Egocentric viewpoint limitation in situated visualization based on mixed reality: challenges and opportunities

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Abstract — **Mixed reality (MR) is well suited for situated visualization (SV), a method to represent data in a context, with potential in many situations. However, MR-based visualizations are commonly constrained to the users' single egocentric viewpoint reducing their ability to explore all the available information. This article discusses the main limitations and challenges of this approach based on the analysis of existing literature and identifies opportunities, as well as relevant aspects that must be considered when devising new methods aimed at overcoming those limitations.**

Keywords* — *Augmented and mixed reality, situated visualization and egocentric viewpoint.

I. INTRODUCTION

The mixed reality (MR) global market is becoming more and more important in line with mobile phones and the internet. In MR, humans can visualize and interact with real contents while augmented with virtual information. To take advantage of the user's real context many MR applications use situated visualization (SV), which comprises all the visualizations that change their appearance based on physical context [1, 2]. Compared with other visualizations, SV offers high adaptability, usefulness and intuitiveness by contextualizing the relevant information in the current physical space, leading to more informed decisions. SV, however, also brings several challenges. For instance, visualizations in MR are commonly constrained to the users' single egocentric viewpoint reducing the user ability to explore all the available information. This limitation is particularly evident when overviews of all information are required, inside and outside of the user's field of view (FOV). This paper is organized as follows: Section II introduces the concepts of MR, SV and egocentric viewpoint limitations. Section III presents the methodology used for collecting references. Section IV discusses the main findings from the literature review and finally, section V draws some concluding remarks and proposes paths for future work.

II. CONCEPTS

For a better understanding of this paper there is the need to present the following fundamental concepts.vcbv vnbvnvnbnb

A. *Augmented and mixed reality*

Augmented Reality (AR) allows humans to enhance their perception by adding a virtual layer over the real world. The term "augmented reality" appears for the first time in [3], although it is commonly accepted that the first AR system has been presented in [4]. However, it was in [5] that were standardised the three main characteristics necessary for an AR experience: the combination of real and virtual content, interaction in real-time and registration in 3D (the virtual elements must be aligned (registered) with real-world structures). MR was defined along a reality-virtuality continuum in [6] and in [7] it was concluded that AR is a subset of MR.

MR applications have been growing significantly with the development of easy to use frameworks and the reduction of hardware costs. The most common domains of MR are education, architecture, games, entertainment, medical, art, industry/military maintenance, business, tourism, indoor navigation, and telecommunications/broadcasting [8, 9, 10] and it is expected that MR will soon spread to daily tasks. Regarding MR device types, [9] shows that most systems rely on mobile-based devices, also known as the handheld display (possible to use with a single hand and equipped with both a display and a camera [11]). Although they are worldwide spread, cheaper and less intrusive, handheld devices are not appropriate for immersive experiences [10, 12]. As an answer to the lack of immersivity and the need to have hands free AR systems, see-through-based devices are gaining ground and will most likely become the new trend. In this equipment the user sees the real-world in a natural form, the device only provides the digital content and the user's brain merges all the real and virtual information together. These devices are an evolution of the famous head-mounted displays (HMD). The HMD merges both real-world images and virtual content and feeds them to the user's eyes simultaneously and belong to the video-see-through-based device group. Other categories of MR devices are the computer-based and projection-based groups. The latter uses video projection techniques, lasers, LCD/LED projectors, holographic technology or radiofrequency and is also known as the spatial display because the display of visual information on real-world objects is usually not connected to the user [10, 12]. It is suitable for multiple users without the need for them to wear any kind of device. [11] introduces other MR devices: user tracking (sensors and motion detection that can be used to detect the user's movements) and haptic and force feedback (wearable devices that provide feedback to the user without distractions from the task to be performed).

