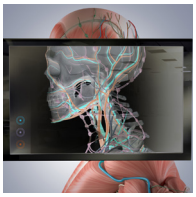
MIXED REALITY
PATENT LANDSCAPE REPORT
2003-2017





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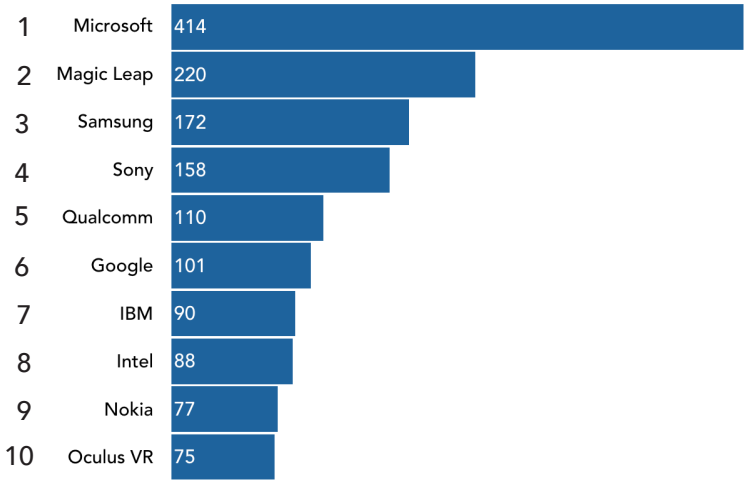
1 Executive Summary

The following companies rank in the top 10 based on the number of **patents and patent applications (P/PA)** assigned to them over the 2003-2017 period.



Except Magic Leap, Nokia, and Oculus VR, these companies were also among the top 11 companies with the most number of patents granted by the USPTO in 2016. Magic Leap has recently received an additional $461 million in funding for a total so far of almost $2.3 billion. It counts Google, Alibaba, and Temasek Holdings among its biggest investors.[1]

The categories listed below ranked in the top 10 based on the number of **mixed reality** (**"MR"**; see. p. 8 for the term's definitions) related P/PA assigned to each of them over 2003-2017 period:

1. Automation of Actions and Processes
2. Data Processing
3. Content Presentation
4. Display Systems
5. System Management
6. Coordinate and Depth Measurement Systems
7. Interface
8. Content Creation
9. Communication Systems
10. Optical Systems

1 www.crunchbase.com/organization/magic-leap

Other than Healthcare, these categories' being in the top 10 is hardly a surprise because they relate to essential MR components, features, or processes.

Across industries, the pace at which MR products are being introduced on the market is accelerating. But MR technology remains hobbled by significant technical issues that preclude wider adoption especially in the consumer market. Portability remains a serious issue with inherently power-hungry MR systems.

Some believe smartphones, rather than head-mounted MR devices, are a more viable platform for consumer MR. The latest generation of smartphones already have processors and GPUs powerful enough to handle any graphic-intensive applications without significant frame rate drops or thermal throttling. They also have newer generation of batteries that can last almost a day with heavy use. But obviously, high MR application usage rates means shorter battery life, so we are back to square one again on the battery life issue. Also, using smartphones as an MR platform would, of course, severely limit the type of applications usable for MR. For one, handheld devices such as smartphones are unsuitable for many hands-free applications such as those designed for manufacturing and task training. In contrast, head-mounted MR devices are ideal for hands-free applications.

The following are some of the major challenges in the MR field that need to be addressed before large-scale adoption of MR technology becomes feasible:

1. ***enhancing battery longevity***
2. ***improving portability of MR systems especially MR displays***
3. ***content and app ecosystem development***
4. ***increasing field-of-view of glasses-type displays***
5. ***data security and privacy***
6. ***environment safety***
7. ***lack of or gaps in technical standards***

While the vastness of the MR applications space offers plenty of opportunities for everyone with the necessary funding and talent, it also has the potential to cause significant technological fragmentation. This, in turn, could substantially impede rapid and broad public and industry adoption of MR-based products and services. Major MR players and organizations will have to focus sooner or later on setting standards covering a broad array of MR-related technology areas and applications.

The IEEE Standards Association already has a standards development group working on the following topics:

Device Taxonomy and Definitions
Immersive Video Taxonomy and Quality Metrics
Immersive Video File and Stream Formats
Person Identity
Environment Safety
Immersive User Interface
Map for Virtual Objects in the Real World
Interoperability between Virtual Objects and the Real World
Immersive Audio Taxonomy and Quality Metrics
Immersive Audio File and Stream Formats
In-Vehicle Augmented Reality
Content Ratings and Descriptors

Finally, it may sound more hype than reality to say that MR tech will truly epitomize a paradigm shift compared to, say, smartphones. But that would be a naïve take in this case. MR is already being used productively in many industrial and training applications and has garnered fans among users. This despite MR's still being a relatively immature technology, with all its technical deficiencies and still-unrealized features and capabilities.

What MR technology has accomplished within a relatively short period, smartphones have failed to do: substantially enhance the efficiency of, for example, manufacturing industries by transforming the way they work. MR has made substantial and tangible benefits for workers on the factory floors by increasing productivity and reducing human errors. These, in turn, help enhance job satisfaction by minimizing work-related stress. On the other hand, mobile phones generally have been geared more towards consumer use and content consumption. It is a technology that many companies would rather have banished from the workplace if they could, cellphones being mostly ill-suited as a tool for anything other than entertainment and everyday communications.

So, MR is surprisingly turning up to be living up to the hype, at least in the industrial sector. But those who are waiting for affordable consumer-ready MR products (e.g., for gaming and entertainment) will have to wait a little bit longer. A critical mass of MR-based content must first be made available to consumers before they start buying all sorts of cutting-edge MR hardware and accouterments to satisfy the most die-hard of MR fans. For now, developers are still waiting and seeing if the technology is already ripe and accessible enough before they begin extensive content development. It's the chicken or the egg thing.

2 Definitions and Methodology

A. Definitions: Mixed Reality (MR) and Related Terms

This sample landscape report (LR) covers patents and patent applications directed to various types of mixed reality technology with effective filing dates from January 2003 to November 2017. We use Milgram et al.'s definition of the term mixed reality, which was defined in their 1994 paper as falling within a reality-virtuality continuum.[2] According to their definition, "mixed reality" refers to a combination of both real and virtual objects presented within a display. The reality-virtuality continuum is bounded by two endpoints corresponding to either a real or virtual environment comprising only real objects on one end (reality) and only virtual objects on the other (virtuality), respectively. Everything else within those two limits constitutes mixed reality.

Hence, the term mixed reality (MR) as used in this report includes virtual reality (VR), augmented reality (AR), and other variations such as hybrid reality, artificial reality, synthetic reality, etc. We define "augmented reality" environment as a MR environment presented on a display that contains more real content (e.g., scenes and objects) than virtual content, hence the word "augmented" which applies to the word "reality." A "virtual reality" environment, on the other hand, contains mostly, if not entirely, virtual or digitally-generated content.

It is important to clarify the meanings of these key terms because the literature on MR-related technologies are peppered with many undefined or obscure terms (e.g., hybrid reality, artificial reality, or synthetic reality). Some of these terms appear to refer to either the more general term MR (which includes VR) or the narrower term AR (which is different from VR). For example, rather than describe or label its products using the widely-used term AR (which many companies use), Microsoft uses the term MR. All these, of course, cause confusion. Worse, the media oftentimes indiscriminately use these terms. Further, a patentee's being allowed to be his or her own lexicographer means that MR-related terms used in patents and patent applications (P/PA) are sometimes either unrecognizable as such or could be construed as essentially covering anything under the entire reality-virtuality universe.

"... the term MR as used in this report encompasses virtual reality, augmented reality (AR), hybrid reality, artificial reality, synthetic reality, etc."

By definition, emerging technology areas are still developing. It is almost inevitable that some of the newly-coined technical terms in emerging fields would begin life as words or phrases whose meanings seem to morph from one journal or business article to the next. But as the technology evolves and becomes more mature, companies, consortiums, associations, or industries eventually adopt one (at least in most cases) among the two or more competing terms and their corresponding proposed meanings. For example, during the early nanotechnology stages, one group argued for the adoption of the term "nanoparticle" to refer to any particle with at least one dimension less than 100 nanometers (nm, 10^{-9} m), while another group lobbied for the broader "less than

2 "Telemanipulator and Telepresence Technologies," SPIE, vol. 2351, pp. 282-292,1994.

500 nm" definition. At a certain point, official or quasi-official definitions of the terms are set by one or more industry groups, consortia, standards-setting bodies, or government agencies, e.g., IEEE, NIST, ITU, IOS, IEC, ISO, and ASTM.

As used in this sample report, the term "category" or "categories" when used alone (as opposed to, say, "market segment category") refers to a P/PA category name selected based on one or more P/PA claims' being directed to a specific type of device, device component, hardware, system, software, or process (e.g., content presentation, pose estimation, interface, or optical systems). Some P/PA claims expressly recite or suggest the industry sector, market segment, or specific application (e.g., fitness, surgical training, or gaming) that the P/PA is directed to. For those P/PA, we also classify them under a subset of categories we refer to as "market segment categories."

B. Our Approach

In the Appendix section of this report (see pp. 55-57), we provide a detailed description of the search and categorization protocol we used, as well as a brief description of how we generated the cluster map shown in Fig. 2.

For some clients with a clear idea at the outset what time frame, industry, market segments, and technology areas they want the report to focus on, the report preparation becomes an active collaboration between the client and Parola Analytics. In this case, the client would typically provide immediate and regular feedbacks during the preparation of the report.

For instance, in one project, we performed a very detailed and complex patent and business analysis involving a widely-used telecommunications technology. The report covered around 20 major categories of products and services and more than 30 companies many of which were the biggest companies in the world. The client company was a pioneer in the industry and thus knew the industry inside out. Thus, the client was ready with a list of initial categories and companies to be included in the report even before the project had begun. We worked closely and iteratively with the client to craft the category definitions. We repeatedly refined them until the overlap among category definitions had been substantially reduced. We then used the optimized definitions to formulate our searches. Besides performing separate patent and business analyses, we also performed a combined patent and business analysis using methodologies that we designed for the client. The completed landscape report was used by the client as one of the bases for their long-term strategic planning.

In another project, a client wanted the report to focus on the analysis of the scope of the P/PA claims assigned to various companies in a related industry. This industry was of interest to the client as a potential area for vertical expansion. One of the major takeaways from the report was the systems and processes developed and used by the companies within the industry of interest were very complex, highly specialized, and custom-built for their clients' unique needs. In addition, relatively few prior art relating to those technologies could be easily found. This suggested that a significant chunk of the companies' intellectual property was stashed away as trade secrets. Also, many, if not most, of the technology developed by the companies were protected by broad patent claims. In addition, entry into the industry required significant capital investment and specialized manpower acquisition and development. Thus, the only way for a new entrant to penetrate the industry of interest was to either (a) acquire at least one of the companies within the industry or (b) obtain licenses from the deeply entrenched incumbents. The latter option was highly unlikely—the industry of interest was one where every slice of the market share, no matter how miniscule, was very hard to come by. This was because the industry's customer base consisted of relatively few large companies and was therefore very limited.

Unless a client says otherwise, we normally incorporate in our full-version landscape reports various data from different sources that include patent, business, technical, and scientific literature. A significant number of business and patent decisions that companies make are now becoming inextricably intertwined. Also, more companies are now realizing the importance of aligning a company's business strategy and long-term goals with those directed to protecting and enhancing its intellectual property. Thus, the inclusion of business and technical data and analysis, along with a comparatively comprehensive patent analysis, provides for a broader, more reliable, and clearer picture of the direction toward which a technology area or industry is headed.

Disclaimer

This patent landscape report is only a sample report and was based on preliminary searches only. It aims to primarily illustrate the variety, scope, and depth of the different possible combinations of data and information that we provide to clients and that we use as bases for analyses. Parola Analytics, Inc. does not make any representation regarding the accuracy or validity of the data, analyses, and conclusions included in this sample report.

3 Analysis of MR Patents and Patent Applications

VR and AR applications have been around since the beginning of the 20th century,[3, 4] but the state of the technology at the time left much to be desired. Now that significant and continuous technical headways have been and are being made, almost every company are aggressively trying to grab a piece of the headlines to help them garner public and investor attention.

Pokemon Go has been widely credited for significantly increasing MR's global public awareness, although many of those who downloaded the game (500 million downloads as of September this year; $600 million mobile AR revenues in its first 3 months) probably were not even aware that Pokemon Go is an MR-based technology. As of 2016, VR has generated $2.7 billion and AR $1.2 billion in revenues for a total $3.9 billion MR market.[5] A market research study estimated that the entire VR device market will reach $11 billion in about four years.

The following are some of the better-known MR products and technologies that are already on the market or are being promoted heavily. Many of these products have already attained widespread name recognition among techies and early MR adopters:

Sony Playstation VR (Sony)
Daydream View mobile VR headset/controller (Google)
Tango mobile AR phone (Google)
Hololens (Microsoft)
Light field engine for producing holograms that look "really touchable" (Samsung)
Processors for phone-based AR with significant battery savings and smaller form factors (Qualcomm)
Project Alloy all-in-one VR headsets (Intel)
Oculus VR (Facebook)

3 Frontiers in Human Neuroscience, vol. 8, pp. 1-15, Mar. 2014.
4 "A New IEEE Initiative Focuses on Augmented Reality, Virtual Reality, and Human Augmentation Technologies," Dec. 2016, http://theinstitute.ieee.org/technology-topics/consumer-electronics/a-new-ieee-initiative-focuses-on-augmented-reality-virtual-reality-and-human-augmentation-technologies.
5 "After mixed year, mobile AR to drive $108 billion VR/AR market by 2021," Jan. 2017, https://www.digi-capital.com/news/2017/01/after-mixed-year-mobile-ar-to-drive-108-billion-vrar-market-by-2021/#.WfMOAteWYoMa.

A. Top MR Categories

We individually classified the more than 5500 P/PA that remained after we deleted irrelevant P/PA. We also performed normalization and standardization of the the initial P/PA dataset generated from our search (see pp. 44-45 for a more detailed description of the search and categorization method we used for the preparation of the report).

We ended up with 32 major categories and several sub-categories for some of the major categories. Some of the P/PA were assigned to more than one category, e.g., Content Presentation and Content Creation or Data Processing and Data Acquisition. We based our decision whether to create a separate category (e.g., Data Sharing when we have previously created a similar category Data Acquisition) according to whether, for example, a certain minimum number of P/PA (e.g., at least around 20 P/PA) have patent claims that specifically refer to data sharing, as opposed to, say, data acquisition.

