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Review of Implementation of Augmented Reality into the Georeferenced Analogue and Digital Maps and Images †

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Abstract: Augmented reality (AR) combines information from databases with information derived directly through the human senses or different sensors. AR is the organic, real-time, and dynamically overlaying virtual images created by computers and other information on a real environment that the observer can see. Virtual information changes according to the movement of the observer, as if that virtual information truly exists in the real world. The convergence of geographic information systems (GIS), web mapping, mobile technology, and augmented reality (AR) implies the emergence of location based systems (LBS) and, in turn, the diminishing use of traditional analog maps by smartphone users. The focus and review of current achievements in this subject on the wider trends of the use of AR also prove that coding of some data and metadata on an image or a map (both in digital and analogue form) permits inter alia the inclusion of, for example, a paper map or analogue image into the chain of digital devices use. Some solutions, remarks, and comments concerning functioning of the digitally augmented (printed) map and their digital counterparts within the information society are presented.

Keywords: augmented reality; data; metadata; map; image; cartography; GIS; mobile technology

1. Introduction

Geographers use metaphors. The most known geographic metaphor is related to Johannes Vermeer's famous painting 'The Geographer' (1668–1669), which can be interpreted as an origin of the idea of virtual reality [1]. Printed (paper) maps and analogue photos (images) are yet (less and less) in use and, nowadays, there is a rising challenge of the growing use of mobile (digital) ones. Technology also influences the traditional understanding of map definition in geography and cartography.

Eyesight is important in cognitive processes. Humans learn during movement and discover the environment (milieu) and eyes acquire the necessary information. Multiplicity of images shapes the sensitivity, thinking, and world perception. People are moving away from verbal communication to image (visual) messages and, nowadays, the supersession of text context by images dominates. Visualization uses the techniques of image, animation, or diagram creation aimed at forwarding messages.

2. Geovisualization, Digital Maps, and Their Usefulness in Information Society

Maps are spatial notations of the reality surrounding us and have been linked to the process of civilization changes since the earliest of times. The problem of map ontogenesis is the question of human–milieu relation. The optimal solution to this issue results from integrated human structures: somatic, psychological, and mental, revealed during human actions in the environment, including the creative and useful role of vision of the map as well. Thus, a map is an oriented information entity based on unity of three concepts: system (target), model (information), and image (transmission), "*tria iuncta in uno*" (Latin) [2]. Taking into account that the relation between the map and human action is causal, the content of definition of a map, according to A.Makowski, is as follows: "Geographic map is a systemic model-image information entity, mapping space-time situations in context of human intentional action in adopted georeferenced system coordinates." [3]

All recent maps are instances derived from geospatial databases (Figure 1). Visualization using maps is an intermediate tool between the human and information system, aimed data analyses, and presentation of results of these analyses.