B. *MR-based visualization – situated visualization*

Visualization could be defined as the communication of data, a process of interpreting abstract or visible data that is not immediately seen and representing it in a visual form to produce readable and understandable images [13]. According to [14], visualization can also be defined as the use of computer-based, interactive, visual representations of data to amplify cognition, corroborating the idea that MR allows the augmentation of the perception of conventional reality.

MR visualizations can be divided in two different categories: visual augmented reality (VAR) and spatial augmented reality (SAR). In VAR, the computer-generated content is overlaid into the user's visual field. In SAR, the digital content is overlaid on the physical space [15]. In [2] the visualization techniques based on MR were organized in three main categories: data integration, scene manipulation and context-driven visualization. Concentrating only on the last category, the visualization techniques can be congregated in the following groups: SV, the object as context, the sensor data as context, the scene as context and the uncertainty as context. In SV, the visualization of the virtual information is intrinsically related to its environment. Since SV is a more open concept, it can deal with issues that are characteristic of the other four groups.

One of the main advantages that MR systems offer is that additional digital information of the process can be visualized and explored directly overlaid on the images of that world. SV, introduced in [1, 16, 17], is exactly all about that advantage. It defines all the visualizations that change their appearance based on context, by considering visualizations that are relevant to the physical context in which they are displayed [2]. In other words, SV occurs when the visualization of the virtual information is intrinsically related to its environment, giving more meaning to White's words "*through the combination of the visualization and the relationship between the visualization and the environment*" [1, 17]. Examples of SV based on MR could be seen in applications that present the underground infrastructure of the place where the user is [53] or that guide a user through assembly tasks. It is important to refer that not all visualizations in MR are situated, as it is the case when the displayed virtual elements are not physically related to the viewed real-world entity [18], as can be seen in Fig. 1(a).

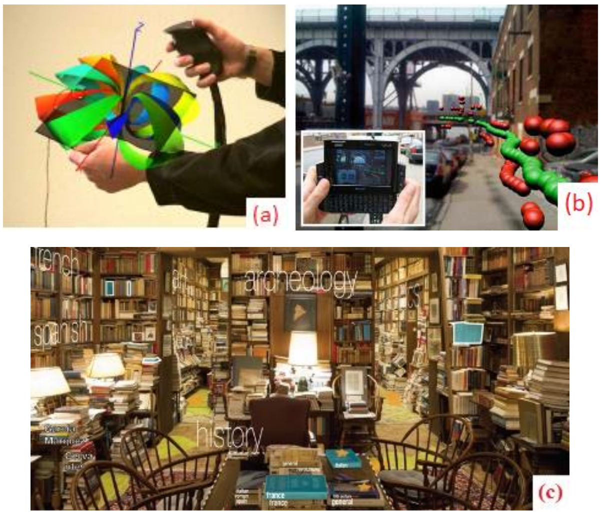

Fig. 1. Examples of: (a) Non-SV, from [19], (b) SV of PBDT, from [17], (c) SV of ADT, from [20].

According to the SV definition, it is not the type of data to be displayed that defines the visualization as situated. Data is a purely logical entity. Thus, it is possible to have SV with both abstract data type (ADT) and physically-based data type (PHDT) [18]. In the PBDT, the real-world elements' behaviour is defined by the physical laws that rule the 3D world, as can be seen in the example of Fig. 1(b). In ADT, the behaviour is defined by a set of values and a set of operations, as can be seen in the example of Fig. 1(c). Regarding technology, SV systems are not dependent on any specific system. SV systems do not even have to use MR technology. For example, SV can be created with simple methods, like printing on a paper a visualization of an object's information and taking it to near the object itself. However, new and emerging technologies make it possible to create elaborate forms of SV based on MR [15]. These technologies must assist users in swiftly building visualizations that combine real information with the digital one. Yet, [21] observe that existing SV toolkits generally lack such responsiveness.