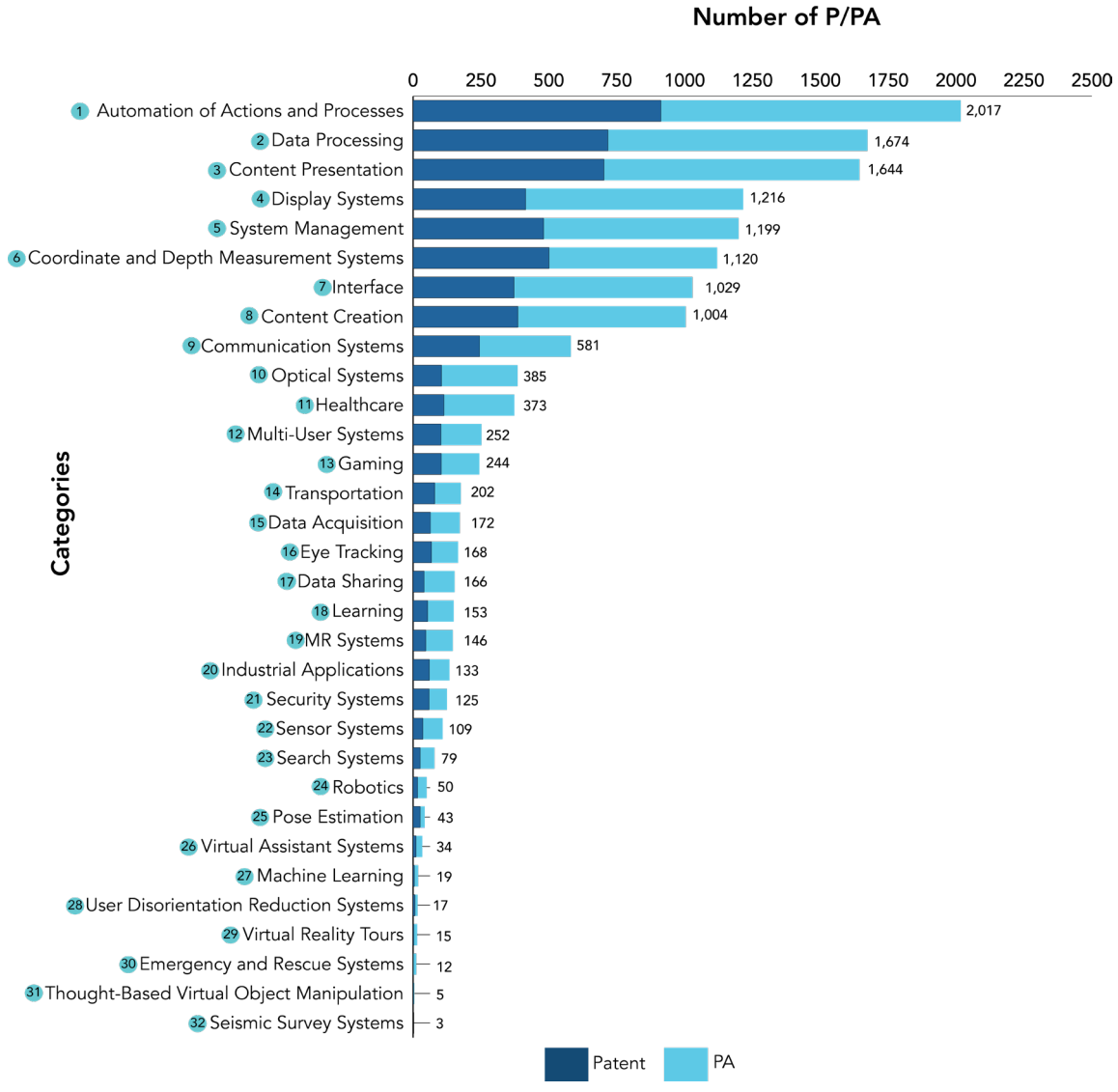


Fig. 1. Ranking of the various categories in terms of the number of P/PA per category (2003-2017).

In terms of total number of P/PA over 2003-2017, the following categories are ranked in the top 5:

Automation of Actions and Processes

2017

Data Processing

1674

Content Presentation

1644

Display Systems

1216

System Management

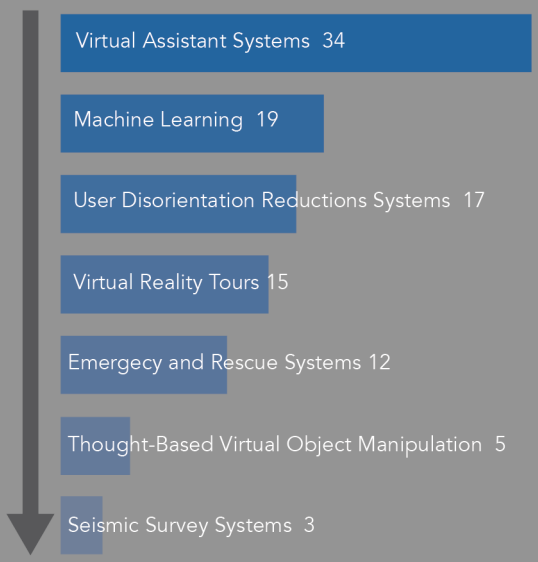
1199

It is not surprising that these categories are in the top 5 because each of them cover essential components or features of a basic MR system.

Healthcare, with 373 P/PA, unexpectedly ranked higher than Gaming (244 P/PA). Even more interesting is Magic Leap's being ranked 1st in Healthcare with 34 P/PA, far greater than that of any company included in this report (see, for example, Table 5).

Also, considering that industrial MR applications are now said to be finding success, the relatively low number of P/PA under Industrial Applications with 133 P/PA is rather surprising (as is the case with Gaming versus Healthcare).

CDS categories with the lowest number of P/PA in 2003-2017



These least active categories are logical and attractive areas for possible development for those seeking to explore uncrowded investment sectors (at least based only on the P/PA numbers). This, however, may be misleading because MR applications involving search systems, machine intelligence, virtual assistant systems, robotics, and automation are expected to assume greater importance as AI becomes more deeply embedded in multiplying market segments and application areas.

Combined AI and AR start-ups are emerging as funding and expertise rise. For example, Eolian, named one of the top 5 AI startups in 2017 by TandemNSI, uses AI to minimize human errors involving dangerous tasks via the use of AR and VR-based training and simulations. Connectar has developed an AR display that uses AI image recognition to facilitate complex aviation maintenance. Virtualitics provides data visualization in VR and AR environments through machine learning and AI. In addition, AI offers many applications in the MR arena such as continuous image recognition for security monitoring using VR displays, training MR/AI systems to recognize more complex scenarios or components, making MR-based gaming more immersive and interactive, providing virtual assistants using MR systems in retail, or enhancing videoconferencing experience via AI-based immersive telepresence enhancements to MR systems.

Table 1 below shows examples of categories we assigned to some of the P/PA from our dataset. We used the format "A/B" for the categorizations (or "A/B/C" when it applies), where A refers to the main category and B and C refers to sub-categories of A and B, respectively. For example, in the first entry under the "Category" column, the category assigned to US8576276 was Display Systems/HMD Systems. This means that the patent was assigned to the main category Display Systems and was further assigned to the sub-category HMD Systems because the patent claims were directed specifically to head-mounted devices. The main category Display Systems includes various types of MR-based display systems such as glasses-type displays, mobile device displays, and projection-display systems.

Table 1. Sample categorizations based on claim 1 of the listed patents.

Category	Patent Number (Effective Filing Date)	Title	Assignee	Claim 1
1. **Display Systems/ HMD Systems** *(Under this notation, "HMD Systems" is assigned as a sub-category of "Display Systems")*	US8576276 (18 Nov 2010)	Head-mounted display device which provides surround video	**Microsoft**	1. A user display apparatus, comprising: a head-mounted display unit including a see-through lens; an augmented reality emitter, associated with the head-mounted display unit, which emits light to a user's eye, the light represents augmented reality video images; a camera which provides an image of a video display screen the user is looking at; at least one sensor which tracks an orientation and location of a head of the user; and at least one control circuit which identifies edges of the video display screen based on the image provided by the camera, and controls the augmented reality emitter responsive to the at least one sensor, to display the augmented reality video images spatially synchronized with the edges of the video display screen and temporally synchronized with video content displayed by the video display screen.

2. Data Processing/ Audio Processing	US8520872 (14 Aug 2008)	Apparatus and method for sound processing in a virtual reality system	**Samsung**	1. An apparatus to perform sound processing in a virtual reality system, the apparatus comprising: a sound processing unit to process and produce sound output corresponding to virtual spaces of a virtual reality environment, the virtual spaces divided into a focus area and a non-focus area, the sound output of the focus area being processed and produced differently than the sound output of the non-focus area; and a control unit to divide the virtual spaces of the virtual reality environment into the focus area and the non-focus area, and to control the sound output of the sound processing unit such that when a space shift from a first virtual space in the virtual reality environment to a second virtual space in the virtual reality environment is detected, a volume of sound corresponding to the first virtual space is gradually decreased while a volume of sound corresponding to the second virtual space is gradually increased.
3. System Management /Control Systems	US8847987 (17 Nov 2010)	System and method for controlling device	**Samsung**	1. A system for controlling a device using Augmented Reality (AR), comprising: an AR server for registering a plurality of device information corresponding to each of a plurality of devices, upon receiving location information from a portable terminal, searching at least one device located within a predetermined range based on the location information, generating an AR screen displaying a type of the at least one device searched using the plurality of device information registered, and transmitting the generated AR screen to the portable terminal; and the portable terminal for transmitting the location information of the portable terminal to the AR server, and displaying the AR screen received from the AR server.

4. Content Presentation	US9170766 (01 Mar 2010)	Method of displaying virtual information in a view of a real environment	**Apple**	1. A method of displaying virtual information in a view of a real environment comprising the following steps: providing a system for displaying of virtual information in a view of a real environment; determining a current pose of at least one part of the system relative to at least one part of the real environment and providing accuracy information of the current pose; providing multiple pieces of virtual information related to at least part of the real environment contained in the view of the real environment, and assigning one of different parameters indicative of pose accuracy information to each of the multiple pieces of virtual information; and displaying at least one of the pieces of virtual information in the view of the real environment according to the accuracy information of the current pose in relation to the assigned parameter of the at least one of the pieces of virtual information; wherein at least one of the multiple pieces of virtual information is not displayed when the accuracy information of the current pose is equal to or beyond a certain threshold; andwherein a first number of the multiple pieces of virtual information are displayed when the accuracy information of the current pose is within a first range, and a second number of the multiple pieces of virtual information are displayed when the accuracy information of the current pose is within a second range different from the first range.
5. Interface/ Gesture Identification and Classification	US2016091964 (26 Sept 2014)	Systems, apparatuses, and methods for gesture recognition and interaction	**Intel**	1. A device comprising: a camera module to capture image data; an object recognition module to analyze the image data to recognize an object, and in response to recognizing the object, to provide data indicative of the recognized object; a gesture recognition module to analyze the image data to recognize a gesture, and in response to recognizing the gesture, to provide data indicative of the recognized gesture; and an output device to perform an operation using the data indicative of the recognized object and the data indicative of the recognized gesture.

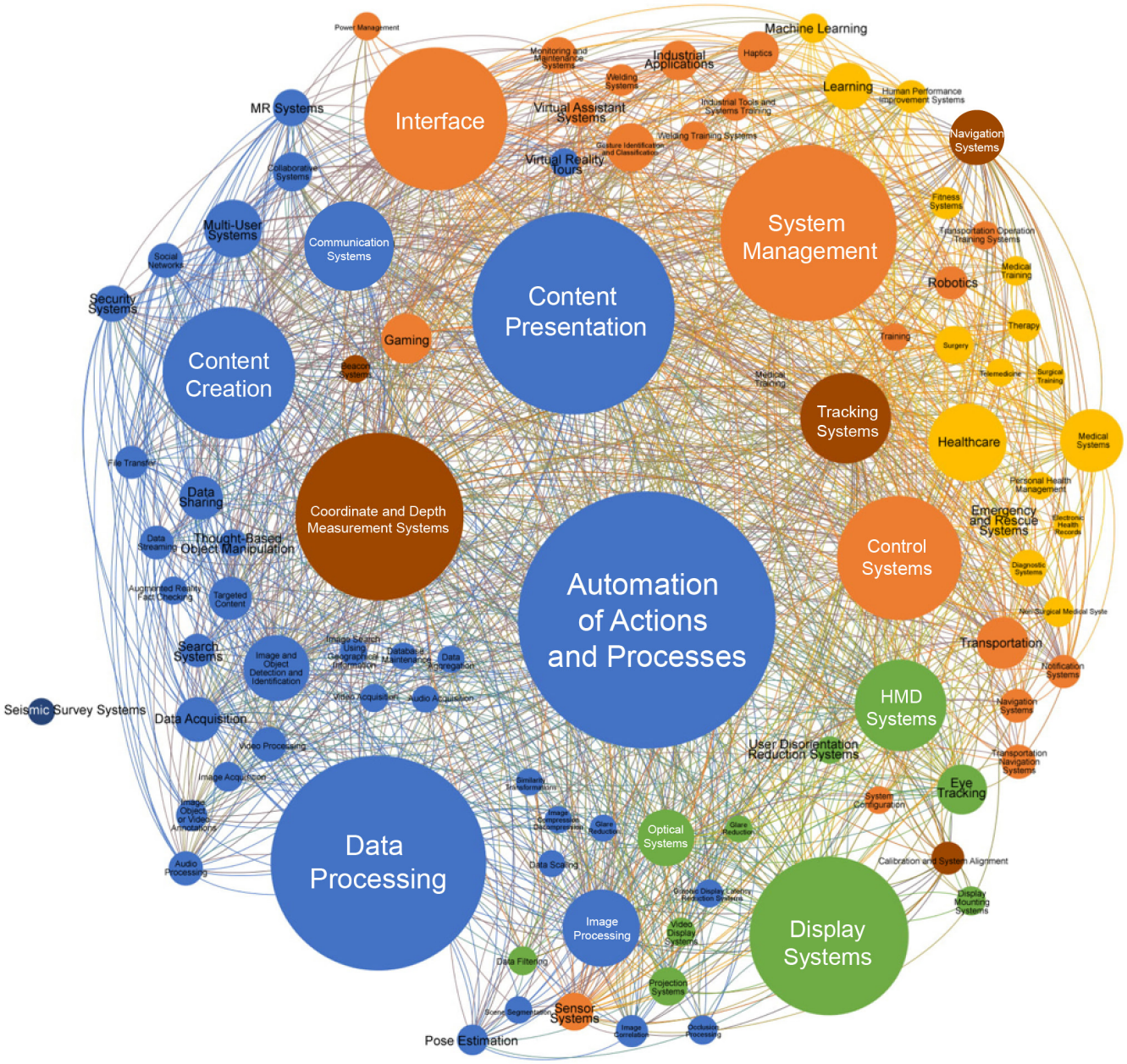


Fig. 2. Cluster map of the various P/PA categories and sub-categories (2003-2017).

Fig. 2 above shows the distribution of the P/PA among various MR categories and sub-categories. Included in this cluster map are two levels of sub-categories of the main categories (level 2 and level 3, where the latter is a sub-category of the former). The circle dimension corresponding to each category is proportional to the number of P/PA assigned to that category or sub-category. Also, categories and sub-categories linked by lines have one or more identical P/PA assigned to them in common.

As Fig. 2 shows, many P/PA are assigned to multiple categories and sub-categories. Most of the P/PA, however, are concentrated among a few categories, e.g., Display Systems, Data Processing, System Management, and Content Presentation. As previously mentioned, this is expected as the largest categories in terms of P/PA form the backbone of a basic MR system. Assignees of the P/PA under these largest categories are thus poised to exert substantial influence, earn significant licensing fees, or acquire significant market share in the MR field. This, of course, assumes that those companies' patented inventions will eventually be widely-adopted or included as part of the standards for the various MR-related technologies. Presently, each company is pushing its own vision of MR. At the same time, they are competing to be first to overcome the various technical issues that need to be sorted out before widespread adoption of MR turns into a full-fledged reality.

Table 2. Top 10 most active categories in terms of number of P/PA for all companies (2003-2017).