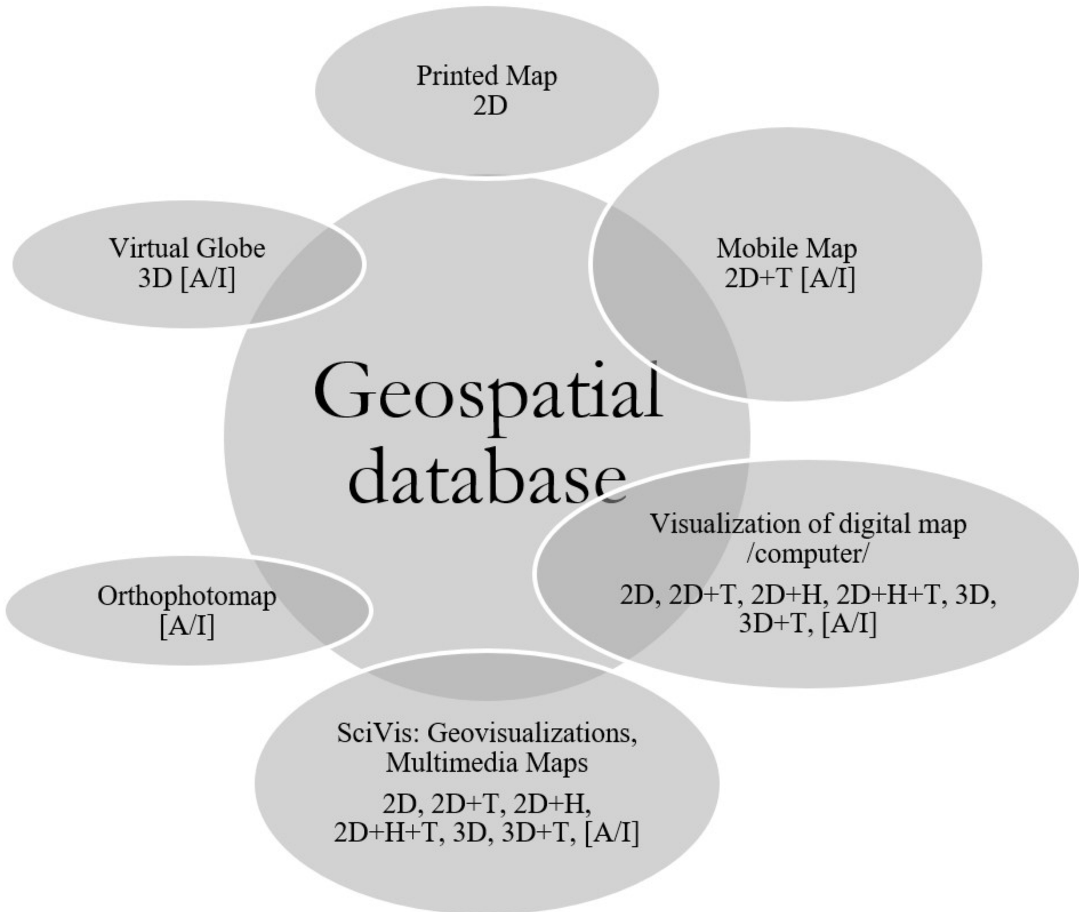

Figure 1. Map instances derived from geospatial database. Legend of symbols: 2D, 3D—spatial dimensions, T—time, H—height/depth, A—animation, I—interaction, SciVis—scientific visualization.

In parallel, geovisualization is understood as the use of visual aspects of spatial information aimed at building the knowledge of milieu (environment) in a holistic approach and making it more easily understood. These processes are supported through the development of techniques and solutions that allow visual interaction between the user and available spatial data, as well as presenting them in the form of spatially registered graphical models. Technologically, geovisualizations are applicable as graphical, scientific, and/or knowledge visualizations. Cartography defines the rules of visualization of spatial data on plane (2D). Three-dimensional geovisualizations, using different raster, vector, or TIN (triangulated irregular network) models combined with images, can achieve a very realistic model of the world. Pillars of geovisualization are, inter alia, methods of cartography, scientific visualization, image analysis, symbolic qualitative and quantitative information visualization, and exploratory spatial data analysis (ESDA).

Almost all map instances characterize interaction and feedback to geospatial database. They make possible updates of the digital maps, but only the hardcopy, that is, the printout of map, is a finished product and seems to be completely separated from the geospatial database. An update of the hardcopy requires restarting the whole production process, and feedback with the geospatial database is limited or does not exist. Interaction of the hardcopy with digital devices is minimal.

Classic processing of spatial data in geographic information systems (GIS) involves several stages: fieldwork and acquisition of spatial data, archiving (management and editing), spatial analysis procedures (e.g., generalization), geovisualization (display on demand), and (in case of need, final) printout.

Different applications of maps and, recently, geovisualizations are continuously expanding. Descriptions of use in scientific literature involves, inter alia, activities supporting analysis and studies of environmental conditions of geographical human or natural objects, as well as extreme natural hazards. They allow accurate and precise interpretation of phenomena and their spatial changes. Traditional approaches, which use 2D maps (even digital), are time-consuming and decrease the number of studied features, diminishing the extent of analysis. Two-dimensional and 3D geovisualizations affect the final results of the projects (design), facilitate making decisions related to rational space management, and offer protection against the effects of geo-hazards. It seems that with the further development of technology, the extent and detail of geovisualizations and range of applications will grow. The knowledge of cognitive relations and human perception targets the best possible graphic information display. These are the basement of most of users' easier perception of complicated spatial dependences.

Most often, static images overlaid on 3D surfaces in geovisualizations are used, as well as maps providing dynamic linking to related text information, animation, and/or fly over models. Time aspect is also important, seeing that it may be applied to comparative or time analysis. Geovisualization has found application in spatial planning (e.g., photorealistic city models), archeology (3D catalogs of artefacts, mapping of archaeological sites), crisis management (interactive modeling of hazards), and environmental protection (different impact maps of environmental factors, determination of buffer zones). Geovisualizations may also display the non-geographical information related to linking them with places of their origin (or possible target locations), that is, Geography of Hate project (covering Geotagged Hateful Tweets in the United States from June 2012 to April 2013, [4]).

This way of reality representation puts emphasis, after all, on methods of scientific visualization in studies and decision processes. The application of different methods of geovisualizations allows the better understanding of the problem under analysis, as well as deeper insight into data in their spatial aspects and then inferring based on revealed information, necessary to undertake the right spatial decisions.

This way, geovisualization seems to be the important element in spatial planning, because it supports processes of public (social) participation. Visual interactions (more intense than with traditional maps) of users with available data presented in the form of georeferenced spatial models (not only in form of maps) result in the process of creation of knowledge. Consequently, active inhabitants, perceiving the holistic model of the real world, are able to influence the processes of undertaking spatial decisions. Geovisualization in the context of spatial planning involves all the processes reinforcing the sharing and understanding of geospatial information, using, inter alia, 3D models, animations, and simulations of spatial processes, which in turn have a better affect on spatial imagination than traditional (printed) maps or even maps displayed on computer screens.

