extensive interest in AR HMD by building strong innovation portfolios (Table 7).

These innovations have translated to numerous products and prototypes already available in the market, for example, Seiko Epson's Moverio [13], Microsoft's HoloLens [14] and Magic Leap's Magic Leap One [15] AR HMD. Nonetheless, the AR HMD market is still innovating and improving on HMD's technical components and aspects (Table 8). Inventions ranging from optics and sensor integrations to data transfer to image processing, are targeted towards addressing issues relating to HMD's size, weight, field of view and level of immersion, and often hefty price tags. The growing vigour by the leading players would further heat up the already-intensive competition in this area. In addition, aggressive patent ring-fencing from these technology giants also implies a congested AR HMD space that is challenging for players with limited expertise to enter.

[e] Commercial interest of a technology area is measured by the average patent family size of its related inventions. Patent family size represents how many jurisdictions an invention is protected in. A widely protected invention, i.e. a large family size, is an indication of high commercial interest.

Along with the on-going AR evolution, leading players are increasingly moving into the translational aspects of AR HMD. With close to 700 inventions and a high growth of 37.3% p.a. relating to industrial deployment of AR HMD in the period of 2013-2017, infocomm media, healthcare, logistics, retail, education and finance have been the frontiers in AR applications (Exhibit 13). Some examples include the use of AR HMD to (1) provide advertising media content upon detecting of a user's arrival, (2) aid surgeons by overlaying virtual body organs images as derived from MRI and CT scans and (3) provide augmented navigation within a logistic warehouse setting to locate a particular object on the shelves through scanning of a barcode. Through an immersive platform which combines real-time information feed with natural human-environment interaction, users of AR, through HMD, are now experiencing media content in a new light - combined augmented content with realism. Given the immense potential as the next generation delivery platform, an explosive growth of HMD deployment in AR applications can be expected in the next three to five years.

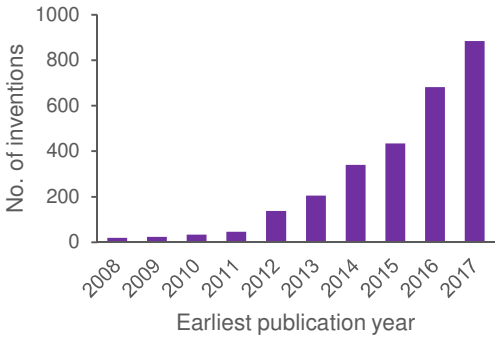


Exhibit 12: Worldwide publication trend of AR wearables

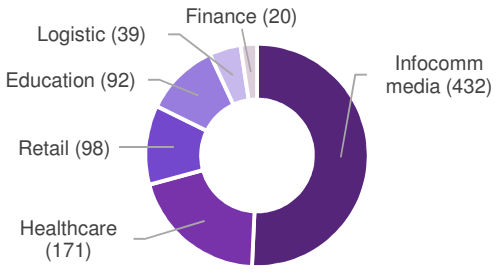


Exhibit 13: Applications of AR head-mount display in various industry verticals

Top applicants	No. of inventions
Seiko Epson Corp	522
Microsoft Corp	243
Osterhout Design Group	88
Magic Leap Inc	78
Canon Inc	62
Google Inc	51
Sony Corp	47
Brother Kogyo	47
DAQRI LLC	36
LG Electronics	32

Table 7: Top applicants of AR wearables

With the potential in deploying AR HMDs in numerous industries, the key HMD players are actively translating their technology into applications in support of the frontier industries. Specifically, Epson and Microsoft are seeking to expand their HMD expertise by entering diverse industries (Table 9). Such strategy is also evident in their efforts in seeking partnerships with stakeholders through integrative programs to build AR solutions via their established HMD platforms [16] [17]

The low number of inventions relating to HMD applications, and the immense potential of HMD deployment in AR applications, reflect that development of HMD-application translation is only at its early stages. Its nascency represents an area of opportunity for stakeholders, particularly for the service providers and info-communication and media solutions providers, in the various industries. While these stakeholders may not possess adequate expertise in AR HMD technologies, the availability of partnership programs by leading HMD players have changed the dynamics of the playing field. Stakeholders interested in transforming or levelling up their businesses/services through AR can now bring in their domain expertise as a strong value proposition and forge strategic partnerships with the leading HMD players through their collaborative programs. This potential partnership will not only allow stakeholders to maintain a competitive edge to their businesses/services, but also be a forerunner in terms of AR deployment in their respective industries.