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Automation of Actions and Processes	16	28	65	35	64	49	59	167	223	294	303	294	279	135	6
Data Processing	27	39	66	29	48	63	56	164	185	231	212	219	216	116	3
Content Presentation	27	35	50	40	50	52	52	191	163	244	246	208	187	95	4
Display Systems	13	16	21	12	16	18	19	88	84	129	199	229	276	94	2
System Management	26	27	25	28	46	36	35	99	96	124	169	190	192	104	2
Coordinate and Depth Measurement Systems	14	33	31	22	31	39	44	126	124	134	156	147	141	75	3
Interface	26	37	40	26	29	32	37	114	83	111	131	132	163	65	3
Content Creation	11	30	36	39	36	42	41	79	105	127	120	123	136	76	3
Communication Systems	8	15	21	11	29	24	28	72	61	78	72	56	78	25	3
Optical Systems	1	3	7	2	2	2	3	30	32	35	110	51	77	29	1

As can be seen from the heat map above, patent filing activity picked up noticeably from 2010 onwards for many of the categories, particularly the top 5-6 categories. The pace of patent filing was maintained or generally increased until around 2015. Patent filing activity dropped in every category by 2016. This drop was mirrored by the decrease in MR-related patent filings from 2015 to 2016 by the top 10 assignees, except Sony and Qualcomm. This was also consistent with the decrease in PCT filings by US patent filers from 57,385 in 2015 down to 56,595 in 2016.

Table 3. Ranking of various categories in terms of total number of P/PA from the top 10 companies (2003-2017).

Categories	Patents (rank)	PA (rank)	P/PA (2012-2017)	P/PA (2003-2017)
1. Automation of Actions and Processes	301 (1)	314 (2)	389 (2)	615
2. Display Systems	157 (4)	345 (1)	400 (1)	502
3. Data Processing	212 (2)	252 (4)	291 (4)	464
4. Content Presentation	197 (3)	256 (3)	303 (3)	453
5. Coordinate and Depth Measurement Systems	145 (5)	165 (5)	198 (5)	310
6. System Management	105 (6)	149	182	254
7. Interface	94	149	154	243
8. Content Creation	98	129	139	227
9. Optical Systems	47	157 (6)	172	204
10. Communication Systems	40	59	56	99
11. Eye Tracking	23	39	47	62
12. Multi-User Systems	15	32	28	47
13. Healthcare	4	41	39	45
14. Data Sharing	11	29	33	40
15. Security Systems	16	17	29	33
16. Data Acquisition	9	22	23	31
17. Gaming	15	15	12	30
19. MR Systems	11	17	21	28
18. Sensor Systems	10	14	13	24
20. Search Systems	7	9	5	16

In terms of the total number of **P/PA** (and percentage) for the top 10 companies over **2012-2017**, the following are the categories with the highest number of P/PA. Each corresponding percentage shown below are relative to the number of P/PA for each of the same category over the entire **2003-2017** period:

1. Automation of Actions and Processes	1131 P/PA	(1311/2017)	**65%**
2. Data Processing	997	(997/1674)	**60%**
3. Content Presentation	984	(984/1644)	**60%**
4. Display Systems	929	(929/1216)	**76%**
5. System Management	781	(781/1199)	**65%**

The above categories are also the same categories with the most number of P/PA over the 2003-2017 period. Again, this is unsurprising since these categories cover components or features essential to a basic MR system. That patent filing activity is occurring mostly over the 2012-2017 period compared to the entire 2003-2017 period is expected as more companies overcome technical hurdles, concurrent with wider adoption of MR products and services in various application areas and market segments.

B. Top MR Companies

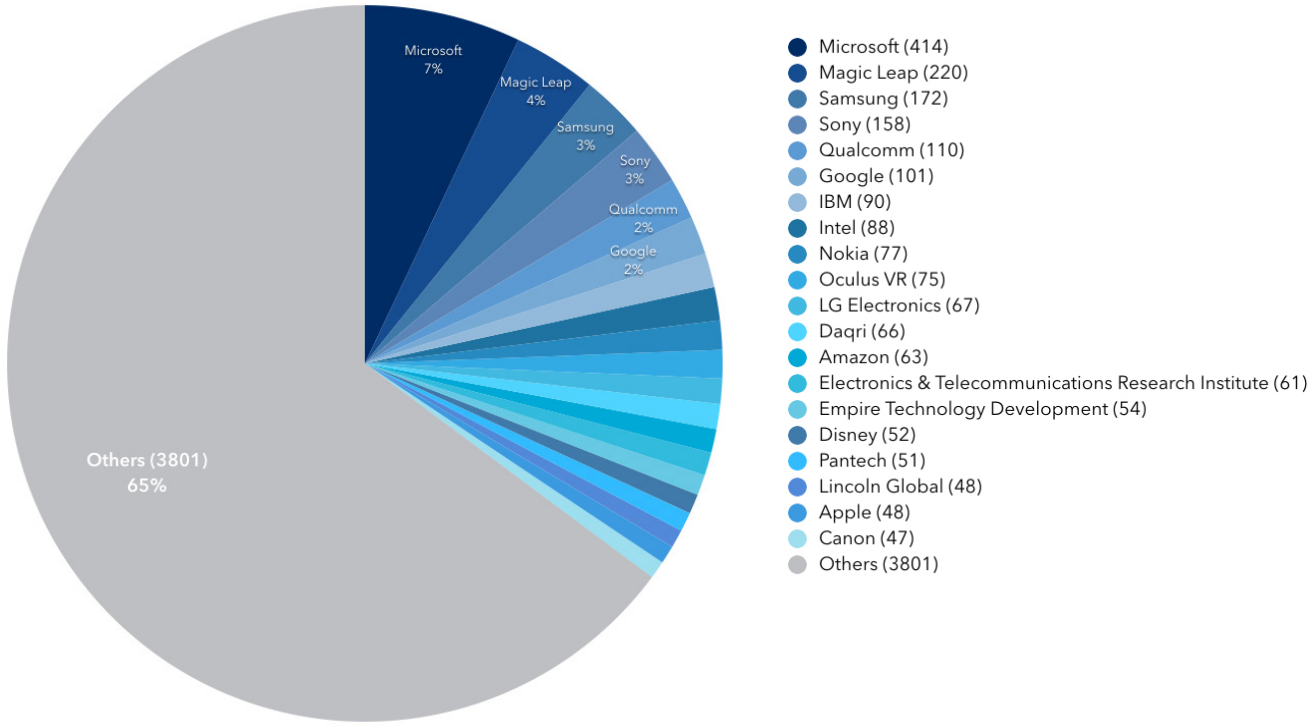
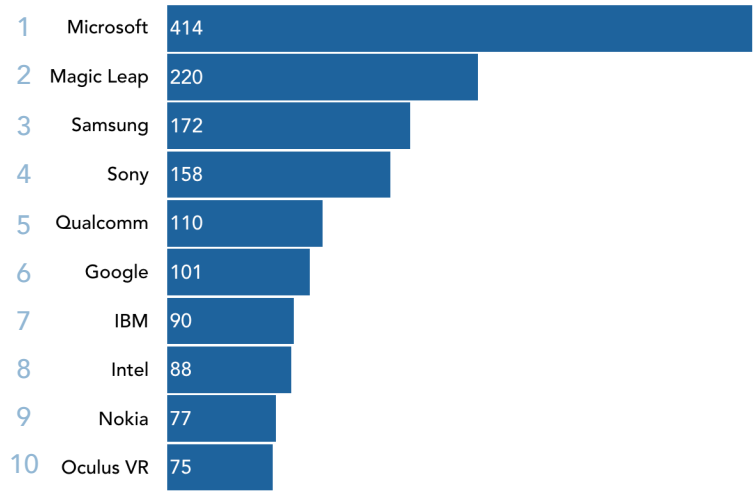


Fig. 3. Companies with the most number of P/PA for all categories (2003-2017).

Over a period of 2003-2017, the following companies rank in the top 10:



Except for Magic Leap, the companies in the above top 10 list represent the who's who in the tech field, with LG Electronics almost making the cut at 11th place with 67 P/PA.

Table 4. Number of times each company from among the top 10 companies appeared on the top 5 list of companies with the highest number of P/PA for each category (2003-2017).

Company	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Total
1. Microsoft	15	4	2	2	--	23
	(Cats. 1, 2, 3, 4, 5, 6, 7, 8, 12, 15, 16, 19, 22, 25, and 26)	*(Cats. 9, 10, 17, and 27)*	*(Cats. 21 and 28)*	*(Cats. 13 and 23)*		
2. Sony	1	6	4	5	4	20
	(Cat. 17)	*(Cats. 2, 6, 7, 13, 15, and 30)*	*(Cats. 1, 5, 8, and 28)*	*(Cats. 3, 12, 16, 19, and 22)*	*(Cats. 4, 9, 18, and 23)*	
3. Samsung	1	5	8	1	1	16
	(Cat. 9)	*(Cats. 5, 8, 15, 23, and*	*(Cats. 2, 3, 4, 7, 17, 19, 22, and 26)*	*(Cat. 25)*	*(Cat. 6)*	
4. Qualcomm	1	1	3	3	3	11
	(Cat. 25)	*(Cat. 1)*	*(Cats. 6, 15, and 28)*	*(Cat. 2, 19, and 23)*	*(Cats. 3, 5, and 8)*	
5. Magic Leap	2	4	2	1	--	9
	(Cats. 10 and 11)	*(Cats. 3, 4, 16, and 27)*	*(Cats. 12 and 19)*	*(Cat. 17)*		
6. Google	--	--	2	3	4	9
			(Cats. 23 and 28)	(Cats. 6, 7, and 16)	(Cats. 10, 15, 17, and 19)	
7. IBM	--	2	1	3	2	8
		(Cats. 21 and 30)	(Cat. 26)	(Cats. 5, 8, and 17)	(Cats. 1 and 19)	
8. Intel	1	--	1	1	4	7
	(Cat. 21)		(Cat. 19)	(Cat. 1)	(Cats. 2, 15, 22, and 23)	
9. Nokia	--	--	2	2	3	7
			(Cats. 9, 23)	(Cats. 17 and 22)	(Cats. 7, 15, and 19)	
10. Oculus VR	--	1	2	1	--	4
		(Cat. 19)	(Cats. 10 and 16)	(Cat. 4)		

** In parentheses are category numbers corresponding to MR categories shown in Fig. 1, p. 7*

Microsoft is ranked 1st in 12 categories, 2nd in 3 categories, and 3rd in 5 categories.

Overall, it is ranked in the top 5 in 25 MR categories.

Table 4 highlights **Microsoft**'s dominance in the MR field in terms of its patent portfolio. Microsoft is ranked 1st in 12 categories, 2nd in 3 categories, and 3rd in 5 categories. Overall, it is ranked in the top 5 in 25 MR categories.

In contrast, **Sony** (ranked 2nd based on the number of times it was in the top 5 companies with the most number of P/PA in various categories) was only ranked in the top 5 in 20 categories (versus 23 for Microsoft). Also, it ranked 1st in only 1 category versus Microsoft's 1st place ranking in 15 categories.

Magic Leap, which ranked 2nd to Microsoft in terms of P/PA over the 2003-2017 period, ranked only 4th overall, having only 9 categories in which it ranked in the top 5.

Apple is an interesting case. It has recently been touted in the press as a soon-to-be major MR player. It has also been heavily promoting its MR capability. But it constantly lags compared to its peer companies Microsoft, Sony, Google, Qualcomm, and Intel in terms of the number of P/PA they own, whether measured over the 2003-2017 or 2011-2016 period.

" Apple has been recently touted in the press as a soon-to-be major MR player. It has been heavily promoting its MR capability. But it constantly lags compared to its peer companies Microsoft, Sony, Google, Qualcomm, and Intel in terms of number of P/PA they own."

Table 5. Rankings of each of the top 10 Companies in terms of the number of P/PA for each of the top 10 categories (2003-2017).

Company	Automation of Actions and Processes	Data Processing	Content Presentation	Display Systems	System Management	Coordinate and Depth Measurement Systems	Interface	Content Creation	Communication Systems	Optical Systems	Other L1 Categories	Total # P/PA
1. Microsoft	**1** (164)	**1** (119)	**1** (127)	**1** (191)	**1** (68)	**1** (91)	**1** (71)	**1** (72)	**2** (22)	**2** (52)	(122)	**1099***
2. Sony	**3** (94)	**2** (66)	**4** (45)	**5** (38)	**3** (45)	**2** (47)	**2** (31)	**3** (23)	**5** (10)	**11** (1)	(56)	**456**
3. Magic Leap	**31** (1)	**10** (25)	**2** (70)	**2** (120)	**13** (8)	**8** (16)	**7** (16)	**8** (15)	**13** (2)	**1** (114)	(63)	**450**
4. Samsung	**8** (43)	**3** (58)	**3** (61)	**3** (43)	**2** (48)	**5** (26)	**3** (26)	**2** (34)	**1** (25)	**8** (4)	(39)	**407**
5. Qualcomm	**2** (95)	**4** (50)	**5** (35)	**9** (18)	**5** (17)	**3** (32)	**8** (15)	**5** (20)	**8** (7)	**11** (1)	(23)	**313**
6. Google	**6** (51)	**6** (36)	**6** (33)	**6** (31)	**13** (8)	**4** (31)	**4** (22)	**7** (16)	**8** (7)	**5** (9)	(21)	**265**
7. IBM	**5** (54)	**6** (36)	**8** (26)	**17** (5)	**4** (23)	**7** (19)	**6** (19)	**4** (22)	**11** (4)	**0**	(19)	**227**
8. Intel	**4** (60)	**5** (41)	**8** (26)	**14** (8)	**7** (15)	**10** (13)	**9** (12)	**10** (13)	**8** (7)	**0**	(26)	**221**
9. Nokia	**7** (48)	**10** (25)	**9** (24)	**16** (6)	**10** (11)	**9** (15)	**5** (20)	**13** (10)	**3** (15)	**10** (2)	(20)	**196**
10. Oculus VR	**27** (5)	**18** (8)	**22** (6)	**4** (42)	**10** (11)	**6** (20)	**10** (11)	**21** (2)	**0**	**3** (21)	(14)	**140**
Others	1402	1210	1191	714	945	810	786	777	482	181	2074	10572
TOTAL # P/PA	**2017**	**1674**	**1644**	**1216**	**1199**	**1120**	**1029**	**1004**	**581**	**385**	**2477**	**14346**

**Numbers under last row counts the P/PA more than once when the PPA are assigned to more than one category.*

As Table 5 shows, **Microsoft** ranked 1st in the following categories (from among the top 10 categories shown on Fig. 1):

Automation of Actions and Processes	Data Processing	Content Presentation	Display Systems	System Management	Coordinate and Depth Measurement Systems
53	119	127	164	68	91

Table 6. Ranking of the top 10 companies in terms of number of patents, PA, and P/PA for all categories (2003-2017).

Company	Patents (Ranking)	Patent Applications (Ranking)	Total P/PA 2003-2017 (Ranking)	Total P/PA 2012-2017 (Ranking)
1. Microsoft	218 (1)	196 (2)	414 (1)	258 (1)
2. Magic Leap	10	210 (1)	220 (2)	211 (2)
3. Samsung	60 (3)	112 (3)	172 (3)	112 (3)
4. Sony	73 (2)	85 (4)	158 (4)	96 (4)
5. Qualcomm	58 (5)	52 (8)	110 (5)	67 (8)
6. Google	39 (7)	62 (5)	101 (6)	66 (9)
7. IBM	37 (9)	53 (7)	90 (7)	69 (7)
8. Intel	37 (9)	51 (9)	88 (8)	72 (6)
9. Nokia	32	45	77 (9)	33
10. Oculus VR	2	102 (6)	104	103 (8)

2003-2017

P/PA and Patents

MICROSOFT

Microsoft has almost twice the total number of **P/PA** at 414 over the 2003-2017 period compared to the 2nd-ranked Magic Leap's 220 P/PA.