However, some (popular, common sense) opinions express and stress the relation of geovisualization to any presentation that is associated to any human daily activity in a defined location; every map, guidepost, sketch, and verbal message may be also named using this term. It can be problematic to think about oral messages or body language as geovisualization, but it does not matter if the visualization is on paper, on electronic display, or a reconstruction in the brain based on acquired information (one exemplified conclusion, drawn from seminar discourse).

People still buy and use printed (paper) maps, despite the digital technologies expansion, for instance, they still buy and read newspapers and books, or display their scanned images on digital devices. Popular online advice from experienced travelers includes, for example, that a separate problem is the fact that during travel with the support of a GPS (Global Positioning System) device, the majority of users come to the conclusion that the paper map may (and absolutely should in any case) calmly lie in a backpack. GPS information completely supports orientation in the hardest terrain, even if the digital map is not very detailed on the device or presents only the waypoints [5].

The paper maps still are in use parallel to mobile maps. One should at least attempt to diagnose several reasons for this situation [6]. The use of maps characterizes habits shaped during curricular and extracurricular education, that is, formal and tacit knowledge of printed maps, atlases, and guidebooks. However, the devices may lose the WiFi or GPS signal (regardless of reason). Users have to rely on knowledge and skills. They can acquire ready made (professional) digital maps on demand, used later offline or prepare own digital map before, using accessible source of spatial data and widely available software and geolocation tools. At last, they can use purchased earlier printed maps and guides.

Moreover, there is also a psychological human mechanism, that is, belief in the "durability" of a printed image, which is available any time without additional equipment. Finally, the hardcopy—that is, printed maps—document the state of the real world at a defined point in time and may be the proof (according to law) of any public or individual decisions, actions, projects, and claims. Several other reasons (omitted above) can be mentioned, for example, maps become historical documentation and also present aesthetical value as works of art.

"Online/mobile maps and products of traditional cartography have different affordances due to the different media in which they are presented (e.g., static paper vs. dynamic screens)". However, currently the majority of online and mobile digital maps characterize "primary high-level purpose: orientation and navigation" [7].

Digital map studies prove that the base layer of these types of maps use location-aware cartographic approaches and possibly topographic maps (or satellite images) to switch on. Location-aware approaches mean intelligent presentation based on the location being viewed, especially for indoor plans or local area maps (e.g., campus, park, zoo, cemetery). The next common feature for these types of maps is you-are-here (YAH) dots. Mobile maps can afford an experience in which a space moves around a user (allocentric YAH dots), in contrast to maps that afford an experience in which a user moves around a space (egocentric YAH dots, [7]). Mobile maps also characterize the presence of additional text information or meta-information associating features presented near YAH dots. Last but not least, another feature of mobile maps is the ability to rotate relative to a dominant object on the map (most often water body) to show the actual orientation ("logically-aligned") of the map [7].

3. Augmented Reality

The definition of augmented reality (AR), avoiding limitation to specific technologies, concerns systems involving three characteristics [8]:

- combines real and virtual [elements];
- interactive in real time;
- registered in 3D.

AR is dynamic overlay of digital virtual images and information concerning the real environment that is being observed. Images and virtual information change constantly while observer is moving. AR involves integrating synthetic information into the real environment and the overlay of spatially-registered computer graphics over a live image of the real world. The range of applications of AR include, inter alia, the following [9]:

- geolocation using GPS and geographic information systems (GIS);
- geonavigation, especially marine and air traffic;
- car navigation, including autonomous car driving;
- UAV (unmanned aerial vehicle) geonavigation;
- geovisualizations of interactive maps, that is, displaying and interactive analysis of terrain, interactive 3D maps, and landscape visualizations;
- building information modeling (BIM): visualization and modeling of buildings and/or urban fabric, also using mobile applications;
- support for visitors: displaying tags and labels of observed objects;
- simulations: flight and drive simulators;
- virtualization of conferences;
- entertainment and education (e.g., mobile treasure hunt games for outdoor learning);
- searching by images (the newest service supported by, for example, Google, is related to geolocation using images of terrain objects, that is, search places by images);
- assembly process by leveraging augmented reality, cloud computing, and mobile devices (which include mobile augmented reality (MAR) and digital maps [10]).

Two different augmented reality display concepts exist to superimpose graphics onto the user's view of the real world; video see-through and optical see-through head-mounted displays (HMD) have been the traditional output technologies for augmented reality applications for almost forty years. Rather new is the spatial augmented reality approach (SAR). SAR involves new display paradigms that exploit large spatially-aligned optical elements, such as mirror beam combiners, transparent screens, or holograms, as well as video projectors. In many situations, SAR displays are able to overcome technological and ergonomic limitations of conventional AR systems [11].

Milestones of AR have been presented in several publications [12–15]. All of them point out reference to diagrams depicting the reality–virtuality continuum by Paul Milgram and Fumio Kishino [16] (Figure 2). There are two types of mixed reality, that is, augmented reality (AR) and virtuality (AV), which are in the scope of interest of geographers and cartographers.