Technical aspects of AR head-mount displays	Earliest publication year										Total
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
Optical element	7	6	13	20	81	112	187	256	403	419	1504
- Waveguide	0	0	3	2	45	25	25	38	46	57	241
Sensors	9	6	6	15	43	67	121	142	221	298	928
Circuit arrangement	6	6	6	11	49	73	58	51	106	98	464
Data recognition/presentation	1	0	4	5	5	24	18	63	80	106	306
Data transfer/processing	7	8	7	15	50	70	124	164	290	319	1054
Pictorial presentation/visualisation	5	5	7	13	40	50	58	97	186	166	627
Image processing/generation	9	9	8	10	32	59	108	178	298	348	1059

Table 8: Worldwide publication trends of various technical aspects of AR head-mount displays

Top applicants ranking	Infocomm media	Healthcare	Logistics	Retail	Education
1	Microsoft Corp (74)	Magic Leap Inc (35)	Osterhout Design Group (10)	Microsoft Corp (8)	Seiko Epson (4)
2	Seiko Epson (27)	Seiko Epson (13)	Toyo Kanetsu Solutions (2)	Seiko Epson (6)	Shenzhen Kechuang Digital (4)
3	Magic Leap Inc (24)	Microsoft Corp (9)	Okura Yusoki Co Ltd (2)	Wal-Mart (5)	Osterhout Design Group (3)

Table 9: Top applicants using AR head-mount display for industry application. Numbers in parenthesis indicate the patent portfolio size

4.3 Head/Eye and Gesture Tracking

Head/eye and gesture tracking, together with other interaction techniques such as voice interaction, sensory feedback, brain-computer interface, and emotion recognition, form the perception/interaction technology sub-domain that enables the AR experience. This sub-domain registered 1510 inventions and a growth of 38.5% p.a. 2013-2017. Its growth, which is the highest among AR technology sub-domains, demonstrates the recent industry focus on inclusion of human-centric features to create the ultimate AR experience.

Head/eye tracking and gesture tracking have not only attracted the highest number of innovative activities among various perception/interaction aspects (Exhibit 14) but have also displayed a higher impact relative to other interaction methods (Exhibit 15). The higher impact of these inventions is not surprising as these inventions relate to essential interaction techniques for accurate virtual information alignment and naturally-intuitive AR experience. Their importance is also evident in the active innovative efforts made by major AR HMDs developers who aim to incorporate these human-centric features into their products (Table 10). Therefore, the emphasis on these interaction methods would spur more efforts from major AR HMD developers, making them another highly competitive areas for new entrants.

In contrast, the impact of voice interaction and sensory feedback on the AR industry is relatively low and the presence of major AR HMDs developers innovating in these two domains is less prominent (Appendix C Table 14). Though AR innovations, involving these two interaction methods are both actively in progress, as evident from their high annual growth rates of 40.8% and 31.6%, the activities appear to be initiated from small entities or even individuals rather than large corporation-backed

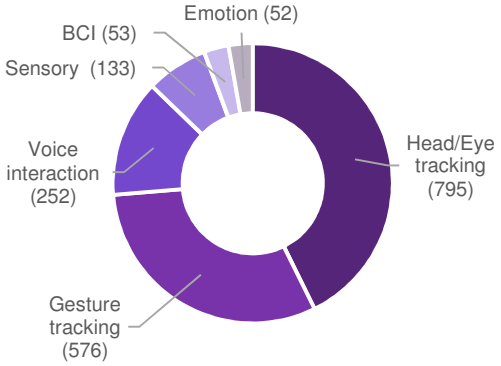


Exhibit 14: Breakdown of the interaction methods in AR platforms

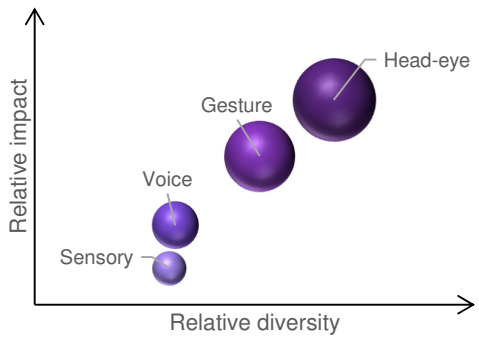


Exhibit 15: Relative impact and diversity (Appendix A: Methodology) of different interaction methods in AR experience. Bubble size reflect the relative number of inventions.