In terms of number of patents (only), **Microsoft** has:
67% more patents than 2nd-ranked Sony
72% more patents than 3rd-ranked Google
73% more patents than 4th-ranked Qualcomm

SAMSUNG

For **Samsung**, 3rd-ranked company in terms of total number of P/PA, 35% are **patents** (60 out of 172 total P/PA). Sony goes up from 4th in terms of number of P/PA to 2nd place in terms of number of patents. Qualcomm, 5th in terms of P/PA, is also 5th in terms of number of patents.

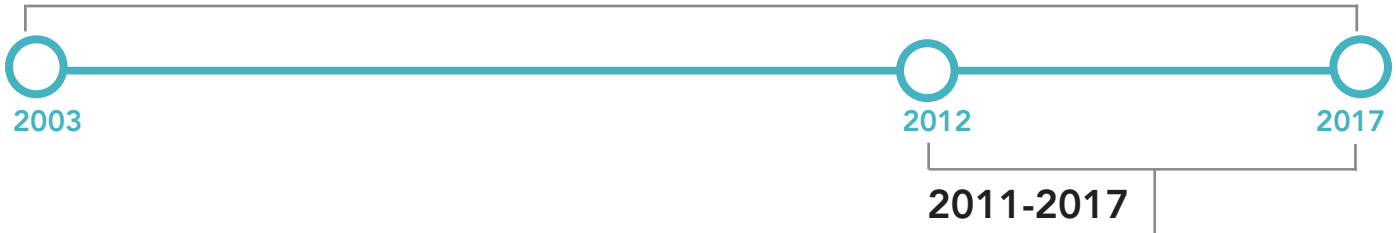
SONY

Sony goes up from 4th in terms of number of P/PA to 2nd place in terms of number of patents.

QUALCOMM

Qualcomm, 5th in terms of P/PA, is also 5th in terms of number of patents.

In terms of PA, Magic Leap leads, with 7% more than the 2nd-ranked Microsoft and almost twice that of 3rd-ranked Samsung.



2011-2017

Considering only the last 5 years covering 2012-2017, the same companies are in the top 4 in terms of total number of P/PA, with **Microsoft** again leading with 258, Magic Leap with 211, Samsung with 112 P/PA, and Sony with 96 P/PA .

This time, both Oculus VR and Intel are neck and neck with 75 and 72, respectively, in 5th and 6th place. Qualcomm has been deposed from the top 5, being now ranked 8th with 67.

The curious thing is **Apple** is nowhere to be found among the top 10 companies in terms of P/PA over the 2012-2017 period (despite Apple's being now frequently touted as a soon-to-be major AR player). One possible explanation is many of its newly acquired P/PA are still assigned under the names of the companies that it acquired during the 2015-2016 period.

IBM is at 7th, Intel at 8th, and Google at 9th place managed to stay put in the top 10 with 66 P/PA, tied with DAQRI, an AR company established in 2010.

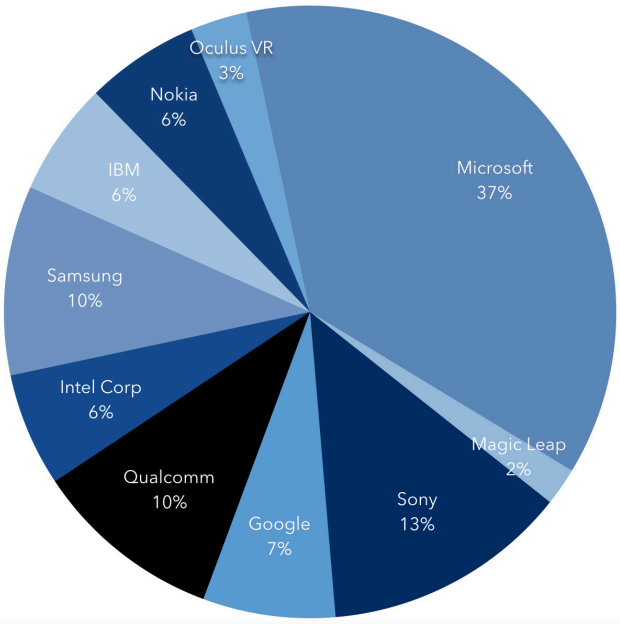


Fig. 4. Percentage of patents covering all categories for the top 10 companies (2002- 2016).

Fig. 4 highlights how dominant Microsoft is in MR. In terms of patents assigned to it over the 2003-2017 period, no other company came close. Sony and Samsung, which are ranked a distant 2nd and 3rd, only have about 1/3 the number of patents Microsoft has.

Table 7A. Top companies in terms of number of P/PA over 2003-2017 and 2011-2016 periods.

2003-2017	2012-2017	% of P/PA 2012-2017 (relative to total P/PA over entire 2003-2017)
1. Microsoft (414)	1. Microsoft (258)	62%
2. Magic Leap (220)	2. Magic Leap (211)	96%
3. Samsung (172)	3. Samsung (112)	65%
4. Sony (158)	5. Sony (96)	61%
5. Qualcomm (110)	4. Oculus VR (75)	

Out of Microsoft's 414 P/PA over the last 14 years, 62% (258) were from 2012-2017. Thus, Microsoft's patent filing activity has significantly picked up during the last 5 years or so. Samsung's patent filings showed a similar increase as Microsoft's, increasing by 65% (112 versus 172) over the same periods.

Sony also showed a similar increase as Microsoft's with 61% (96 versus 158).

Magic Leap is a startup that was founded only in 2011. Thus, its 96% jump in the number of P/PA it owns is mainly due to its having only 9 P/PA over 2003-2011, which increased to 220 by 2017.

Table 7B. Top companies in terms of number of patents over 2003-2017 and 2011-2016 periods.

2003-2017	2012-2017	% of P/PA 2012-2017 (relative to total P/PA over entire 2003-2017)
1. Microsoft (218)	1. Microsoft (109)	50%
2. Sony (73)	3. Sony (31)	42%
3. Samsung (60)	5. Intel (27)	
4. Amazon (59)	2. Amazon (33)	56%
5. Qualcomm (58)	4. Qualcomm (28)	48%

In terms of patents, Magic Leap, which is 2nd-ranked behind Microsoft in terms of P/PA, is not even in the top 20 companies in terms of patents owned. Magic Leap has mostly patent applications over the period 2012-2017, which again, is hardly surprising since Magic Leap was founded only in 2011.

Microsoft and Amazon have the highest percentage of patents over the 2012-2017 period relative to the total number of patents they own during the entire 2003-2017 period.

Note that the following companies have the highest number of patents (all categories) granted by the USPTO as of 2017. As can be seen from the list, Apple is also a laggard when it comes to total US patents granted.

1.	*IBM*	*9.043 patents*
2.	*Samsung*	*5,837*
4.	*Intel*	*3,023*
6.	*Qualcomm*	*2,628*
7.	*Google*	*2,457*
8.	*Microsoft*	*2,441*
11.	*Apple*	*2,229*
12.	*Sony*	*2,135*

Source: IFI Claims

Table 7C. Top companies in terms of number of patent applications (PA) over 2003-2017 and 2011-2016 periods.

2003-2017	2012-2017	% of P/PA, 2012-2017 *(relative to total P/PA over entire 2003-2017)*
1. Magic Leap (210)	1. Magic Leap (203)	97%
2. Microsoft (196)	2. Microsoft (149)	76%
3. Samsung (112)	3. Samsung (91)	81%
4. Sony (85)	4. Sony (65)	76%
5. Google (62)	5. Oculus VR (57)	

Magic Leap and Samsung showed the most significant increase in patent filings over the 2012-2017 period compared to the entire 2003-2017 period.

Osterhout Design Group ("Osterhout") was founded in 1999 as a technology incubator. It is one of the leading developers and manufacturers of MR-based mobile head-worn computing devices. In January 2014, Microsoft was reported to have paid up to $150 million for wearable computing IP assets from Osterhout directed to AR and head-mounted computers. The acquisition reportedly included over 81 patents with 20 issued patents and more than 70 patent applications filed in the U.S. and internationally.

Out of the 198 patent applications published by Osterhout after the IP asset acquisition by Microsoft, 41 were later granted as patents. These patents relate to optics, augmented reality and head-mounted technology. Osterhout has also developed three new models of head-mounted devices. In December 2016, Osterhout was able to raise $58 million trough a Series A funding round which involved strategic investors such as Vanfund Urban Investment & Development, Schenzhen O-film Technology, and 21st Century Fox.[6]

6 Tilley, Aaron. "Military Tech Company ODG Raises $58 Million To Grow Its Augmented Reality Business." Forbes, Forbes Magazine, 1 Dec. 2016, www.forbes.com/sites/aarontilley/2016/12/01/military-tech-company-odg-raises-58-million-to-grow-its-augmented-reality-business/#673a12155a33.

C. Microsoft: The MR Powerhouse

In terms of P/PA, Microsoft has more than twice that compared to the 2nd-ranked company, Magic Leap (414 total versus 220). Microsoft's top position in terms of the number of MR-related P/PA is not unexpected because Microsoft has been investing heavily in the field. Its Hololens product is one of the first MR products on the market that has shown significant market potential.

In the Market Segment categories (see Fig. 5, p.33), Microsoft ranked 1st or 2nd not only in Gaming, Collaborative Systems, Commerce, and Design, but also in Learning, Fitness, Social Network, Healthcare, and Entertainment. This suggests that Microsoft does not intend to limit its focus on certain market segments only. More likely, it plans to establish its presence in most, if not all, MR market segments in the same way it dominated the PC market via its Windows OS. At the very least, Microsoft is probably targeting to garner significant market share early on in as many market segments as possible. With this approach, it is more likely to avoid ending up with a tiny market despite its having many powerful competitors in the MR field. Its earlier miscalculations in the mobile phone arena has clearly taught Microsoft that being a laggard and not having a coordinated plan for developing an entire ecosystem for its clients is a likely recipe for failure.

It thus makes sense for Microsoft to try to replicate with MR what it has done with personal computers via its Windows, MS Office, Skype, Cortana, Xbox, and network services, and recently with cloud and AI among others, in the next few

> *"Microsoft wants to build an interoperable network of AR, VR, and MR headsets from different manufacturers, all talking to one another and running Windows 10 Universal Apps."*

> *"There are three prongs to this approach: Microsoft's first-party hardware (Hololens), the evolving software stack housed within the Windows MR platform, and Microsoft's third-party hardware partnerships with Acer, Asus, Dell, HP, and Lenovo to build $299 MR headsets running Windows 10. The first of these, the Acer Windows MR Development Edition headset, is already shipping to developers."*

years. As described in one article:[7]

> *"Microsoft's offering, with inside-out tracking (inherited from HoloLens) is a game changer at a $299 price point. Plus it doesn't need a brand new PC to run it, which makes it a genuine consumer product."*

> *"Microsoft's Windows 10 VR is a game changer for the PC/console VR market with its inside-out tracking, low price and basic platform requirements, and the company is staying true to its Windows playbook with partners HP, Dell, Lenovo, Acer and Asus making the hardware. There's also a good chance Xbox One Scorpio will see a Windows VR headset bundle at launch to drive console VR growth."*

According to another article:[8]

In the healthcare arena, most consumers would probably not consider Microsoft as a major healthcare technology player. In fact, Microsoft has already been developing its healthcare business. It has, for example, been marketing its healthcare-focused enterprise solutions with various partners that include Doctors2U and Nuance. Microsoft considers the healthcare industry as being already at an inflection point where technology can revolutionize the way things are done, e.g., by introducing significant efficiency gains and human error reductions through use of advanced electronic health records and medical diagnostic systems.

7 http://sea.pcmag.com/feature/15007/microsofts-MR-plans-go-far-beyond-hololens.
8 "The reality of VR/AR growth," T. Merel, Jan. 11, 2017, https://techcrunch.com/2017/01/11/the-reality-of-vrar-growth/.

One article highlighted the immense market size of the healthcare industry: [9]

"Healthcare is one of the world's largest industries. Globally, the size of the healthcare market can be estimated to be between five trillion to six trillion dollars. Three trillion, or over half of which is spent in the United States, meaning that just 5% of the world's population accounts for over 50% of the world's total health bill. To further compound the impact of healthcare on the US economy, it is well known that the US spends anywhere between 16 to 18% of its GDP on healthcare, which is over twice what most developed countries spend."

"As one example of how large the healthcare industry actually is globally, consider this: all spending on products and services concerning the heart (pharmaceuticals such as beta-blockers, cardiovascular surgery procedures. etc) is actually larger than the entire automotive industry. Therefore it is no wonder that both entrepreneurs and investors have traditionally looked at healthcare as a lucrative industry to disrupt and invest in."

As mentioned previously, healthcare is figuring prominently in the MR arena. With Microsoft's formidable expertise and talent pool in AI, it is poised to become a major player in the healthcare industry via its AI-enhanced MR products and services, e.g., AI-enhanced medical diagnostic systems and electronic health record systems.

Microsoft's number one ranking in Gaming with 25 P/PA is also no surprise, its gaming business under its Entertainment and Devices Division having been one of its major business segments for many years now. In the Gaming category, Sony is its only competitor that really counts for now, although Apple could soon pose a major threat to the Microsoft-Sony duopoly in the MR Gaming arena.

D. Additional Information About Other MR Companies

MAGIC LEAP

As most people in the MR field already know, Magic Leap is a Florida-based company that has leapt into prominence early on because of significant financial backing from blue-chip companies such as Google, JPMorgan, and Alibaba. Recently, however, the company has been beset by controversies and setbacks partly due to its failure to launch a product since its inception in 2011. Still, it has recently acquired additional funding and has again been pumping up the volume on its supposed soon-to-be-released small form factor product.

With 220 P/PA, Magic Leap has about 22% more P/PA than the 3rd-ranked company, Samsung, which has 172. Magic Leap is notable in that although it is ranked 2nd in terms of P/PA, it has a paltry 10 patents. Those patents accounts for a meager 4.6% of its total of 220 P/PA, 210 of which are patent applications. Compared to Microsoft, Magic Leap's 10 patents is merely 5% of Microsoft's total of 218 MR-related patents. Magic Leap does have relatively many PA (210) over the period 2001-2016, second only to Microsoft.

For Magic Leap, its highest ranked categories in terms of PA over the 2003-2017 period are the following:

1.	Display Systems	116 PA
2.	Optical Systems	111
3.	Content Presentation	66
4.	Healthcare	33

9 "Seven global medical technology trends to look out for in 2017," M. Al-Razouki, Dec. 22, 2016, https://www.weforum.org/agenda/2016/12/seven-global-medical-technology-trends-to-look-out-for-in-2017/.

One thing that might strike one as odd is Magic Leap's having the **4th highest number of P/PA in the Healthcare category**. This is because healthcare is not an industry sector which most people would associate Magic Leap with. It also appears to be the only company that is investing significantly in healthcare-related MR applications. (The Healthcare category includes the 1st-level sub-categories Medical Systems, Personal Health Management, and Therapy and the 2nd-level sub-categories Diagnostic Systems, Electronic Health Records, Non-surgical Medical Systems, Surgery, Surgical Training, and Telemedicine.)

In fact, Magic Leap's CEO Rony Abovitz was cofounder of the biotech startup Mako Surgical, which was sold to Stryker for $1.65 billion. Also, in August 2017, Magic Leap posted a wanted ad for a healthcare application developer responsible for "architecting, developing, testing and modifying software designs in mobile-network based MR healthcare applications."[10] These show that Magic Leap is intent on further developing healthcare-related MR products and services.