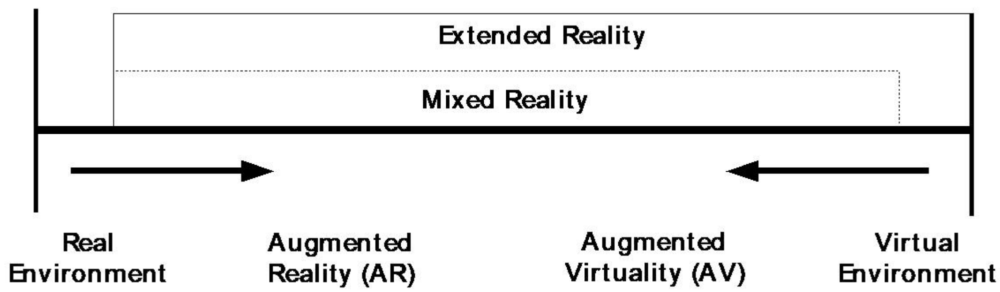

Figure 2. Reality–virtuality continuum.

A recent point of view, emphasizing rather the way people experience the physical and virtual environment, operates with the umbrella term extended reality (XR), encompassing virtual, augmented, and mixed reality [17].

"Industry analysts have dubbed AR the "eighth mass medium" of communications." [18] Roots of AR technologies adoption are seen in theories and concepts well-grounded in behavioral psychology, sociology, and the economy, including TAM (technology acceptance theory), UTAUT (unified theory of acceptance and use of technology), U&GT (uses and gratification theory), media richness theory, and social presence theory. The perceived benefits of XR technology based on different dimensions have been defined as (i) technology-specific, that is, utilitarian, hedonic, and social; (ii) fashion-specific, that is, impression management and wearable comfort; and (iii) media-specific, that is, sensual benefit, immersion, experienced realism, and virtual presence [17]. A systematic review of AR usability studies has been compiled by Dey et al. [19]. Most of the examples concern indoor situations, but the main trend observed is the domination of use smartphones as the primary display (over HMD, head mounted displays) for AR applications. Authors categorized the phenomena into nine applications areas, concerning the following: perception, medical, education, entertaining and gaming, industrial applications, domain of navigation and driving, tourism and exploration, collaboration, and interaction. It must be stressed that navigation and driving, as well as tourism and exploration, are domains in which the cartographic pillar plays the most important role, especially outdoor in a realistic testing environment, including the use and capture of huge volumes of a variety of qualitative and quantitative spatial data [19]. Other authors define the range of AR applications as follows: tourism and navigation, entertainment and advertisement, training and education, geometry modeling and scene construction, assembly and maintenance, and information assistant management [20].

Another feature is the psychological aspect concerning the perception of distances, directions, and areas while using AR systems. Some results suggest the depth distortions that AR application developers should expect with mobile and tablet-based AR.

Prevailing use of smartphones' AR applications has been defined in scientific papers as MAR (mobile augmented reality). "MAR combines wireless communication, location-based computing and services (LBS), and augmented reality to create an integrated interactive environment" [21] and is a challenge for UI (user interface) designers. The extensive use, inter alia, of devices' sensors, accuracy of tracing technologies, and UI design is indicated in this context [21].

Tracing and registration in AR systems can be sensor-based and vision-based. "Sensor-based employ inertial and electromagnetic fields, ultrasonic and radio wave measure and calculate pose information; vision-based methods estimate gesture information from point correspondent relationships of markers and features from captured images or videos" [19]. Some (hybrid) systems use both methods.

The progress of AR technology recently distinguished a fifth generation of media, so-called wearable augmented reality devices (WARD), which promise a new digital turn after the previous achievements (milestones: computer offline, Web 1.0, Web 2.0, Mobile Social Web) [22]. The new wearable AR devices are termed augmented reality smart glasses (ARSGs, e.g., Google Glass or Microsoft HoloLens). Although they can be seen as a new quality of head mounted devices, in fact, ARSGs are really perceived as disruptive innovation, because of the potential added internal and external value creation. Internal value creation involves research and development (fostering and facilitating innovation processes), promotion of collaboration, and process effectiveness. External value creation increases the value of firms offering their services and products using ARSGs for customers because of utilitarian, hedonic, and social/symbolic benefits, as well as strengthening of customer interactions (services and AR branding) [22]. On the other side, the expected (customers) benefits are also accompanied by new kinds of expected and perceived (individual) risks, such as the threat of own and others' privacy and possible loss of self autonomy due to external interference in certain situations [23]. The recent classification of AR technologies based on their physical characteristics distinguishes between virtual and augmented technologies in stationary, mobile, and wearable technologies, emphasizing smartwatches and virtual reality glasses as strict virtual technologies and ARSGs as augmented technologies [24].