Top applicants	No. of inventions	
	Head/eye	Gesture
Microsoft Corp	130	61
Osterhout Design Group	68	31
Magic Leap Inc.	55	31
Seiko Epson	50	23
Sony Corp	19	23

Table 10: The same top applicants of head/eye tracking and gesture tracking in AR

funding (Appendix C Table 15). It is, therefore, interesting to see how innovations relating to these two methods would scale up, and in particular, the uptake by the big technology companies.

4.4 Hologram

A hologram is a three-dimensional image of an object existing in real space that is reproduced through interference and diffraction of light. Holographic technology not only produces stereoscopic aerial illusions, but also enables virtual objects to interact with real person together for a stunning experience. It is not a new concept and has been demonstrated for example in many futuristic films. In fact, the first patent about holography [f] can be traced back to 1947, when a British physicist Dennis Gaber discovered electron holography when conducting a research on electron microscopes. He was then awarded Nobel Prize in Physics in 1971 [18]. However, holograms were then monochromatic and thus did not generate significant public interest.

Though there have only been 194 inventions relating to holographic technology published worldwide from 2008 to 2017, this technology area has seen high annual growth of 41.7% (Exhibit 16), signifying the great excitement revolving around the "hologram" concept. However, current holographic solutions have not met the expectations due to various limitations. For example, holographic inventions from top applicants (Table 11), such as Microsoft, were mostly projected within head mount displays. These, as the critics analysed [19], cannot be considered truly holographic as a true hologram can be seen by the naked eye without the aid of special glasses or other intermediate optics. Similarly, while some holographic musicals, such as those of synthetic pop star Hatsune Miku and late songbird Teresa Teng, have gained a lot of cheers and screams, the technology behind, namely Pepper's ghost illusion, required costly films or glass sheets to be positioned between the audience and the stage [20]. It is unlikely that such technology can be made widely available to consumers.

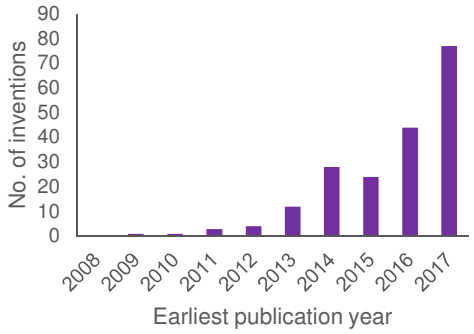


Exhibit 16: Worldwide publication trend of hologram

Top applicants (hologram)	No. of inventions
Microsoft Corp	63
Seiko Epson Corp	10
Essilor International	5

Table 11: Top applicants of hologram

[f] GB 685286: Improvements in and relating to microscopy

Significant progress has been made in producing true holograms as exemplified in one recently published invention [g]. Inventors from Brigham Young University used a near-invisible light field to trap and move a small particle through a volume of space to present a so-called photophoretic-trap volumetric display. This discovery has subsequently been published in the high-impact scientific journal Nature [21]. However, these projections are confined to a finger-tip scale with difficulties in scaling.

As illustrated above, current hologram techniques have yet to be optimized in aspects pertaining to portability, scalability and costs, presenting challenges for mass-market adoption and commercial applications.

[g] US 20160161068 A1: Full-colour freespace volumetric display with occlusion

4.5 Occlusion

Insertion of virtual objects in AR currently involves a simple overlay of the objects onto a real world scene, resulting in the virtual objects always appearing in front of the real world, even if the intended position is for the virtual objects to be behind a real object. This conundrum could be solved by occlusion techniques, which represent the biggest and the most elusive piece of the AR puzzle. In the AR industry, occlusion is the ability to hide virtual objects behind real-life objects to preserve the line of sight rule when creating an AR scene. This requires additional recognition of depth information of the real scene, as well as fast graphics processing for realistic image presentation.