But Magic Leap—although ranked 1st in Healthcare and Optical Systems and 2nd in Display Systems and Content Presentation—is still merely a startup, although one backed by some of the biggest names in the industry. Thus, its survival rests largely on its ability to come up with at least one blockbuster product.

GOOGLE

While many viewed the original commercial version of Google Glass as a failed experiment and a product that was way ahead of its time, Google gained real-life insights on what people do not want in an MR system. But instead of reintroducing an upgraded version of Google Glass for the consumer market, Google decided to redirect its MR efforts to the industry and enterprise segments.

"Instead of reintroducing an upgraded version of Google Glass for the consumer market, Google decided to redirect its MR efforts to the industry and enterprise segments."

The new version of Google Glass is a lightweight wearable device that attaches to eyeglass frames. It is designed to make manual tasks easier by providing contextual information directly on the job site. The new version of Google Glass is now being used in the manufacturing industry for consulting instruction manuals, reminders, and checklists. It is also being used for communicating in real-time and for transmitting and receiving files such as images and videos, also in real-time. The many applications of Google Glass extend to business-related field operations, healthcare, manufacturing, education, and inventory management.

Google is also continuing to improve its Daydream View mobile VR headset/controller Tango, Google's fundamental enabling technology for both VR and AR, e.g., for mobile phone AR, was reported last year to be shutting down by March 2018. Google has since introduced a new augmented reality system known as ARCore.

"The applications of Google Glass extend to business field operations, healthcare, manufacturing, military field operations, education, and inventory management.

Daydream is Google's platform for mobile VR. Daydream-ready phones such as Samsung's high-end smartphones are already available on the market, with more phone manufacturers expected to incorporate Daydream. Stand-alone headsets, which is a new device category built by Google's partners, are also coming to Daydream later this year. Further, Daydream already has more than 150 apps. With upcoming new release for all headsets, Daydream will provide features that would, for example, allow one to capture what they see and share them with others, watch YouTube videos in VR, and share their virtual experiences with others.

10 https://www.linkedin.com/jobs/view/430864092/.

APPLE

In terms of MR-related P/PA, whether over the 2003-2017 or 2012-2017 period, Apple is consistently behind its competitors Microsoft, Sony, Google, Qualcomm, Samsung, and Intel.

It is important to note however, that Apple has acquired several small companies such as Metaio, Prime Sense, Faceshift, Flyby Media, Emotient, and Real Face. Metaio's focus has been on developing AR-based technology, but the other companies' 3D technology that covers sensing, mapping, and interface could prove to be important in various AR applications as well. This shows that part of Apple's MR strategy involves acquiring externally any MR technology that they do not presently have, rather than developing all its MR tech in-house to beef up its MR capabilities.

Apple has made significant company acquisitions involving small companies such as Metaio, Prime Sense, Faceshift, Flyby Media, Emotient, and Real Face.

Apple's CEO, Tim Cook, believes that AR is going to be bigger than VR because AR allows people to interact with the real world while using the technology. Still, he thinks VR has interesting applications in education and gaming.

Apple is also promoting ARKit among developers. ARKit is a set of software development tools that allows developers to create AR apps for iOS. AR apps and games developed using ARKit are readily available in iOS 11. With ARKit, an iOS device can identify a surface, e.g., a table, and then add virtual objects to it.

"Apple's CEO, Tim Cook, believes that AR is going to be bigger than VR because AR allows people to interact with the real world while using the technology."

Although Apple believes that AR is going to be bigger than VR, Apple is introducing support for VR in Metal 2 (an update of Apple's Metal, a low-level, low-overhead hardware-accelerated graphics compute API). It is also partnering with the creators of the VR gaming platform Valve and Unreal, as well as Unity (a company behind the popular game developer tool of the same name), to introduce VR creation tools to the Mac. Apple's latest Macs and upcoming iMac Pro are also said to be designed to support existing VR hardware and VR content creation. This suggests that Apple plans to develop some type of VR hardware in the future.

Accordingly, Apple now employs hundreds of VR and AR experts working on both hardware and software. Its recent hires have previously worked on Oculus and HoloLens and for companies like Lucasfilm, Amazon (from the VR team), and the 3D animation company Weta Digital.

"Part of Apple's MR strategy involves acquiring externally any MR technology that they do not presently have, rather than developing all its MR tech in-house to beef up its MR capabilities."

Table 8. Examples of companies recently acquired by Apple.

Name of Acquired Company	Date of Acquisition	Product/Technology Developed by Acquired Company
Metaio	May 2015	Metaio SDK - allows developers to use content without prior encryption. No offline tools or server side encryption is needed when generating and deploying 3D assets and tracking patterns. The SDK is currently supported on Android, iOS and Windows with an additional plugin for development in Unity for Android, iOS, Windows and OS X platforms. Metaio Creator - an augmented reality software that allows users to create a complete AR scenario without specialized programming knowledge through a drag and drop interface. Metaio CVS - manages marker searching online for instant image recognition Metaio Cloud - allows developers to store and manage content online. Junaio – an AR browser which allows users to experience mobile augmented reality through multiple channels on their mobile devices. Metaio Engineer - provides solutions for technical assignments from the visualization of future facilities within a current production environment over illustrating working instructions on a component to deviation measurement between virtuality and reality.
Flyby Media	Early 2016	App worked with Google's 3D sensor-equipped Project Tango smartphone, which permits annotations to be attached to real world objects and viewed by others using one of Google's devices, e.g., a person could take an image of a scene or landmark and annotate and attach the annotation to it. App could recognize different objects that were imaged, which could be used in apps like Apple's Photos and Maps. Technology can be used for "indoor mapping and navigation, autonomous navigation for drones and automotive vehicles, and advanced tracking for Head Mounted Display (HMD) systems."
Prime Sense	November 2013	3D depth technology and motion sensing capabilities used in Microsoft's initial Kinect platform 3-D sensing; 3-D interface; 3D-mapping; distance-varying illumination and imaging techniques for depth mapping; object reconstruction; multiprocessor system-on-a-chip for machine vision algorithms Motion-based controls for software interfaces, but it's also able to do things like measure virtual objects and provide relative distances or sizes, useful for augmented reality applications like interactive gaming, indoor mapping PrimeSense technology can also create highly accurate 360-degree scans of people and objects, potentially useful for virtual reality applications.

Emotient	January 2016	Emotient technology uses AI and machine learning to read human emotion, features that have been used in the real world by advertisers to determine emotional reactions to advertisements. Allows better facial detection in the Photos app to analyzing customer feelings in Apple retail stores to unlocking iOS devices, but it also has potential AR/VR uses. Could be used to analyze and transform facial expressions for the creation of virtual avatars, useful for social media purposes and games.
SensoMotoric Instruments (SMI)	June 2017	SensoMotoric Instruments is an eye-tracking firm which created a kit for HTC Vive VR headset.
Vrvana	Nov 2017	Vrvana specializes in AR and has developed the Totem headset.

E. MR Market Segment Categories

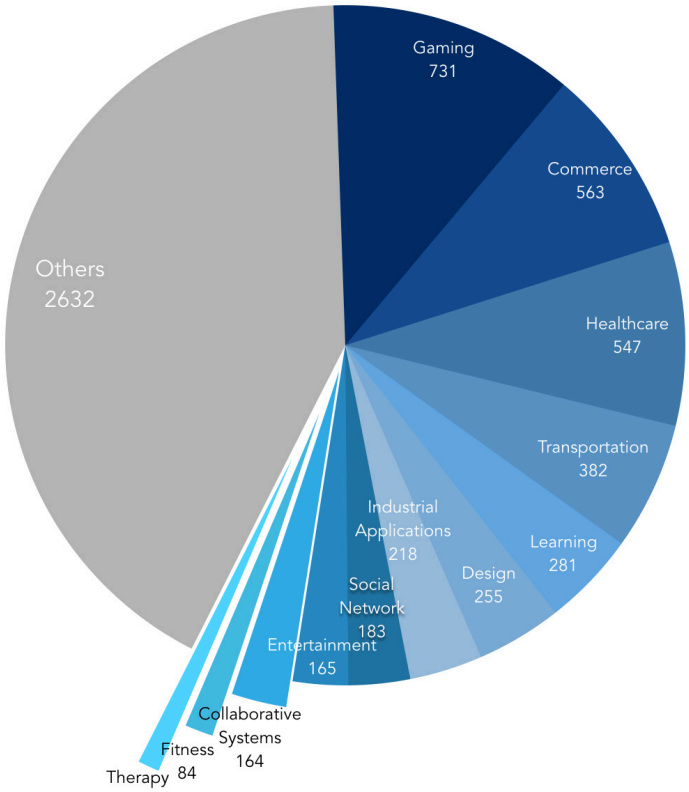


Fig. 5. Number of P/PA for the various Market Segment categories (2003-2017).

For those P/PA whose claims are expressly directed to specific applications or market segments (e.g., their claims recite applications of MR systems or processes in gaming, healthcare, etc.), the following are the top market segment categories:

Gaming	Commerce	Healthcare	Transportation	Learning
731	563	547	382	281

If there is any sort of surprise from the rankings, it is that Industrial Applications (7th), Social Network (8th), and Entertainment (9th) are ranked lower than, say, Healthcare (3rd), Transportation (4th), and Design (6th). Social Network is poised to become a massive MR market segment. Facebook, Google, Apple, and Microsoft, not to mention Samsung, are thus expected to be competing aggressively to grab the biggest slices of that category. There is no question Entertainment will become an enormous market, but it will have to wait until MR's many technical kinks are straightened out and content becomes widely available. Industrial Applications is already quietly becoming one of MR's early success stories, and it's just going to get even bigger as more applications are soon enabled by a wider gamut and more sophisticated versions of MR-related products and services.

F. Patents with the Highest Number of Forward Citations

FORWARD CITATIONS (2003-2017)

Table 9. Patents with the highest number of forward citations (2003-2017).

Publication numbers	Assignee	Effective Filing Date	Grant Date	Number of Forward Citations
1. US9183560	Abelow, Daniel H.	05/28/2010	11/10/2015	596
2. US8547401	Sony	08/19/2004	10/01/2013	320
3. US8400548	Apple	01/05/2010	03/19/2013	310
4. US8180396	Yahoo! Inc.	10/18/2007	05/15/2012	293
5. US8786675	Spy Eye	01/23/2008	07/22/2014	286
6. US7567844	Honeywell International Inc.	03/17/2006	07/28/2009	284
7. US9384594	Qualcomm	03/29/2011	07/05/2016	260
8. US7564469	Nantworks	08/29/2005	07/21/2009	229
9. US8027518	Microsoft	06/25/2007	09/27/2011	207
10. US7672543	Ricoh	08/23/2005	03/02/2010	207
11. US7680694	III Holdings 1	03/11/2004	03/16/2010	191
12. US8576276	Microsoft	11/18/2010	11/05/2013	187
13. US9185361	Curry, Gerald	07/29/2008	11/10/2015	185
14. US8411149	Alterface SA	08/03/2008	04/02/2013	185
15. US8012023	Microsoft	09/28/2006	09/06/2011	173

Aside from having the most number of P/PA over 2003-2017 (218 P/PA), Microsoft also has

- the most number of patents with 100 or more forward citations (13 P/PA)
- 28 patents with forward citations ranging from 50-99
- 3 patents among the top 15 P/PA with the highest number of forward citations (US8027518, US8576276, and US8012023 with 207, 187, and 173 FC, respectively).

Sony and Apple each has one patent in the top 15, with 320 (US8547401) and 310 (US8400548) forward citations, respectively.

Table 10. Claim 1 of some patents with high number of forward citations.

Patent/PA Number Effective Filing Date Assignee	Claim 1
1. **US9384594** "Anchoring virtual images to real world surfaces in augmented reality systems" 29 Mar 2011 **Qualcomm** Forward Citations: 260	1. A **method for rendering virtual images** in an augmented reality system, comprising: **capturing an image** with a body mounted camera; **capturing spatial data** with a body mounted sensor array; **recognizing an object** within the captured image; **receiving a first user input** selecting a first anchor surface in the captured image that corresponds to a first surface located in the image; **calculating parameters including distance and orientation** with respect to the body mounted camera that correspond to the first anchor surface; **displaying a virtual object so the virtual object appears anchored to the selected first anchor surface;** receiving a second input selecting a second anchor surface within the captured image that is different from the first anchor surface, wherein the second anchor surface corresponds to a second surface located in the image and the first and second surfaces are different; calculating parameters including distance and orientation with respect to the body mounted camera that corresponds to the second anchor surface; and **displaying the virtual object so the virtual object appears to the user to be anchored to the selected second anchor surface and moved from the first anchor surface.**
2. **US8576276** "Head-mounted display device which provides surround video" 18 Nov 2010 **Microsoft** Forward Citations: 187	1. A user display apparatus, comprising:: **a head-mounted display unit** including a see-through lens; an **augmented reality emitter**, associated with the head-mounted display unit, which emits light to a user's eye, the light represents augmented reality video images; a **camera** which provides an image of a video display screen the user is looking at; at least one **sensor** which tracks an orientation and location of a head of the user; and at least one **control circuit which identifies edges of the video display screen** based on the image provided by the camera, and controls the augmented reality emitter responsive to the at least one sensor, to display the augmented reality video images **spatially synchronized with the edges of the video display screen and temporally synchronized with video content displayed by the video display screen.**

3. US8814691 "System and method for social networking gaming with an augmented reality" 28 Feb 2010 **Microsoft** Forward Citations: 141	1. A system, comprising: an interactive head-mounted device configured to be worn by a user, wherein the device includes an **optical assembly** configured to display virtual content and through which at least a portion of a surrounding environment is viewable, a **camera** mounted on the device, an **integrated processor** for processing content for display to the user, and an **integrated image source** for introducing the content to the optical assembly; and a **wireless communications facility** that accesses a database of users, wherein the interactive head-mounted device is adapted for at least one of initiating and **joining a game of an online gaming site** with at least one additional interactive head-mounted device, and wherein the integrated processor and the camera are adapted for **capturing and interpreting gestures** of a user during use and for **receiving gesture-related data** from the at least one additional interactive head-mounted device during the game.
4. US9292973 "Automatic variable virtual focus for augmented reality displays" 8 Nov 2010 **Microsoft** Forward Citations: 126	1. A method for displaying virtual objects with variable focus by an augmented reality system comprising: identifying by one or more processors a three dimensional location of one or more virtual objects within a user field of view of a near-eye display device of the augmented reality system, the near-eye display device comprising a **microdisplay assembly** and a display unit optically coupled to receive one or more images from the microdisplay assembly, the microdisplay assembly including one or more **light processing elements** including at least one optical element and a microdisplay unit aligned in an optical path with the at least one optical element; determining by the one or more processors a three dimensional current focal region of a user wearing the near-eye display device within the user field of view; identifying which of the one or more virtual objects are in the current focal region of the user based on the three dimensional locations of the one or more virtual objects within the user field of view; adjusting a focal region of a the microdisplay assembly for generating image data in the current focal region by moving a position of the one or more light processing elements in the optical path of the microdisplay assembly under control of the one or more processors; generating a series of **layered image data** at different focal regions, by the microdisplay assembly, for each of the one or more virtual objects, such that the one or more **virtual objects identified as being in the current focal region at the adjusted focal region are generated in focus** and the one or more **virtual objects outside of the focal region are generated blurred**; and receiving from the microdisplay assembly and displaying by the display unit the generated image data of the one or more virtual objects.