The main potential of disruptive innovation in the future of ARSGs lies not only in advent the of technology, but in the possibility of surpassing over mobile devices, such as smartphones or tablets, because users (consumers) may also consider wearables devices as "fashion" or "fashnology" (fashion and technology or fashionable technology) [25,26]. Pilot studies concerning perceived health risks on the usage of Microsoft HoloLens did not confirm their direct negative influence, however, an "indirect negative influence of perceived health risk on behavioral intention to use through perceived enjoyment" has been confirmed [27].

4. GIS and AR

The progress in the information, communications, and technology (ICT) sector has brought rapid development of AR coexisting with GIS technology on portable devices. The GIS and AR processing chain involves gathering of the following: specific user requests, display parameters concerning scale, symbology and metadata of requested map and users' position (location), and orientation.

The combination of GIS and AR supports both indoor and outdoor exploration of spatial data. Augmented virtuality (AV) is related to exploration of geospatial data directly from the real or virtual (digital) world and may be defined as an augmented map (AM), which implies the extensive use of maps as the base element of searching for information. Augmented reality (AR) as the interactive tool makes possible gathering additional information during exploration of the natural environment or anthropogenic (e.g., urban) milieu, which can be defined as augmented territory (AT).

These types are designed and implemented into mobile applications (e.g., GPS navigation) [11].

Some authors and MAR creators announced AR as the next big innovation. Undoubtedly, MAR is the candidate technology for disruptive innovation in mapping [28].

Mobile AR and Paper Maps

So far, the combination of GIS and AR is predominantly related to mobile (digital) maps, and there are few other practical applications except navigation. Ann Morrison (et. al.) experimented with augmented reality (AR) using a 'magic lens application' over a paper map using a smartphone. "Maps are one of the main application categories for mobile AR. The focus is in augmentation of physical maps with useful and interesting real-time information. Paper maps have a large static surface and AR can provide a see-through lens without forcing the user to watch map data only through the small 'keyhole' of the display" [29] (p. 1).

Some findings point out that the type and layout of a physical map that has undergone augmented reality operation (augmented map) affect its efficiency while using mobile devices (through spatial pattern analysis and ways of users' interaction). "The maps act as mediation objects for multimodal discourses providing resources such as a context and facilitation for embodied communication" [30] (p. 3).

Some other examples are related to geocaching—outdoor recreational activity using GPS receivers (often in smartphones) and, for example, its latest, new instance Pokémon Go application, globally available since 2016. However, its root can be derived from orienteering—a formal olympic discipline, which requires users to possess navigational skills using (specially prepared, without labels) maps and compass while moving through unknown terrain at speed during the race.

Yet another example of augmented maps—similar to paper, but not exactly—is commercially available portable document format (PDF) maps offered on the market (e.g., Avenza Maps).

Geospatial PDFs involve georeferenced location data and allow finding specific or users' locations and measuring distances, perimeter, and areas using predefined coordinate systems and units, as well as copying location coordinates for further use. The base layers can be raster, that is, GeoTiff or JPEG 2000, format, and are georeferenced retaining the control points saved in (meta)tags or vectors—using shape files (ESRI shape file format) with attribute data (dbf, dBase file format). The limited functionality of geospatial PDF involves the operations of displaying geographical coordinates, as well as searching and marking the desired locations. Geospatial PDF can also contain the attachments (or links) to the web pages or other maps, images, or any other documents. This way, the form of tiling of map sheets into classic atlas form is realized. Another proposal is OpenGeo PDF. "In essence, OpenGeo PDF is the incorporation of the Open Geospatial Consortium's (OGC) GeoPackage standard to store feature attributes in a universally accessible PDF container" [31]. This way, the analog (classic) paper map gains a new quality that brings the implementation of augmented reality into it closer.

There are several challenges highlighted in the summarizing tendency of augmented expression for paper maps [32]. The technology using markers is the hardware aspect of the mainstream of possible future paper map AR systems using mobile terminals (smartphones; however, HMD (head mounted display) technologies are an alternative solution, ibid.). A key technical challenge is tracking the location using obviously visible markers on paper maps compared with the location obtained from GPS signals. The competing solution uses geographical, natural (or artificial) features (or textures) using smart algorithms for geolocalization supporting GPS signals (ibid.). Combining these two procedures also requires the use of remote geolibraries, providing both spatial data and applications (in form of SaaS or PaaS, i.e., software as a service and/or platform as a service technologies). In this case, a reliable wireless connection is necessary. This way, the paper map must be characterized by value added information, presenting new utility. The obvious characteristic seems to be wider scene presentation, which is not (or not adequately) shown on small smartphone displays (despite the possibility of zooming and panning). The wireless connection characterizes the AR real-time systems—when the paper map is only the historical documentation (for previously recorded spatial situation situation) and aims, inter alia, at updating the spatial data. Then, the whole system may function as the "unified cartography standard" and the "AR system for paper map will be universal" [32]. The geolocation service of such a system (based on GPS signal) should operate without disturbances even in the case of a lost wireless network connection, necessary for updates or acquisition of detailed features of spatial data. Another quality, showing the advantage of such a system, is an emergent phenomenon rising from the quality of the paper map, that is, created and prepared by authorized and qualified professionals (cartographers), which is used to synthetize and generalize spatial information in the form of a cartographic map and aims at the non-professionals helping them to undertake their spatial decisions, targeting their movements, directions, or perception of detailed location features or values. This conclusion has also been confirmed by studies of the use AR in tourism, which revealed that the user experience (UX) is formed by the correlation of AR system features and the perceptions and experience of tourists [33], both in urban heritage areas (outdoor) and inside buildings (indoor) [34].