A total of 113 inventions relating to occlusion were published worldwide in 2008-2017 (Exhibit 17). A high annual growth of 33.8% from 2013 to 2017 was observed, surpassing the overall growth rate of AR technology domain (27.3%). Compared to other AR technology areas, the published occlusion inventions were more closely related to fundamental scientific research (Exhibit 11), which is a strong signal indicating its early development stage with much room for further research and development. Given the limited innovation activities, top players in this space have only up to 10 inventions each (Table 12). The lack of dominant players implies a less protected space that allows relative ease for new players to navigate and to establish a foothold in this area.

As such, occlusion is considered a nascent space with significant potential for further exploration. This provides the infocomm media sectors and research organisations strong motivation to further develop and exploit advanced AR occlusion solutions, so as to achieve technological breakthroughs that will give them the first-mover advantage to tap into the enormous market potentials.

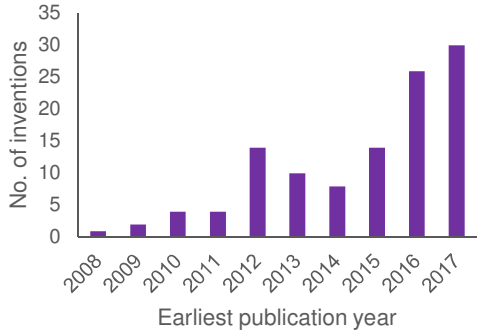


Exhibit 17: Worldwide publication trend of AR occlusion

Top applicants (occlusion)	No. of inventions
Microsoft Corp	11
Qualcomm Incorporated	7
Sony Corp	7

Table 12: Top applicants of occlusion

5 CONCLUSION

The advancement of enabling technologies for immersive media will result in an entirely different interactive experience between human and digital media in the near future. Technologies relating to immersive media is likely to grow further, penetrating the consumer market and our everyday life. Within the immersive media technology, the domain of media capture has the lowest growth rate and is dominated by big established cameras and media capture devices manufacturer such as Samsung, Sony, Fuji Film and Canon. The presence of these top players and the relatively low growth indicates that present technology for media capture is sufficient to capture immersive media content and thus a lower emphasis is placed on innovating new media capture devices.

In contrast, the domains of VR and AR have seen an explosive growth in recent years. A large amount of investments are reportedly poured into the development of AR/VR technologies. In particular, AR with its many possible industrial applications, has seen the rise of many wearable products and prototypes in the market, especially in HMD. A number of big players have already released their prototypes aiming at enterprise level adoption and this indicates the maturity of basic enabling technologies in HMD. However, to enter the mass consumer market, these players are innovating actively to improve various components and technological aspects of the current state of the art, resulting in the strong patent filings in recent years. Due to the versatility of AR, HMD makers are targeting to make their product as versatile as possible, targeting to penetrate many industries. This presents opportunities for industry players to partner with the HMD makers to come up with specific industrial applications.

From the patent data, the technology field of occlusion within the AR-content creation sub-domain is the least explored with a small number of inventions among various technology areas in this study. However, strong interest in this area can be seen from the fast growth in recent years. Furthermore, as top players have yet to build up their portfolios, it is imperative that new entrants explore and gain their foothold in this growing immersive media market, before top players manage to sufficiently ring-fence their technologies in this field.

6 REFERENCES

[1] World Intellectual Property Organization., “World Intellectual Property Indicators 2017”, 2017.

[2] McKinsey & Company, “Augmented and virtual reality: The promise and peril of immersive technologies,” October 2017. [Online]. Available: https://www.mckinsey.com/industries/media-and-entertainment/our-insights/augmented-and-virtual-reality-the-promise-and-peril-of-immersive-technologies.

[3] Deloitte Insights, “Digital reality: The focus shifts from technology to opportunity,” December 2017. [Online]. Available: https://www2.deloitte.com/insights/us/en/focus/tech-trends/2018/immersive-technologies-digital-reality.html.