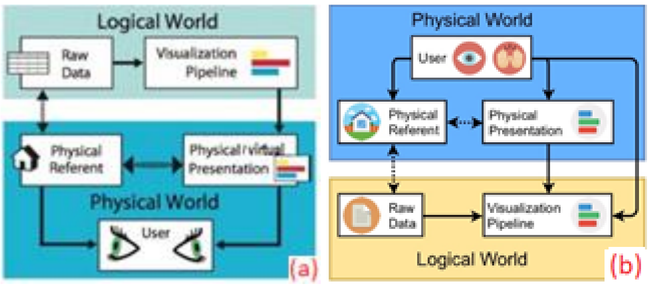

Fig. 2. (a) The theoretical model of SV, adapted from [22]. (b) The theoretical model for interaction with SV, adapted from [15].

The characterization of SV must start with the understanding of what it means for data visualization to be spatially situated. According to [15], a "*visualization is spatially situated if its physical presentation is close to the data's physical referent*". A physical referent is "*a physical object or physical space to which the data refers*" [22]. The term "*close*", used in this definition, is left vague on purpose because situatedness is lying on a continuum with different levels. For example, a visualization projected on a physical object (the referent) is spatially more situated than a visualization viewed on a mobile device near the referent. For a better explanation, [15] presents a theoretical model of a spatially SV, mainly based on the model from [22], which covers both logical and physical worlds, as can be seen in Fig. 2(a). The visualization pipeline only requires the logical world, but the existence of a physical world is necessary for SV since data visualizations are intertwined with the physical environment. Fig. 2(a) only represents the information path between the raw data and the user, ranging from the transformation of the raw data, the visualization pipeline (composed of a sequence of geometric transformation matrices), to a comprehensible visual representation (the rendered images). One of the existing connections between the logical and the physical world links the visualization pipeline with the physical presentation module, as can be seen in Fig. 2(a). A physical presentation is "*the physical object or apparatus that makes the visualization observable*" [23]. Only with physical presentation can the user see the information created from the transformed raw data [23]. Another way to connect the logical and the physical worlds is through the dashed connection between the raw data and the data's physical referent – shown in Fig. 2(a) – meaning that the raw data can have several referents and that sometimes some referents may not be seen by the user [15]. The dashed arrow between the physical referent and the physical presentation represents the distance among them. If the physical referent and the physical presentation share the same space, both can be seen by the user, at the same time. When that happens, the visualization is called spatially situated. It is common knowledge that distance is perceived in a relative way. This divergence in the perception of the distance between physical referent and the physical presentation is common in MR [8]. So, to avoid the vagueness of the definition of spatially SV, [15] suggests the following definitions: "*A visualization is physically situated in space if its physical presentation is physically close to the data's physical referent*" and "*A visualization is perceptually situated in space if its percept (physical or virtual presentation) appears to be close to the percept of the data's physical referent*". Thus, perceptually SV can be related to virtual presentations and that is the reason to include the component of virtual presentation in Fig. 2(a). Another important physical property in the characterization of SV is embedded visualization (EV). According to [22], EV "*is the use of visual and physical representations of data that are deeply integrated with the physical spaces, objects, and entities to which the data refers*". So, this differentiates the SV situations, in which the data is displayed close to data referents, from EV, which displays data so that it spatially coincides with data referents. The concept of EV presents more challenges than SV. According to [15], SV may also be related to another physical dimension when the data changes over time. In their definition "*a visualization is temporally situated if the data's temporal referent is close to the moment in time the physical presentation is observed*". An example of temporally SV could be the user's water consumption, which can be estimated and visualized at different moments. A spatially and temporally situated example is presented in Fig. 1(b), because it shows in real-time a representation of the polluted air, measured within the place where the user is.