On the other side, research experiments proved that experience and qualification of map users matter. Those that had previous experience of the spatial data handled the tasks better using only the printed maps, contrary to those less experienced, who smartly and more efficiently used AR [35]. Some other researchers indicated the importance of affordances (theory and concept of assets and possibilities perceived, developed in psychology), which users can perceive in real and virtual worlds [36].

5. Map Context and AR Technology in Details

Since some time ago, each year, Gartner, Inc. has identified and reported top strategic technology trends and hype cycles of emerging technologies on the market. In 2016, the company put virtual reality and augmented reality in fourth position after intelligent things (third) and intelligent applications (second) on the list, enumerating the importance of the Information Technologies in 2017. Simultaneously, AR has been pointed out as the information technology that crossed the peak of inflated expectation and is closer to maturity. Designers, programmers, and users got rid of illusions of AR and the technology will enter into the next stages of enlightenment and (real) productivity [37,38]. In 2018, Gartner, Inc. highlighted AR as part of a common technology trend (in sixth position) named an 'immersive experience', together with VR and MR—all enumerated technologies create "combined shift in perception and interaction models, changing the way in which people interact with the digital world" [39].

Scientific approaches differentiate between two main types of AR technologies: marker based AR (prevailed indoor applications) and markerless/gravimetric AR (used in outdoor applications).

Marker-based AR uses template markers or 2D barcodes, (e.g., Quick Response Code i.e. QR-codes, or similar Datamatrix, etc.). "This reality type uses visual marker known as fiducial or AR card to determine center, orientation and range of coordinate system. The system detect marker, identify and calculate pose of the object with help of computer vision techniques. (. . .) Marker-less AR utilizes GPS (geopositioning), compass and other related sensors. Augmented reality browsers help users to navigate between POIs (Point of Interests) appear on camera view for exploring AR contents based on location and context." [15] (p. 115).

Simultaneously, authors point out that there are challenges of mobile augmented reality related to the following [15]:

- Image capturing capabilities of smartphones cameras, which are dependent on lighting conditions.
- Energy consumption, which remained an open challenge for smartphones (energy efficiency).
- Access a large amount of data of AR applications over networks for locating/navigating points of interest; any downtime of network access may harm instant response to users (networking, constraint power computing of MAR, and data management).
- Accuracy of sensor information, which is a vital component for indoor and outdoor navigation.
- Lighting conditions, with which technologies are struggling, to remain readable in bright outdoor conditions.
- Technology adoption life cycle rising from the fact that people resist change to adopt new operating mechanisms for handling devices and learning new methods of interactivity and realism (UI/UX challenges).

Last but not least is the problem of security and privacy of using networked MAR.

On the other side, some significant voices warn that the growing volume of digital data might disappear as a result of a sudden crash, or might be wiped out in result of crime or war. " . . . digital data of crucial importance to archivists and future historians are potentially under threat from deletion, corruption, theft, obsolescence and natural or man-made disasters. (. . .) We're only just beginning to understand how important this data is and what the consequences might be if we lost it." [40] Maps, as the most valuable and important product of human culture, science, and economy, are especially vulnerable to the above-mentioned threats. Other instances derived from geospatial databases (as described on Figure 1), as well as all the digital images (photos), can be similarly treated.

6. Summarizing Problems Concerning MAR and Maps

The literature review, covering the time since 2009, reveals the changing focus on problems concerning AR. The database searched with most cited publications was Microsoft Academic. There were 5000 scientific papers. A contextual analysis of titles has been visualized using the VOSviewer tool (v.1.69, [41], Figure 3).

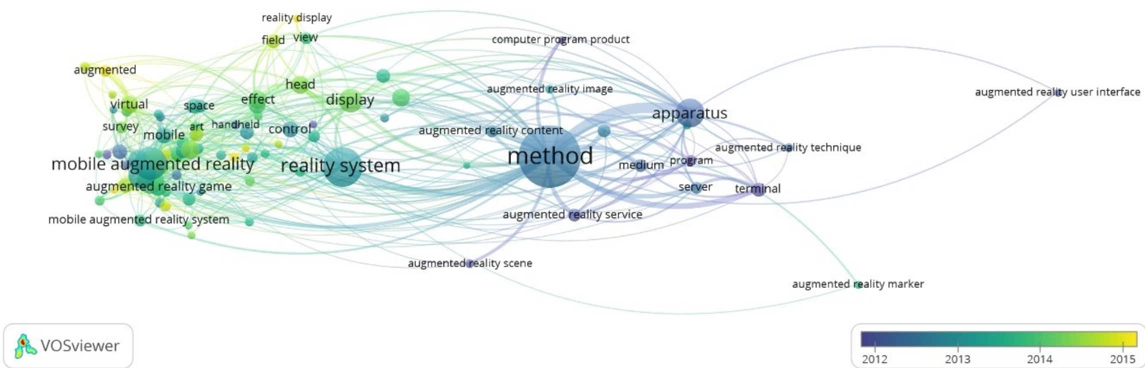

Figure 3. Contextual analysis of titles of publications concerning augmented reality (AR) in the Microsoft Academic base since 2009.