[4] Citi GPS, “Virtual and Augmented Reality. Are you sure it isn't real?,” 2016.

[5] CB Insights, “What comes after smartphones? The next mobile computing platform is already emerging.,” August 2018. [Online]. Available: https://www.cbinsights.com/research/mobile-computing-platform-future/.

[6] Gartner, “Transform Business Outcomes with Immersive Technology,” May 2017. [Online]. Available: https://www.gartner.com/smarterwithgartner/transform-business-outcomes-with-immersive-technology/.

[7] Techcrunch, “Facebook's $2 Billion Acquisition of Oculus Closes, Now Official,” July 2014. [Online]. Available: https://techcrunch.com/2014/07/21/facebooks-acquisition-of-oculus-closes-now-official/.

[8] Grand View Research, “Gesture Recognition Market Size Worth $33.05 Billion by 2025,” November 2017. [Online]. Available: https://www.grandviewresearch.com/press-release/global-gesture-recognition-market.

[9] Grand View Research, “Brain Computer Interface (BCI) Market Analysis by Product, By Application, By End-use And Segment Forescasts,” February 2018. [Online]. Available: https://www.grandviewresearch.com/industry-analysis/brain-computer-interfaces-market.

[10] TechCrunch, “Sources: Google is buying Lytro for about $40M,” March 2018. [Online]. Available: https://techcrunch.com/2018/03/20/sources-google-is-buying-lytro-for-about-40m/.

[11] TechrRadar, "Do We Really Need 8K TVs yet?" August 2018. [Online]. Available: https://www.techradar.com/news/do-we-really-need-8k-tvs-yet

[12] Research and Markets, “Augmented Reality and Virtual Reality Market by Offering, Device Type, Application, and Geography - Global Forecast to 2023,” February 2018. [Online]. Available: https://www.researchandmarkets.com/research/qq837j/global_augmented?w=4.

[13] Epson, “Moverio - Smart Glasses,” [Online]. Available: https://moverio.epson.com/.

[14] Microsoft, “Microsoft HoloLens - the leader in mixed reality technology,” [Online]. Available: https://www.microsoft.com/en-us/hololens.

[15] Magic Leap, “Magic Leap One: Creator Edition,” [Online]. Available: https://www.magicleap.com/magic-leap-one.

[16] Microsoft, "Mixed Reality Partner Program", [Online]. Available: https://www.microsoft.com/en-us/hololens/partner-program?activetab=hololens_pivot%3aprimaryr5

[17] Epson, "Moverio - Partners", [Online]. Available: https://epson.com/moverio-augmented-reality-partners?pg=4

[18] The Nobel Prize, “The Nobel Prize in Physics 1971 was awarded to Dennis Gabor "for his invention and develppment of the holographic method", [Online]. Available: https://www.nobelprize.org/prizes/physics/1971/summary/.

[19] Business Insider, “Microsoft's New HoloLens Headset is very Similar to a Secret Product Google has Invested in”, Jan 2015. [Online]. Available: https://www.businessinsider.com/hololens-isnt-really-a-hologram-2015-1/?IR=T.

[20] CBSnews, “Bringing musical stars back via hologram”, [Online]. Available: https://www.cbsnews.com/news/bringing-musical-stars-back-via-hologram/.

[21] D. Smalley and E. Nygarrd, “A photophoretic-trap volumetric display,” *Nature,* vol. 553, p. 486–490, A photophoretic-trap volumetric display”.

APPENDIX A: METHODOLOGY

Dataset

The final dataset relating to immersive media and related advanced interfaces was retrieved on 30 September 2018. The dataset consists of worldwide patent applications published from 2008-2017, retrieved from the Derwent World Patents Index™.

Search string

To ensure optimal recall and accuracy of the data sets retrieved, the search strings used in this study were formulated incorporating keywords (and their variants) and/or patent classification codes and indexing, e.g. International Patent Classification (IPC) and Cooperative Patent Classification (CPC).

Detailed lists of the main keywords and the patent classification codes used are presented in Appendix B.