5. US8264505 "Augmented reality and filtering" 28 Dec 2007 **Microsoft** Forward Citations: 104	1. A system that facilitates augmenting reality, comprising: a processor; a memory; an **information gathering component** stored in the memory and executed by the processor having a reality monitor component that **gathers real-world data for at least one real-world object** and a **query component** stored in the memory and executed by the processor that establishes a **query based at least in part on context-related information for the real-world data**, the query providing access to virtual-world data supplied by one or more remote sources; and an **interface component** stored in the memory and executed by the processor and configured to receive at least a portion of the real-world data and the virtual-world data from the information gathering component, the interface component having a **consolidation component that aggregates the received real-world and virtual-world data**, the interface component establishes, in real-time, an augmented-reality experience in which **at least a portion of the received real-world data is overlaid with at least a portion of the received virtual-world data.**

G. Additional Information of Some Highly-Cited Patents Based on the Patents' Prosecution History

1. US Patent No. 9,182,596

"See-through near-eye display glasses with the optical assembly including absorptive polarizers or anti-reflective coatings to reduce stray light"

Filed: Mar. 26, 2012 (actual filing date)
Granted: Nov. 10, 2015
Original Assignee: Osterhout Group, Inc.
Current Assignee: **Microsoft Technology Licensing, LLC**
Number of forward citations - **95**

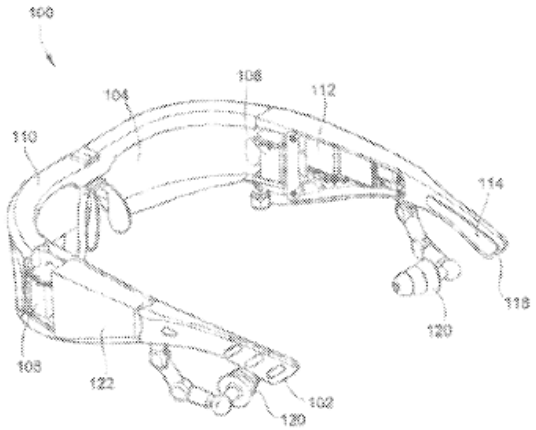


FIG. 1

This patent claims priority to 4 CIP and 19 provisional applications. It has 241 pages, 122 figures (same number as that of US Patent No. 8,964,298 below), about 12 pages of cited references (consisting of 1,219 cited patent references and 134 cited non-patent references), 3 independent claims (claims 1, 4, and 11) and 17 dependent claims (2 depending on claim 1, 6 depending on claim 4, and 9 depending on claim 11).

1. An interactive head-mounted device, comprising:
   an optical assembly through which a surrounding environment is viewable, the optical assembly including a **partially transparent curved mirror** optically intermediate the surrounding environment and a user's eye and a polarizing beam splitter optically intermediate the partially transparent curved mirror and the user's eye;
   an integrated processor for handling virtual content for display;
   an integrated image source for introducing the virtual content to the optical assembly; and
   an absorptive polarizer optically intermediate the integrated image source and the polarizing beam splitter.

4. An interactive head-mounted device, comprising:
   an optical assembly including a **curved mirror through which a surrounding environment is viewable;**
   an integrated processor for handling **virtual content for display;**
   an i**ntegrated image source for introducing the virtual content to the optical assembly, the curved mirror of the optical assembly configured to reflect the virtual content to a user's eye;** and
   an anti-reflective coating in the optical assembly to reduce stray light

11. An augmented reality system, comprising:
   an image source for projecting virtual content, the image source including an absorptive polarizer;
   a **curved mirror** optically intermediate a surrounding environment and a user's eye; and
   a beam splitting layer optically intermediate the image source and the curved mirror on a reflection path and optically intermediate the curved mirror and the user's eye on a transmission path;
      wherein **virtual content projected from the image source** reflects off the beam splitting layer on the reflection path to the curved mirror, and **reflects off the curved mirror** through the beam splitting layer on the transmission path to the user's eye; and
      wherein light from the surrounding environment passes through the curved mirror and the beam splitting layer on the transmission path to the user's eye.

Claim 4 appears broader than claim 1, the former not reciting a "polarizing beam splitter" and an "absorptive polarizer." In contrast to claim 1, claim 4 expressly recites an anti-reflective coating for reducing stray light.

The HMD claimed in claim 4 clearly covers an augmented reality HMD because the recited curved mirror is at least partially transparent, which allows viewing of the user's surrounding environment and overlaying of virtual content on the display. This claim covers basic HMD components that includes an optical assembly, processor, and image source, with additional limitations that recite the mirror as being curved and the processor and image source as being integrated into the HMD.

To overcome the rejection of what was then claim 5 and is now claim 4, applicant added essentially two limitations into the previous claim 5: (a) curved mirror and (b) the curved mirror's being configured to reflect the virtual content to a user's eye. According to the applicant, these two features distinguished the invention from prior art cited by the Examiner.

The mirror's being curved is an advantageous feature according to the patent. For example, the patent states that '"[a] cassegrain reflector is a combination of a primary concave mirror and a secondary convex mirror. These reflectors are often used in optical telescopes and radio antennas because t**hey deliver good light (or sound) collecting capability in a shorter, smaller package**." (col. 50, 2nd par., lines 8-12)

A product comprising an interactive HMD that incorporates a curved mirror, or any process that makes use of it, would likely be covered by this patent.

2. US Patent No. 8,964,298

"Video display modification based on sensor input for a see-through near-to-eye display"

Filed: Sep. 26, 2012
Granted: Feb. 24, 2015
Original Assignee: Osterhout Group, Inc.
Current Assignee: **Microsoft Technology Licensing, LLC**
Number of forward citations - **376**

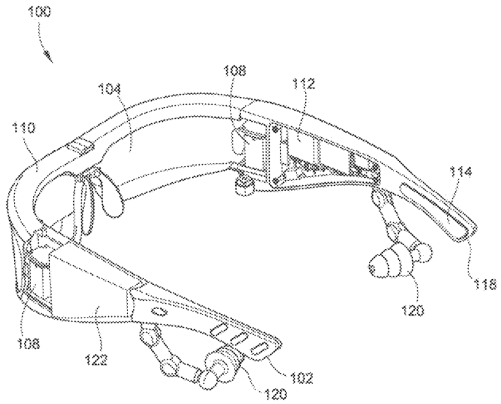


FIG. 1

This patent claims priority to 7 CIP and 31 provisional applications. It has 362 pages, 122 figures, about 12 pages of cited references, two independent claims (claims 1 and 8) and 6 dependent claims all depending on claim 1. Claim 1 differs from claim 8 in that the former recites "an environmental sensor," while the latter recites a "an integrated virtual image capture facility that images an aspect of the surrounding environment and provides the virtual content for display."

1. An interactive head-mounted device, comprising:
   an optical assembly through which a surrounding environment is viewable;
   an integrated processor for handling virtual content for display;
   an integrated image source for introducing the virtual content to the optical assembly; and
   an environmental sensor;
      wherein the integrated processor is adapted to initially display, via the integrated image source and the optical assembly, the virtual content with a display parameter having a first setting, and;
      wherein the integrated processor is adapted to display, via the integrated image source and the optical assembly, the virtual content with the display parameter having a second setting, different from the first setting, responsive to a change in the surrounding environment as recognized by the environmental sensor.

8. An interactive head-mounted device, comprising:
an optical assembly through which a surrounding environment is viewable;
an integrated processor for handling virtual content for display;
an integrated image source for introducing the virtual content to the optical assembly; and
an integrated virtual image capture facility that images an aspect of the surrounding environment and provides the virtual content for display;
wherein the integrated processor is adapted to initially display, via the integrated image source and the optical assembly, the virtual content with a display parameter having a first setting, and
wherein the integrated processor is adapted to display, via the integrated image source and the optical assembly, the virtual content with the display parameter having a second setting, different from the first setting, responsive to a change in the surrounding environment as recognized by the integrated virtual image capture facility.

In an Office Action dated Dec. 11, 2013, claims 1-12 were rejected under pre-AIA 35 U.S.C. 102b as being anticipated by US2007/0052672 (Ritter). Applicant overcome the rejections by amending the claims by incorporating the following two wherein clauses:

(a) "wherein the integrated processor is adapted to initially display, via the integrated image source and the optical assembly, the virtual content with a display parameter having a first setting"; and
(b) "wherein the integrated processor is adapted to display, via the integrated image source and the optical assembly, the virtual content with the display parameter having a second setting, different from the first setting, responsive to a change in the surrounding environment as recognized by the environmental sensor."

On p. 6 of the Response to the Office Action dated March 11, 2014, the applicant stated that:
(a) **"The claimed device allows the settings of a display parameter to be dynamically modified in response to a change in the surrounding environment."**
(b) "Ritter does not disclose this concept, and instead merely discloses a user-actuatable haptic sensor that provides input when a user touches the sensor."
(c) "Ritter does not disclose modifying a parameter of displayed virtual content responsive to any event, let alone a recognized change in the surrounding environment."

H. Examples of Patents with Broad Claims

Table 11. Examples of MR-related patents with broad claims.

Patent	Claim
1. **US6985168** 2003 **Qualcomm** "Intelligent method and system for producing and displaying stereoscopically-multiplexed images of three-dimensional objects for use in realistic stereoscopic viewing thereof in interactive virtual reality display environments" No. of forward citations (FC) - 78	7. A process for producing stereoscopically-multiplexed images of either real or synthetic 3-D objects for use in realistic stereoscopic viewing thereof, said process comprising the steps: (a) acquiring parameters specifying the viewing process of a viewer positioned relative to a display surface, said display surface having a micropolarizer array associated therewith; (b) using said acquired parameters to produce stereoscopically-multiplexed images of said real or synthetic 3-D objects wherein said stereoscopic multiplexed images maybe used in realistic stereoscopic viewing of said either real or synthetic objects.
2. **US8531447** 2007 **Cisco Technology, Inc.** "Reactive virtual environment" FC - 53	13. A computer-implemented method for dynamically displaying an immersive **collaborative environment**, comprising: monitoring context of a plurality of users; binding a subset of the users to an activity to dynamically group the plurality of users associated with the activity in a spatial representation without user intervention; and rendering the spatial representation that dynamically depicts a subset of the plurality of users as a function of context of the activity, the context of the plurality of users, and the context of the environment of the users, with a processor-implemented dynamic rendering component.

3. **US6982700** 2003 **Magic Leap** "Method and apparatus for controlling force feedback interface systems utilizing a host computer" FC - 51	1. A device comprising: a user manipulatable object moveable in at least one degree of freedom; at least one sensor operative to detect a position of said user maniputable object; at least one actuator operative to output a force based on a control signal; and a local controller in communication with said at least one sensor and said at least one actuator, and operative to: receive a force command, and output said control signal in response to said force command, wherein said force command describes a tactile sensation and comprises a deadband parameter that specifies a deadband region centered about the origin of the at least one degree of freedom.
4. **US8769437** 2009 **Google** "Method, apparatus and computer program product for displaying virtual media items in a visual media" FC – 32	1. A method comprising: receiving a first media content item that includes location information; determining a capture zone for the first media content item based upon the location information; receiving a second media content item that includes location information; and determining to render at a user interface a presentation of the second media content item within a presentation of the first media content item when the location information of the second media content item indicates that the second media content item is or was located within the capture zone.
5. **US9105083** 2012 **Google** "Changing the arrangement of text characters for selection using gaze on portable devices" FC – 23	1. A method comprising: displaying an arrangement of text characters on a screen of a portable device from which a user can select; sensing a user's gaze towards a part of the screen to make a text selection; and changing the arrangement of characters on the screen from which the user can next select; wherein the method further includes displaying, in said arrangement, less than a complete alphabet of text characters from which the user can select, and also providing a region that, when selected by the user, presents a virtual keyboard comprising a complete alphabet of text characters from which the user can select.

I. Examples of MR Products from Some of the Top 10 Companies

Table 12. Examples of Mixed Reality products from some of the top 10 companies with the most number of P/PA (2003-2017).

Top 10 Company	Brand Name or Trademark (Date Introduced)	Brief Description
1. Microsoft	**A. Hardware**	
	Microsoft HoloLens (2016 - Dev't edition)	"Microsoft HoloLens is the first self-contained, holographic computer, enabling you to engage with your digital content and interact with holograms in the world around you." Reference: https://www.microsoft.com/en-us/hololens
	Windows Mixed Reality Headsets (Aug 2017)	"Instead of scrolling through a menu to select things, the Windows Mixed Reality launcher requires the user to virtually explore a luxurious virtual home in order to discover and launch apps. These apps are scattered throughout the environment: one appeared in the living room, for example, while another was situated on the roof. It's Microsoft's attempt to create a virtual reality interface analogous to a computer's desktop." References: https://www.microsoft.com/en-us/store/collections/vrandmixedrealityheadsets; http://time.com/4917466/microsoft-virtual-reality-headset-demo/
	Windows Mixed Reality Ultra PC (2017)	Desktops and laptops with discrete graphics card, immersive headsets will be able to run at 90 frames per second "Windows Mixed Reality Ultra grants you access to a massive library of great VR games, and what will be available at launch is just the tip of an impressive iceberg." Reference: https://www.windowscentral.com/what-windows-mixed-reality-ultra
	B. Software	
	MR Apps for Microsoft HoloLens (2016)	"The first apps for Microsoft HoloLens showcase the promise of mixed reality: RoboRaid, Fragments, HoloTour, Skype, Young Conker, HoloStudio, Actiongram" Reference: https://www.microsoft.com/en-us/hololens/apps

	Windows Mixed Reality simulator (2016)	"The Windows Mixed Reality simulator allows you to test mixed reality apps on your PC without a Windows Mixed Reality immersive headset." Reference: https://developer.microsoft.com/en-us/windows/mixed-reality/using_the_windows_mixed_reality_simulator
	Mixed Reality Capture Studios (2017)	"Mixed Reality Capture Studios record human performances from every perspective imaginable." "Create holograms from real life" "Capture human holograms for a range of devices" Reference: https://www.microsoft.com/en-us/mixed-reality/capture-studios
2. Magic Leap	**A. Hardware**	
	Creator Portal (2018)	"… open access to our SDK along with all of the tools, documentation, learning resources and support you'll need to begin your journey." Reference: https://www.magicleap.com/
	B. Hardware and Software	
	Magic Leap One (2017 - unveiling of creator edition)	"How does Magic Leap One work? It uses lightfield photonics to generate digital light at different depths and blend seamlessly with natural light to produce lifelike digital objects that coexist in the real world." "Not all of Magic Leap One is contained in the Lightwear goggles. The computing power is relegated to a Lightpack that fits in a pocket ... ." Reference: http://www.techradar.com/news/magic-leap-one
3. Samsung	**A. Hardware**	
	Odyssey (2017 - development stage)	"Development of the Samsung stand-alone virtual reality headset that will fall under the Odyssey brand is moving forward. Unlike Samsung's current Gear VR headset, it will be a self-contained unit that doesn't rely on a snap-in smartphone. Instead, it will reportedly have a built-in, ultra-high-resolution display with a 2,000-pixels-per-inch (ppi) density, which is significantly sharper than what's seen on the Samsung Galaxy S8 smartphone." Reference: https://www.digitaltrends.com/virtual-reality/samsung-standalone-vr-headset-2000ppi/