The centroid weight of issues moved during the observed time from the methodological problems related to hardware and software challenges to well formed MAR with aspects such as reality systems, surveys concerning users, applications, learning, and space.

A similar procedure has been applied to the 1000 most cited publications in the Google Scholar base (Figure 4). The current main issues again concern mobile augmented reality systems and their applications and users, which confirms previous observations.

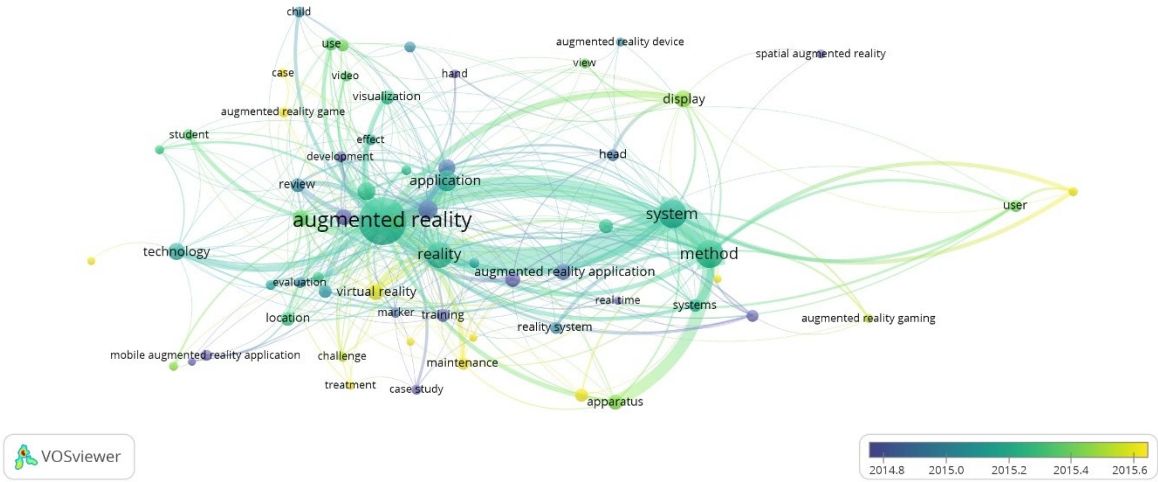

Figure 4. Contextual analysis of titles of publications concerning AR in the Google Scholar base since 2014.

Considering the search within publications of the Google Scholar base of the terms AR, digital map, and paper map, the results reveal slightly different aspects: the mainstream of publications focused on the real world using earlier overworked achievements concerning AR. Current problems involve depicting the human past and present milieu using either MAR or SAR technologies in real-time (Figure 5).

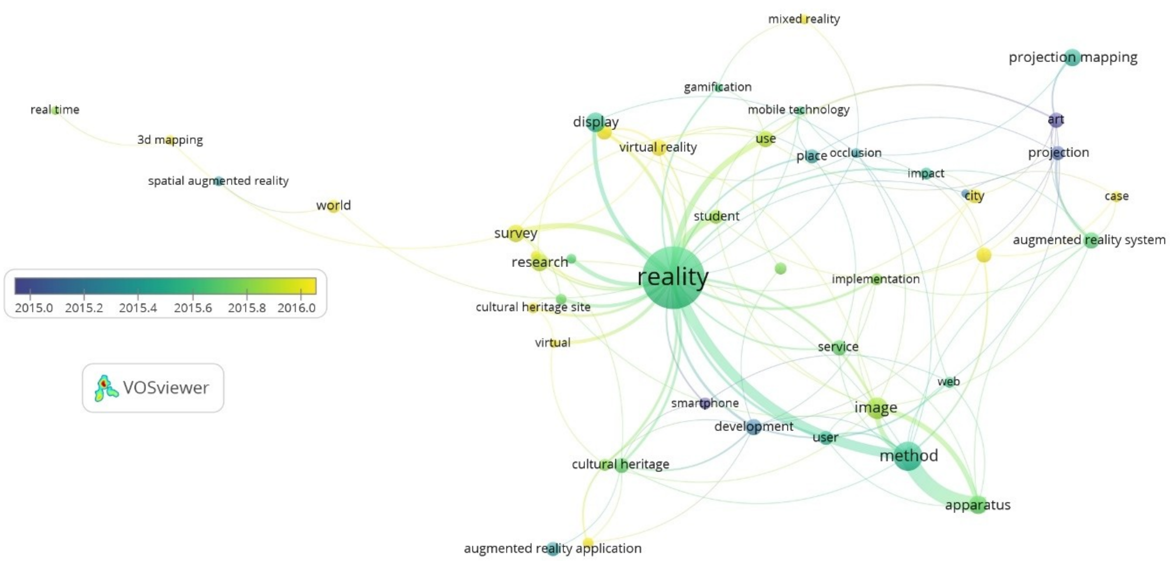

Figure 5. Contextual analysis of titles of publications concerning AR and map Google Scholar base since 2014.