Grouping by patent family

A patent family is a group of patents related to the same invention. Analyses based on unique patent families can reflect the innovation productivity more accurately. Considering individual patent applications will inevitably involve double counting as each patent family may contain several patent publications if the applicant files the same invention for patent protection in multiple destinations.

Data cleaning

The dataset retrieved was first subjected to automated data cleaning using an IPOS' in-house proprietary patent data cleaning platform for the following purposes:

1) Removal of duplicates of a patent application record in a jurisdiction as a patent application may be published with different kind codes ('A1', 'A2', 'B1', 'B2' *etc.*)
2) Deletion of non-patent specifications, e.g. utility models and search-report-only publications
3) Grouping/collapsing of different patent applications relating to a common invention to one patent family. In this report, the representative for a patent family (i.e. an invention) is chosen to be the earliest published family member.

Manual review was subsequently carried out to ensure the relevance of the dataset prior to carrying out the analyses.

Growth rate calculation

Annual growth rate refers to the average annual growth and was derived by using the best-fit exponential line method for the set of data, $y = a*e^{bx}$, where b is the growth rate.

Grouping of technology domains

Grouping of individual patent records into the respective technology domains and sub-domains were carried out based on patent classifications codes, text-mining and semantic analysis of the patent specifications in particular claims, titles, original and/or DWPI abstracts, as well as a manual review of the individual patent applications.

Refinement of the applicant field

IPOS' in-house proprietary patent data cleaning platform and automated algorithms from commercial tools were used to refine applicants' information, e.g. by removing various spelling and punctuation mark discrepancies.

The refined results were manually checked for accuracy. Top patent applicants were also checked for known subsidiaries and acquisitions, and were named according to the parent company.

Patent indicators

Innovation focus

Innovation focus is a relative measure of whether an invention relates closer to fundamental research or to commercial exploitation. It is calculated based on the ratio of the number of cited patents to the number of cited scientific literatures. In general, inventions referenced to more patent documents are considered to be closer to commercial exploitation, while those citing more scientific journals are considered to be more related to fundamental research.

Commercial interest

A patent is a territorial right granted to an invention and gives the assignee the sole right to market the invention and exclude others from making or selling the invention. Hence, players who seek protection for their inventions in multiple jurisdictions are likely to be motivated by the commercial potential of the inventions. Therefore, the average family size of a published invention is used as a proxy to indicate the applicants' interest in commercialising the particular technology.

As fillings into different jurisdictions might be delayed due to factors such as PCT application timeline, and/or existing patent applications might not be captured due to delays of publications at various patent offices, the family sizes of various portfolios of recent inventions are projected so as to depict a more accurate estimate of the eventual family sizes, and as such, a more accurate assessment of commercial interest by industry players.

Relative impact

The number of citations that an invention receives is a good proxy for the impact of the invention in the development of future technologies [h]. It provides a good indication of how extensive the technology used in the invention would be adopted or adapted in subsequent inventions.

Relative impact is an indicator derived from the number of citations that an invention received and is an estimate of the importance of a technology in shaping future innovations. Citations are normalised to factor in the time an invention is available to receive citations, in particular for recently published inventions.

Relative diversity

Relative diversity refers to the diversity of technologies involved or application areas of an invention. It is determined based on the range of patent classification codes used to categorise the invention.

[h] OECD, "Chapter 2: Measuring the Technological and Economic Value of Patents", [Online]. Available: http://www.oecd.org/sti/ieconomy/Chapter2-KBC2-IP.pdf

APPENDIX B: SEARCH STRING

Immersive Media

Main keywords used
Immersive media, haptic, kinaesthetic, tactile, sensory, simulation, experience

Virtual/Augmented Reality

Main keywords used
Virtual, reality, world, space, environment, VR, Augmented, mixed, extended, mediated, reality, Head-mounted, head-worn, display, HMD, smart, intelligent, wearable, goggles, headset, helmet, glasses, eyeglasses