	Gear VR (2015)	In partnership with Oculus "Use the Gear VR controller as a remote control to navigate your virtual reality with ease or use it as a gamepad complete with trigger to win battles. The controller is designed to be used naturally with one hand." References: https://www.digitaltrends.com/vr-headset-reviews/samsung-gear-vr-review/ http://www.samsung.com/global/galaxy/gear-vr/
	360 Round (2017)	"The Korean firm has unveiled a camera with 17 lenses, called the 360 Round. Looking not dissimilar to a Roomba, the 360 Round can be used to livestream 3D video and "spatial" audio. It's even water- and dust-resistant with an IP65 rating, for those who want to livestream in inclement weather." Reference: http://fortune.com/2017/10/19/samsung-360-round-virtual-reality/
	Exynos VR III (TBA)	"The headset has gaze tracking — hence the Visual Camp press release — in addition to hand tracking and facial expression recognition. There's no mention of inside-out motion tracking, the next big frontier for mobile headsets, but presumably there are enough sensors on here to make that possible. The press release does mention foveated rendering, made possible by the gaze tracking, which concentrates rendering power wherever the eyes are actually focused." Reference: https://haptic.al/samsung-all-in-one-virtual-reality-headset-exynos-8f90d5ed73c8 https://www.theverge.com/circuitbreaker/2017/7/3/15915938/samsung-standalone-exynos-vr-iii-headset-prototype-gaze-tracking
	B. Hardware and Software	
	VuildUs (2017)	"An app that allows users to see what furniture looks like in their house before they buy it. It uses a 360-degree camera to measure distances and depth, and works via an app for "compatible" VR devices." Reference: https://www.theverge.com/circuitbreaker/2017/2/21/14682126/samsung-c-lab-ar-vr-projects-mwc https://www.sammobile.com/2017/03/03/hands-on-samsungs-c-lab-project-vuildus/

4. Sony	**A. Hardware**	
	PlayStation VR Bundle (2016)	PS VR headset, PS4 system and PlayStation Camera "PlayStation VR is the latest member of the PS4 family – so whichever PS4 console you own, you're PS VR ready; connect the headset to your PS4, add a PlayStation Camera* and leave reality behind." "The PlayStation®VR headset was engineered to be balanced, comfortable, and adjustable. It's designed to feel like it's not there – keeping you free from distraction as you explore new gaming worlds." Reference: https://www.playstation.com/en-ie/explore/playstation-vr/
	PlayStation VR Accessories (2016)	Aim Controller - "PlayStation®VR Aim Controller heightens the experience of any compatible shooter for your PlayStation®VR. Precise motion tracking, ergonomic design, and deeply intuitive controls keep your shots lightning fast and deadly accurate. Together with vibration feedback, the Aim Controller lets you feel the action as you are transported to incredible and unexpected gaming worlds." PlayStation® Camera - "Discover new ways to play and share with the PlayStation®Camera for PlayStation®4. Depth-sensing 3D technology accurately tracks you, your DUALSHOCK™4, and PlayStation®Move controllers to provide an intuitive and extraordinary gaming experience. Personalize and share your gameplay livestreams with picture in picture video. Then combine the Camera with PlayStation®VR to transport yourself to incredible and unexpected gaming worlds." Precise Motion Tracking: PlayStation® Move (2-pack)- "The PlayStation®Move Motion Controllers enable the most exciting and intuitive gaming experiences in compatible PlayStation®VR titles. Precise motion tracking and easily accessible buttons give you the ability to act intuitively, further immersing you in the game." Reference: https://www.playstation.com/en-us/explore/accessories/vr-accessories/?cid=playstation-accessories-vr-accessories-icon-three-column-02-us-03feb17
	B. Software	
	PlayStation VR Games (2016)	Ultra-sensory games Reference: https://www.playstation.com/en-us/explore/playstation-vr/games/

	PlayStation VR Worlds (2016)	"Immerse yourself in new worlds with these five virtual reality experiences – all exclusive to PlayStation®VR." Reference: https://www.playstation.com/en-ie/games/vr-worlds-ps4/
5. Qualcomm	**A. Software**	
	SLiMTM (Structured Light Module) (2017)	"The SLiMTM is a turn-key 3D camera module that delivers real-time depth sensing and 3D point cloud generation with high resolution and high accuracy performance for indoor and outdoor environments." ". . . the project to enable 3D computer vision technologies in smartphones, virtual reality and augmented reality products." Reference: https://www.qualcomm.com/news/releases/2017/08/30/qualcomm-and-himax-technologies-jointly-announce-high-resolution-3d-depth
	Qualcomm® Vuforia™ (2014)	Qualcomm Vuforia is a product of Qualcomm Connected Experiences, Inc. the Vuforia SDK for Digital Eyewear includes a calibration method to provide precise eye calibration that takes into account the complex relationship between the real world, mobile camera lens, the see-through display and an individual user's eyes." Reference: https://www.qualcomm.com/news/onq/2014/09/18/envisioning-innovation-right-your-eyes-qualcomm-vuforia-sdk-digital-eyewear
	B. Hardware and Software	
	Qualcomm® Snapdragon™ 835 (2016)	"...mobile platforms, processors, cellular modems, and chipsets are designed to allow you to fully immerse yourself in virtual and alternate realities, take vibrant photos and videos, stream hi-def movies and enjoy breathtaking download speeds with battery life to spare." "Every Snapdragon mobile platform is designed to deliver experiences you have to see to believe. The robust processing strength, LTE speeds, cutting-edge power efficiency, exceptional graphics and comprehensive security solutions of Snapdragon mobile platforms help bring innovative user experiences to life." Reference: https://www.qualcomm.com/products/snapdragon

	Tilt Brush by Google (2016)	"Tilt Brush lets you paint in 3D space with virtual reality. Your room is your canvas. Your palette is your imagination. The possibilities are endless." "Paint life-size three-dimensional brush strokes, stars, light, and even fire. Experience painting as you have never before." Reference: https://www.tiltbrush.com/
	C. Hardware and Software	
	Google Daydream (2016)	"A platform for high quality, mobile VR made to take you on incredible adventures." "VR headset built for comfort and choice. Powered by any Daydream-ready phone, Daydream View is a comfortable, easy-to-use headset designed with choice in mind." Reference: https://vr.google.com/daydream/
6. Google	**A. Hardware**	
	Google Cardboard (2014)	VR experience in a simple, fun, affordable way "Get it, fold it and look inside to enter the world of Cardboard. It's a VR experience starting with a simple viewer anyone can build or buy. Once you have it, you can explore a variety of apps that unfold all around you. And with plenty of viewer types available, you're sure to find one that fits you just right" Reference: https://vr.google.com/cardboard/
	Google Jump (2015)	"Jump is Google's professional VR video solution. Jump makes 3D-360 video production at scale possible with best-in-class automated stitching. Jump cameras are designed to work with the Jump Assembler to enable seamless VR video production." Reference: https://vr.google.com/jump/

	B. Software	
	Google ARCore (2017 - limited preview)	Augmented reality camera platform "...ARCore is Android's equivalent to Apple ARKit: a baked-in augmented reality platform for developers." "...new software development kit (SDK) called ARCore. It brings augmented reality capabilities to existing and future Android phones. Developers can start experimenting with it right now." References: https://www.theverge.com/2017/8/29/16219696/google-arcore-augmented-reality-platform-announce-release-pixel-samsung; https://www.blog.google/products/google-vr/arcore-augmented-reality-android-scale/
	Tilt Brush by Google (2016)	"Tilt Brush lets you paint in 3D space with virtual reality. Your room is your canvas. Your palette is your imagination. The possibilities are endless." "Paint life-size three-dimensional brush strokes, stars, light, and even fire. Experience painting as you have never before." Reference: https://www.tiltbrush.com/
	C. Hardware and Software	
	Google Daydream (2016)	"A platform for high quality, mobile VR made to take you on incredible adventures." "VR headset built for comfort and choice. Powered by any Daydream-ready phone, Daydream View is a comfortable, easy-to-use headset designed with choice in mind." Reference: https://vr.google.com/daydream/

7. IBM	**A. Software**	
	IBM Watson (2010) VR Speech Sandbox (2017)	What can game developers do with Watson in VR? ... In the 'VR Speech Sandbox' sample code, when compiled into a demo, it's used in more of a voice control interface ... Imagine a collaborative productivity tool you can speak to call up different data sets." "Wimbledon Launches Virtual Assistant, AI-Edited Highlights and Mixed Reality ... Fred, an IBM Watson-based virtual assistant built into the Wimbledon app ... the assistant builds on the chatbot functionality introduced in 2015, and aims to put "cognitive in the hands of the fan" ... ." References: https://www.ibm.com/blogs/bluemix/2017/06/ibm-watson-powering-virtual-reality/ http://mobilemarketingmagazine.com/wimbledon-launches-virtual-assistant-ai-edited-highlights-and-mixed-reality
8. Intel	**A. Hardware**	
	HTC Vive VR Headset* (2017)	In partnership with HTC "The HTC Vive* is a best-in-class VR experience. Through partnering with Intel® worldwide, we can exceed the expectations of developers and customers alike; advancing virtual reality capabilities and adoption." References: https://www.forbes.com/sites/paullamkin/2017/05/30/intel-to-power-wireless-htc-vive-vr-headset/#7ed14d993534 https://www.engadget.com/2017/06/14/intel-wireless-vr-htc-vive/ https://www.intel.sg/content/www/xa/en/virtual-reality/virtual-reality-overview.html
	Intel® RealSense™ Depth Module D400 Series (2017)	"The Intel® RealSense™ Depth Module D400 Series provides a turnkey solution for rapid product development and integration for VR, Robotics, and any market where depth matters. Choose the module that has the best combination of power consumption, field of view, and shutter type, to optimize depth vision integration into your product. This tailored depth module adds "eyes" to your product as an enhanced solution." References: https://www.intel.sg/content/www/xa/en/architecture-and-technology/realsense-overview.html https://communities.intel.com/thread/117159

	Oculus Rift (2016)	In partnership with Oculus "The Oculus Rift is a virtual reality system that completely immerses you inside virtual worlds." "Rift's advanced display technology combined with its precise, low-latency constellation tracking system enables the sensation of presence – the feeling as though you're actually there. The magic of presence changes everything. You've never experienced immersion like this." Reference: https://www.oculus.com/rift/ https://newsroom.intel.com/chip-shots/intel-and-oculus-bring-virtual-reality-experience-to-best-buy-stores-across-the-us/
	B. Hardware and Software	
	Project Alloy (Aug 2016)	"Project Alloy, an all-in-one virtual reality solution made from the ground up. A clear example of the future of merged reality today, the Alloy platform completely redefines what is possible in an all-in-one VR platform." Reference: https://newsroom.intel.com/chip-shots/intel-unveils-project-alloy/
9. Nokia	**A. Hardware**	
	Nokia City Lens (2012)	"Nokia City Lens for Windows Phone works as an augmented reality browser to discover surrounding points of interest via the phone's camera. Nokia City Lens also provides reviews, directions, opening hours, and other useful information for points of interest. The application is available now for Lumia Windows Phone owners through Nokia's beta labs site." Reference: https://www.theverge.com/2012/5/8/3006816/nokia-city-lens-augmented-reality-lumia-windows-phone
	B. Software	
	Nokia's Liquid Applications (2015)	"Building on the aptly named Gt 4G brand - which stands for three things: 'Great Technology', 'Get Together' and 'Good Time' - the operator used Nokia's Liquid Applications to bring the brand to life by providing a real-time augmented reality (AR) experience for the store customers." Reference: https://www.nokia.com/en_int/blog/11549

	Nokia AirScale Radio Access (2016)	"Nokia AirScale technology helps service providers deliver ultra-low latency and massive capacity, which is essential to support real-time IoT, VR, augmented reality and new applications such as remote surgery and autonomous cars. Nokia AirScale allows service providers to run multiple technologies simultaneously on the same platform, supporting both traditional and flexible cloud-base architectures." Reference: https://www.nokia.com/en_int/news/releases/2016/10/16/nokia-and-du-demonstrate-middle-easts-first-4k-3d-360-virtual-reality-video-streaming-using-5g-ready-network-at-gitex-2016
	C. Hardware and Software	
	NetAct and AR glasses (2016)	"In practice, the field engineer scans the serial code of the network element with his device, which then summons the alarms from Nokia NetAct. He then receives a visual overlay on his device of the alarms and a set of instructions to follow in order to resolve his trouble ticket. The AR glasses come into play when he needs free hands to work on the resolution. This technology will help him resolve the trouble ticket much faster so he can move on to his next field job." Reference: https://www.nokia.com/en_int/blog/nokia-augmented-reality
	Nokia OZO Virtual Reality Camera and software (2015)	"KT equipped Jeonju World Cup venue - where the championship opening ceremony and the initial game for Korea team happened - with cutting edge 3D VR multimedia recording equipment – among them the Nokia OZO Virtual Reality Camera.KT created a public 5G demo area in front of the venue where anyone could try how 5G will redefine the spectator user experiences." Reference: https://www.nokia.com/en_int/blog/front-row-view-wherever-5g-immersive-experiences-kt
10. Oculus VR	**A. Hardware**	
	Oculus Rift (2016)	In partnership with Intel "The Oculus Rift is a virtual reality system that completely immerses you inside virtual worlds." "Rift's advanced display technology combined with its precise, low-latency constellation tracking system enables the sensation of presence – the feeling as though you're actually there. The magic of presence changes everything. You've never experienced immersion like this." Reference: https://www.oculus.com/rift/ https://newsroom.intel.com/chip-shots/intel-and-oculus-bring-virtual-reality-experience-to-best-buy-stores-across-the-us/

	Oculus Go (2017)	"Today at its fourth developer conference in San Jose, Oculus announced its newest and most affordable VR headset, called Oculus Go." ". . . the Oculus Go standalone virtual reality headset is making its way out to developers. Even better, the photos suggest that the packaging for the device is already finished, suggesting that a public release might be close behind." References: https://newsroom.fb.com/news/2017/10/oculus-announces-new-standalone-headset-venues-at-oculus-connect/ http://www.techradar.com/news/oculus-go-standalone-vr-headset-appears-in-new-photos
	Oculus Santa Cruz Controllers (2018)	"Oculus also showcased updates to its Santa Cruz prototype, including new positionally tracked controllers with six degrees of freedom that bring the power of Rift and Touch to the standalone category." Reference: https://newsroom.fb.com/news/2017/10/oculus-announces-new-standalone-headset-venues-at-oculus-connect/

J. Some Examples of VC-funded Startup Companies and their MR Products

Table 13. Examples of startup companies that have obtained substantial VC funding.

Company	Background Information (All funding amounts as of January 2017)	Product(s)
1. Unity	Founded 2004 Funding: $289 million, Series C	Platform for 2D, 3D VR/AR games; many Samsung Gear VR and Oculus Rift games were created using Unity; partnering with Apple to create VR creation tools for the Mac
2. Lytro	Founded 2006 Funding: $150 million, Late Stages	Lytro Immerge is a used to combine live action and computer graphics as a light field solution for cinematic VR.
3. NextVR	Founded 2009 Funding: $115 million, Series B	Live VR sports and entertainment experiences, which are already broadcast for NBA, FOX Sports, HBO, and Live Nation channels
4. MindMaze	Founded 2012 Funding: $108 million, Early Stages	Blends VR, motion capture and brain recording technologies to create neurological rehabilitation, game training and real-time 3D imaging interfaces. Their product, MindMotionPro, is used for in-hospital early motor rehabilitation for post-stroke patients.
5. JAUNT	Founded 2013 Funding $100 million, Series C	End-to-end solution for creating 360-degree, cinematic VR experiences focusing on immersive content; developed Jaunt ONE, a 360-degree video camera.
6. Blippar	Founded 2011 Funding: $99 million, Series D	Uses AR, computer vision, and AI to link the digital with the physical world to enable IoT technologies. Their original software allows overlaying digital content onto real life products using image recognition.
7. Sphero	Founded 2010 Funding: $79 million, Late Stages	Combines robotics, AR and mobile tech to develop a new generation of toys to create immersive entertainment experiences. With Lighting Lab, they provide apps to teach programming using Sphero robots.
8. Meta	Founded 2012 Funding: $73 million, Series B	Their Meta 2 Development Kit offers one of the widest field of view and direct hand interaction with holograms and digital contents.
9. CCP Games	Founded 1997 Funding: $66 million, Pre-seed	A VR game developer working on online massive multiplayer VR games. Their EVE Online video game made them one of the main leaders in online gaming.