7. Intelligent Augmented Geovisualization, Digital, and Paper Map

Paul Levinson, in his book, The soft edge a natural history and future of the information revolution, wrote the following: "(...) an information technology will survive to the extent that it satisfies human needs better than its rivals. (. . .) First, the ongoing evolution of new media, usually with profound unintended consequences, means that the rivals of any given medium are often in flux. Second, a given medium usually performs a variety of tasks, which results that it may well best its rivals in one area, and fail against the same or a different set of rivals in another area." [42] (p. 185).

The idea concerning an intelligent augmented analogue map (or analogue image) is based on the opinion that a classic map (or image/photo) would have advantages not only in critical situations (blackout, no mobile or WiFi coverage, or no GPS signal for any reason). A mobile device application could reveal and interpret especially prepared markers (e.g. radio-frequency identification - RFID tags) hidden in the analogue map. This set of hidden tags included into the symbology and legend of the map allows using the map (or image) in the classic, traditional way without disturbing human perception. Simultaneously, these tags expand the volume of information contained on the printed paper map (or photo, e.g., they reveal metadata).

From the point of view of a cartographer/geographer, it is necessary to prepare an additional steganographic information layer of the map, overlaid on basic, printed content, thematic layers and calibrated with markers, which make its augmenting possible. The mix of known technologies can be used to include the intelligent, augmented paper map into the digital world, inter alia:

- digital and classic steganography;
- augmented reality, software applications;
- fiducial markers;
- mobile devices with different sensors, GPS, etc.;
- access to GPS and WiFi signal;
- (last but not least) analogue (printed) paper map (or image/photo).

This way, augmented paper (printed) maps (or photos) would become the (more) intelligent things included into the chain of digital device use, and does not lose its primary function. On the other side is mobile intelligent application. The new idea to use AR markers is also discussed in scientific discourse. Once the POI (point of interest) in the real world coupled with its location on the map (no matter if analogue or digital) is identified, the novel mobile interaction technique utilizing projected markers (using pico-projectors) makes it possible to reveal additional information about the place and/or surrounds [43]. Markers can be presented on demand depending only on recognized locations of POI in the real world (empirical studies provided the value of such a solution, despite some limitations related to lightning), but the same can be applied to analogue map or images, if only the location is known. A comparison of users' behavior during navigation using AR either on a digital or augmented paper map proved that they "did not subjectively perceive differences between these options" [44]. On the other side "Augmented Reality compared to virtual reality offers a stronger feeling of immersion for the user" [45]. The conclusion of merging the natural way using paper and digital maps seems to be the optimal solution [46].

Another trend is convergence of the two above-mentioned technologies: AR and geovisualization (AR&GeoVis), which intertwined themselves, and created rather new possibilities in science and economy (as well as in entertainment, e.g., in games). Science gains from easier identification and interpretation of spatial patterns and complex relations in a geographical context. Moreover, an interactive approach of mixing AR&GeoVis reflects variability of geographic objects and facilitates the right decisions. Geovisualization uses visual representations of geospatial information and reflects consciousness, understanding, and construction of knowledge about human milieu and the environment at a geographic scale, and in turn, facilitates the creation of visual representation of these aspects, more often also using AR tools. It has to be realized in an intelligent way, attracting the recipients using understandable transfer of information.

Advancement of ‘digital geographies’, understood as the modus operandi of geographical studies and applications in spatial economy, is the signal of fundamental disciplinary turn of geographic praxis. “Emphasis remains on how an engagement with the digital develops our collective understandings of cities and development, as well as health, politics, economy, society, culture, and the environment, among others” [47]. AR plays an important role in this digital turn. The convergence of GIS, AR, WebGIS, and digital mobile maps, which are the fundamentals of the recent technology named (generally speaking) story maps, created quite a renewed way of presenting spatial data, and aimed to reach two targets, scientific and commercial, using online geospatial technologies (e.g., ESRI story maps, Google Earth Outreach).

Rather new possibilities are opening for intelligent map creation with the use of augmented reality smart glasses. Extending the volume of attributes and spatial data on maps with georeferenced digital hologram information from a network may be the next real step in map construction and ARSGs, cooperating with some of the above-mentioned technologies, and may far better address human needs such as cognitive, tension-release, affective, social integrative, and personal ones, gratifying life efficiency, enjoyment, desired enhancement of reality, physical (sensual), social, and self-expression [24].

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