Main patent classification codes used
G02B 27/012

Human-computer Interaction

Main keywords used
Human, man, computer, machine, interaction, collaboration, co-operation, interface, action, capability, feature
Head/eye/ocular/gaze tracking, monitor, detection, control
Gesture, posture, body, hand, movement, motion, signal, tracking, monitoring, detection, recognition, control, determination
Emotion, feeling, facial expression, tracking, monitoring, detection, recognition, control, determination
Voice, speech, conversation, chat, dialogue, accent, natural language, language processing, translation
Brain, mind, computer, machine, interface, interaction, collaboration, link, control
Tasting, aroma, fragrance, smell
User, player, customer, viewer, human, position, location, site, coordinates, venue, bearing, orientation, direction, rotation
Scene, object, environment, surrounding, tracking, identification, recognition

Main patent classification codes used
G06F 3/01, G06F 3/011 to G06F 3/017, G06F 17/27, G06F 17/28, G06K 9/00201, G06K 9/00624+

Media Capture

Main keywords used
360-degree, omnidirectional, media, audio, acoustic, video, image, content, film, capture, record, camera, coding, decoding
3D, 4D, three-dimensional, four-dimensional, media, audio, acoustic, video, image, content, film, capture, record, camera, camcorder, scanner, coding, decoding
3D, three-dimensional, image, object, processing, construction, generation, rendering, creation,
Light-field, plenoptic, capture, record, camera
Haptic, kinaesthetic, tactile, capture, record

Main patent classification codes used
H04N 3/00+ to H04 11/00+

Media Display

Main keywords used

Ultra-high, super-high, definition, UHD, television, TV, UHDTV, display, monitor, screen, LCD, panel
4k, 8k, 16k, television, TV, HDTV, UHD, display, monitor, screen, LCD, panel
360-degree, omnidirectional, display, presentation, theatre, projection, television, screen, broadcast, streaming, transmission, telecast
Hologram, holographic display
Smart, intelligent, interactive, mirror
Auto-focus, variable, adjustable, focus, display, screen, panel, television
Volumetric, floating, free-space, free-standing, image, display

Main patent classification codes used

H04N 3/00+ to H04 11/00+, H04N 13/388, H04N 13/39, H04N 13/393, H04N 13/395, G02B 27/2271, G02B 27/2278, G02B 27/2285, G02B 27/2292

APPENDIX C: ADDITIONAL INFORMATION

C.1 Sub-domains within AR technologies

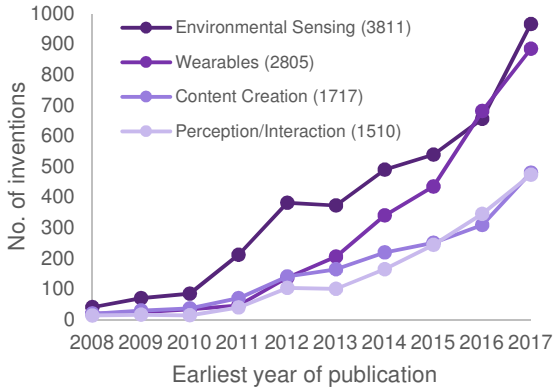


Exhibit 18: Publication trends of sub-domains within AR technologies. Bracketed values represent the total numbers of inventions published over 2008-2017.

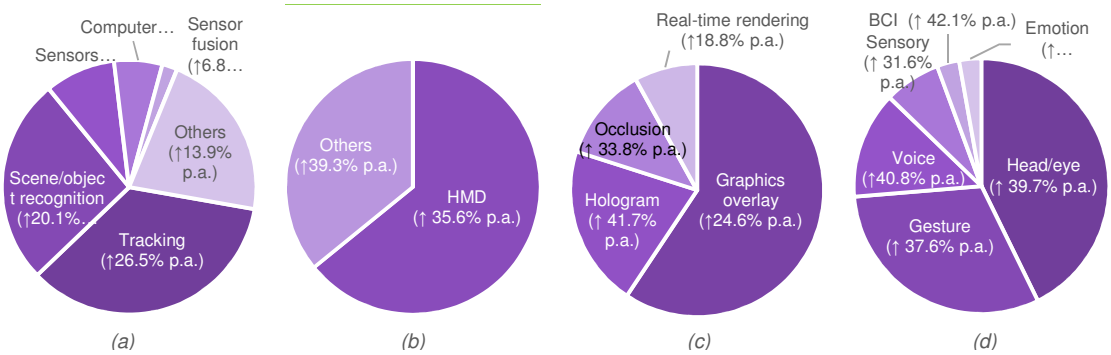


Exhibit 19: Proportion of technical areas in the corresponding sub-domains of AR, namely (a) Environmental Sensing, (b) Wearables, (c) Content Creation, (d) Perception/Interaction. Numbers in parenthesis represent the annual growth rate over the period of 2013-2017.