**Source: https://everisnext.com/2017/01/20/top-funded-startups-vr-ar/*

K. Standards

The IEEE Standards Association already has a standards development group working on the following MR-related topics (https://standards.ieee.org/develop/wg/VRAR.html):

In addition, Mozilla is developing a combined framework that gives developers standardized and well-documented tools for accessing any MR platform a user selects, e.g., desktop browser, mobile, or VR/AR head-mounted device. Mozilla previously worked with Google and others on WebVR API, which for the last year has enabled browsers to provide VR experiences without much difficulty. WebVR API's successor, WebXR, includes AR features and incorporates many functions similar with those of WebVR API. But to allow linking concepts such as object anchoring regardless of implementation changes in ARCore, ARKit, Hololens, and other platforms requires developing the same language for use across different platforms.[11]

Device Taxonomy and Definitions
Immersive Video Taxonomy and Quality Metrics
Immersive Video File and Stream Formats
Person Identity
Environment Safety
Immersive User Interface
Map for Virtual Objects in the Real World
Interoperability between Virtual Objects and the Real World
Immersive Audio Taxonomy and Quality Metrics
Immersive Audio File and Stream Formats
In-Vehicle Augmented Reality
Content Ratings and Descriptors

11 "Mozilla proposes combined WebXR standard for virtual and mixed reality in the browser," D. Coldewey, Oct 20, 2017, https://techcrunch.com/2017/10/20/mozilla-proposes-combined-webxr-standard-for-virtual-and-mixed-reality-in-the-browser/

L. Examples of Companies Involved as Plaintiffs in Many Litigation

Table 14. Examples of companies involved in many patent infringement cases.

Company	Number of Litigation per year	
1. Empire IP LLC	8 patent litigations (2011) 138 patent litigations (2012) 149 patent litigations (2013) 80 patent litigations (2014) 72 patent litigations (2015) 51 patent litigations (2016) 19 patent litigations (2017)	02/10/2017 X-Mobile Technologies LLC v. **Samsung Electronics America, Inc. et al** (Open) 02/10/2017 X-Mobile Technologies LLC v. **Microsoft Corporation** (Open) 02/10/2017 X-Mobile Technologies LLC v. **Sony Corporation** (Open) 02/10/2017 X-Mobile Technologies LLC v. **Apple Inc.** (Open) 05/16/2014 MAZ Encryption Technologies LLC v. **Samsung Electronics Co Ltd** (Closed) 05/16/2014 MAZ Encryption Technologies LLC v. **Sony Electronics Inc.** (Closed) 02/21/2014 MAZ Encryption Technologies LLC v. **Apple Inc.** (Closed) 02/25/2013 MAZ Encryption Technologies LLC v. **Apple Inc.** (Closed) 12/4/2013 Data Speed Technology LLC v. **International Business Machines Corporation** (Closed) 12/04/2013 Data Speed Technology LLC v. **Microsoft Corporation** (Closed) 11/11/2013 Message Notification Technologies LLC v **Microsoft Corporation** (Closed) 11/29/2012 CreateAds LLC v. **Google Inc.** (Closed)
2. Clean Energy Management Solutions	4 patent litigations (2015) 8 patent litigations (2016) 5 patent litigations (2017)	03/20/2017 Clean Energy Management Solutions LLC v. **Lowes Companies Inc** (Closed) 06/19/2017 Clean Energy Management Solutions LLC v. **Cisco Systems, Inc.** (Open) 10/12/2017 Clean Energy Management Solutions LLC v. **Ingersoll-Rand Nexia Intelligence LLC** (Open) 04/15/2016 Clean Energy Management Solutions LLC v. **AT&T Inc.** (Closed) 09/06/2015 Clean Energy Management Solutions LLC v. **Siemens Corporation** (Closed) 07/10/2015 Clean Energy Management Solutions LLC v. **Honeywell International Inc** (Closed) 09/06/2015 Clean Energy Management Solutions LLC v. **Schneider Electric USA, Inc.** (Closed)
3. Immersion Corporation	1 patent litigation (2000) 1 patent litigation (2002) 1 patent litigation (2004) 1 patent litigation (2008) 1 patent litigation (2009) 2 patent litigations (2012) 2 patent litigations (2016) 3 patent litigations (2017)	05/05/2016 Immersion Corporation v. **Apple Inc. et al** 1:16-cv-00325 (Closed) 02/11/2016 Immersion Corporation v. **Apple Inc. et al** 1:16-cv-00077 (Closed) 03/02/2012 Immersion Corporation v. **HTC Corporation et al** 1:12-cv-00259 (Closed) 02/07/2012 Immersion Corporation v. **Motorola Mobility Holdings Inc.** 1:12-cv-00148 (Closed) 02/11/2002 Immersion Corporation v. **Sony Computer Entertainment America Inc et al** 4:02-cv-00710 (Closed)

4.	Digimarc Corporation	4 patent litigations (2000) 2 patent litigations (2001) 1 patent litigation (2002) 2 patent litigations (2009) 1 patent litigation (2010)	11/16/2009 Digimarc Corporation v. **Shazam Entertainment, Ltd.** (Closed) 10/24/2002 Digimarc Corporation v. **Spectra Systems** (Closed) 10/10/2001 Digimarc Corporation v. **Sesac Incorporated** (Closed) 08/31/2001 Digimarc Corporation et al v. **Verance Corporation et al** (Closed) 03/17/2000 Digimarc Corporation v. **Signum Technologies Limited** (Closed) 09/19/2000 Digimarc Corporation v. **Verance Corporation** (Closed) 08/03/2000 Digimarc, Corp. v. **Verance Corporation** (Closed)

From 2011-2017, Empire IP has been involved in at least 517 patent infringement cases . According to their website, (http://www.empireipllc.com),

> "Founded by patent attorneys who formerly worked in prestigious New York City law firms representing some of the world's largest corporations, Empire IP's principals realized that the patent playing field often presented insurmountable obstacles to individuals and small companies. When licensing inquiries were ignored or rejected by large corporations, individuals and small companies simply did not have the time, expertise or resources to pursue more aggressive licensing strategies or bring patent infringement actions in court."

Included in their patent portfolios are "Virtual Retail Systems" and "Virtual Tour Systems." Prominent defendant companies they have sued included Samsung, Microsoft, Sony, Apple, IBM, and Google.

Not much is known about Clean Energy Management Solutions, LLC, except that it was registered as a domestic limited liability company in Texas in September 2014. It has sued Cisco, AT&T, and Honeywell, among others.

Immersion Corporation was founded in 1993 and specializes in touch feedback technology used in various devices including mobile devices, gaming consoles, medical training equipment, and other consumer electronics. It previously worked with Microsoft in 1997 to incorporate Immersion's TouchSense technology into Microsoft's DirectInput API for DirectX 5.0. Immersion sued Microsoft and Sony in 2002 alleging that their game console controllers infringed on two of Immersion's patents. Microsoft and Sony were said to have settled with Immersion in a multimillion-dollar deal. Immersion has also previously sued Apple, Motorola, and HTC.

Digimarc Corporation is a publicly-traded technology company that markets enterprise software and services for various industries, e.g., retail banking, publishing, media, and entertainment. Digimarc's offers several types of products and services that cover security, digital rights management including anti-piracy, counterfeit deterrence, and copyright protection. It also markets products and services relating to advertising, content delivery, mobile and embedded systems software development, digital commerce, inventory management, and product packaging. It owns a global patent portfolio comprising more than a thousand patents and patent applications. These include patents directed to digital watermarking systems for which it is well-known. Digimarc developed the Digimarc Barcode, which is a machine-readable code undetectable by human eyes and ears. The company also provides a software for detecting information contained in the Digimarc Barcode. The barcode can be used with different content forms, including physical items such as product packaging, audio, as well as printed materials like photographic images.

4 Conclusion

MR application areas are vast and have the potential to touch every aspect of our lives. This allows many companies to stake their own territory in the MR landscape if they get there early enough. But even if they're late into the game, there are many niche applications, segments within industries, and sectors within segments that will provide ample opportunity to establish one's area of expertise and client base.

The pioneering and highly-publicized Google Glass, which failed to establish a foothold in the consumer segment, has found quiet acceptance and even appreciation from the industrial sector in its latest incarnation. But this time, Microsoft has emerged as an MR leader. Obviously, Microsoft has no desire to repeat whatever miscalculations it made with Windows Phone, which failed to make an imprint on the mobile device arena. Instead, our findings show that Microsoft is likely to implement a multi-prong strategy that includes integrating its already ubiquitous Windows operating system, Cortana, Skype, MS Office, Office 365, Bing, and Xbox, among many others, into its array of MR-based products and services. As part of this multi-faceted approach, Microsoft is also likely to parlay its existing client base as entry points into the various MR markets. Further, Microsoft will undoubtedly take advantage of its enormous expertise in AI and cloud to further differentiate its MR products and services from those of its competitors.

Apple, Facebook, Samsung, Qualcomm, and Intel are of course not going to be far behind. But many smaller and much-lesser known companies, including many new startups, are already creating their own unique and highly specialized MR systems and applications, including platform-agnostic ones. So, while the competition to be first to create or accomplish something groundbreaking in the MR field is very intense, the number of potential MR application areas are far-reaching enough to accommodate anyone with aspirations big and small, especially those with a mix of money and talent to boot.

APPENDIX

A. Description of the Search and Categorization Methodology

1. The following search protocol description is intended to only illustrate the general process we follow when we perform our P/PA searches for the preparation of an LR. The sample landscape report ("sample LR) was prepared using only a preliminary search that was different from the following search protocol that we describe. Also, we used a different database for this sample report (LexisNexis TotalPatent).

2. To prepare the sample LR, we searched for MR-related US patents and patent applications (P/PA) using the commercial patent database Orbit.

3. We restricted the keyword search to the P/PA's title, abstract and claims. We did not Include the rest of the specification because that would increase the number of irrelevant P/PA in our search results.

4. We also restricted the search to P/PA with effective filing dates that fall within the period from Jan. 1, 2003 to Nov. 7, 2017. We selected Jan. 1, 2003 as the earliest effective filing date so the patents we find would have a remaining patent term of at least between 2-5 years.

5. We initially performed the search using the broad terms commonly used in and most-often associated with the MR field to obtain an estimate of the maximum number of MR-related P/PA.

6. For any search that we perform for any LR topic, we come up with initial search keywords by quickly scanning patent and non-patent literature to identify the most commonly-used technical terms. For the MR report, the preliminary keyword selection was quite straightforward.

   As can be seen from the table below, using only the two most popular terms "virtual reality" and "augmented reality" yielded 5,728 P/PA, which suggests that the number of MR-related P/PA were probably around more than 6,000. Our hunch was confirmed when we added several other MR-related terms such as "mixed," "hybrid," etc., and the search yielded around 6,300 P/PA. This number or search results suggested that few P/PA used the alternative terms "hybrid reality" or "simulated reality," and most P/PA used the terms "virtual reality" and "augmented reality."

   Just to make sure, we included additional keywords in lieu of the term "reality" such as "representation," "imaging," or "rendering" and their variations (using the wildcard character "+"). In this case, the resulting number of search results was more than 125,000, which was obviously too high, most likely due to contributions from generic phrases such as "mixed rendering" or "artificial representation." Based on the Set 1 and Set 2 search results, we believe we were already quite close to the correct number of P/PA that were directed to MR.

   Adding the terms "overlay," "interactive," "interface," "tracking," or "3D" yielded 6,171. We thus selected the results generated by the Set 2 keyword string, just to be on the conservative side.

	Search Strings	# of P/PA
Set 1	virtual reality OR augmented reality	5,728
Set 2	[virtual OR augmented OR mixed OR hybrid OR artificial OR simulat+ OR synthe+] AND [realit+]	6,261
Set 3	[virtual OR augmented OR mixed OR hybrid OR artificial OR simulat+ OR synthe+] AND [realit+ OR represent+ OR imag+ OR render+]	125,306
Set 4	[virtual OR augmented OR mixed OR hybrid OR artificial OR simulat+ OR synthe+] AND [realit+] AND [overlay+ OR superimpose+ OR interact+ OR "3D" OR three dimension+ OR stereo+ OR stereoscopic OR "2D" OR two dimension+ OR optic+ OR display+ OR immers+ OR interfac+ OR visual+ OR position+ OR locat+ OR coordinat+ OR depth+ OR project+ OR track+ OR object+ OR control+ OR feedback+ OR avatar+]	6,171

7. We always perform several search iterations every time we perform a search, which entail revising our keyword strings multiple times until we are satisfied that random checks of our initial dataset show that we already have relatively very few irrelevant P/PA from our initial dataset.

8. Once we have our initial P/PA dataset, we perform multiple reviews, normalizations, and any necessary standardizations of the P/PA in our dataset. While performing these steps, we also begin to conduct some categorizations as we review the P/PA claims one at a time.

9. Once we complete the normalization step, we begin the categorization process. We typically initially randomly pick a small P/PA subset from our collection, e.g., 100 P/PA, and then we identify the various categories based on the title, abstract, and claims of each P/PA from the subset. Based on the categories we initially identify from the subset, we then perform categorizations for the rest of the P/PA collection, adding newly-identified categories as we go through the entire dataset.

10. In this case, we were in luck because we typically only cover between 4,000-5,000 P/PA when preparing an LR. So, we would normally only work with a maximum of 6,000 P/PA as our initial dataset. Otherwise, the initial reviews, normalizations, standardizations, and categorizations would take an inordinate amount of time.

B. Cluster Mapping Description

To provide a visual overview of the MR-related US patents/patent applications (P/PA), we generated cluster maps (see, for example, Fig. 1 above) based on the different MR-related P/PA categories. The term "category" or "categories," when used by itself (as opposed to, say, "market segment category"), refers to a set of P/PA categories that we label "Components, Devices, and Systems" (CDS) categories. The term CDS is used in this report mainly as a descriptive term for the MR-related P/PA in our collection that generally cover hardware and software, or systems and processes, some of which specifically recite MR-specific terms in the claims, while others don't. Some P/PA explicitly recite the specific sector or market segment (e.g., medicine, education, or transportation) that the P/PA is directed to in the claims themselves. For the market-related discussions of the P/PA in this report, we classify those P/PA under an alternative category label "Market Segment Categories." The category group names or labels are, of course, mainly that, labels.

The categories of all the P/PA of all companies were used as inputs to the cluster mapping software (CMS). The CMS we used was Gephi 0.9.1. Using the various inputted categories, Gephi generated a cluster map by depicting the various categories as nodes (represented by the different colored and different sized circles), the size of which being a measure of the number of P/PA assigned to each category.

At least two nodes (or categories) may be linked by at least one line called "edge" whenever the two clusters share at least one common P/PA that was assigned to the at least two different categories. The number or density of edges connecting two nodes represents how closely-related the two nodes are.