Environmental Sensing	Wearables	Content Creation	Perception/ Interaction
Microsoft (184)	Seiko Epson (522)	Microsoft (119)	Microsoft (163)
Seiko Epson (104)	Microsoft (243)	Canon (71)	Seiko Epson (75)
Sony (82)	Osterhout (88)	Seiko Epson (61)	Osterhout (73)
Samsung (75)	Magic Leap (78)	Sony (59)	Magic Leap (58)
Canon (69)	Canon (62)	Google (30)	Sony (34)

Table 13: Top applicants for each sub-domain of AR technologies. Numbers in parenthesis represent the number of inventions published in 2008-2017 by the respective top applicant.

Voice interaction	Sensory feedback
J.H. Chan, KR (10)	Immersion Corporation (5)
Seiko Epson (10)	Seiko Epson (5)
Microsoft (9)	Magic Leap (4)
Osterhout (6)	Eye Labs LLC (3)
Electronics and Telecomm Research Institute ETRI, KR (4)	Philip Morris USA (3)

Table 14: Top applicants for inventions involving voice interactions and sensory feedback in AR applications

Sub-domain	% of inventions
Head/eye tracking	5.9%
Gesture tracking	8.2%
Voice interaction	19.8%
Sensory Feedback	18.0%

Table 15: Percentage of Inventions for interaction methods in AR applications which is filed without any corporate association

C.2 Media displays – 4K and 8K/16K-UHD displays

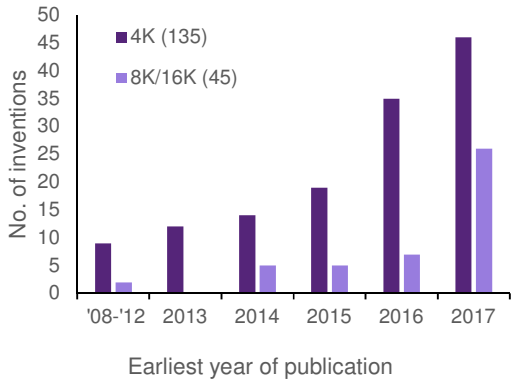


Exhibit 20: Publication trends of inventions relating to 4K and 8K/16K UHD displays. Bracketed values represent the total numbers of inventions published in 2008-2017

4K displays	8K/16K displays
Sony (19)	Sony (11)
Korea Electronics Tech Institute (7)	Nippon Hoso Kyokai (NHK) (3)
Sharp (5)	Sichuan Changhong Electric Co. Ltd. (3)
Panasonic (5)	Sharp (2)
Sichuan Changhong Electric Co. Ltd (5)	Korea Electronics Tech Institute (2)

Table 16: Top applicants for 4K and 8K/16K UHD displays inventions. Numbers in parenthesis represent patent portfolio size

About The Intellectual Property Office of Singapore (IPOS)

The Intellectual Property Office of Singapore (IPOS) is a statutory board under the Ministry of Law. We develop the right legal regime and business ecosystem to support an innovation-driven economy, build IP skills and expertise and foster innovation and creativity for Singapore's future growth. We deliver on our commitments through our core values of integrity, professionalism, team work and by investing in our greatest asset – our people. More information on IPOS can be found at www.ipos.gov.sg.

Contact us

P Kiruthika
National Research Foundation Singapore
DID: +65 6694 5022 ▪ FAX: +65 6684 0384
Email: P_Kiruthika@nrf.gov.sg

Ang Wunly
IPOS-International, IPOS
DID +65 6330 8673 ▪ FAX +65 6339 0252
Email: Wunly.ANG@iposinternational.com