Fig. 2(b) presents the theoretical model for interaction with SV proposed in [15] and constructed from the EV [22] and the beyond-desktop [23] visualization models. This conceptual model represents all the possible interactions between a user and a spatially SV system. Since all the interactions are originated from the user, the information flows – black and dashed arrows in Fig. 2(b) – have opposite directions regarding the model presented in Fig. 2(a). Both the user interactions that need the visualization pipeline (passing or not by the physical presentation) could belong to any kind of interactive visualization system (situated or not). The flow that comes from the user to the physical referent is specific to SV. The first mode of interaction with the visualization system happens when the user performs operations that modify the visualization pipeline. Examples of such operations are selecting, filtering or highlighting data, changing the visual representations or changing the camera parameters [23]. To accomplish these modifications in the visualization pipeline through interactions, information from sensors must be collected and combined with software to understand the user's actions. Changing the physical representation is the second mode of interaction the user can perform. According to [23], the reorganisation of the physical elements (by moving it or by moving around) can give the user new perceptions of the physical presentation and extend the possibilities of interactions, overcoming the limitations of the interaction's first mode. The reason for having a black arrow linking the physical presentation to the visualization pipeline, in Fig. 2(b), is because some of the user's physical interactions affect the visualization pipeline as well. When the information that flows from the user passes through the physical referent, as mentioned, the visualization system is situated, and the third way of interaction appears. It also makes the physical referent visible and, usually, accessible and manageable [22]. If the user interacts with SV, analysis and actions can be interlaced and actions could be taken forthwith, including modifying the raw data if the system is in real-time and the physical referent is the data source – dashed link between the raw data and the data's physical referent in Fig. 2(b). For example, a visualization of traffic lights could dynamically update itself according to traffic accumulation. Classical visualization usually does not support this type of interaction [15].

C. SV challenges – egocentric viewpoint limitation

Compared to regular MR-based visualizations, SV may have several benefits. According to [1], "*tasks, such as inspection/comparison, spatial learning, and in-situ pattern-seeking and discovery can benefit from enhanced cognition through situated visualizations compared to alternatives*". However, these benefits imply challenges that influence their applicability and utility. [22] discuss these compromises and highlight various research challenges. Some of these common to several visualization areas. Other problems are specific to MR [24]. SV even presents additional difficulties due to the dynamic and distracting nature of the real-world. According to [18], when using SV combined with real-world, several challenges must be considered: egocentric viewpoint limitation of the user (to see/collect data outside of the current viewpoint, avoiding or mitigating alterations of the user's position), data overload (to provide the needed information, avoiding confusion and lack of clarity), visual interference (to distinguish crucial information from the irrelevant one, avoiding the occlusion of vital data by the virtual content), visual coherence (to deliver data that makes sense), registration error (to overlay the digital content at the exact position), dynamics of MR (to keep track of the changes done in the scenario or the user's viewpoint when digital content is merged, avoiding confusing outcomes), and temporal coherence (to deliver data that makes sense in the exact time). All these challenges are exemplified in Fig. 3.

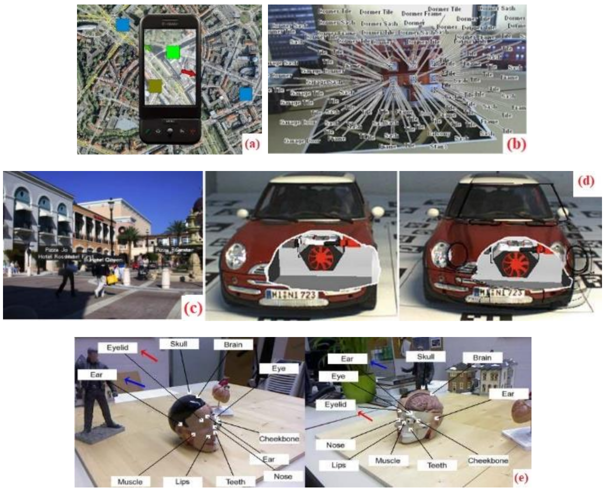

Fig. 3. SV challenges. (a) Egocentric viewpoint limitation of the user, from [25]. (b) Data overload, from [18]. (c) Visual interference, from [26]. (d) Visual coherence and registration errors, from [2]. (e) Temporal coherence problem due to the dynamics of MR, from [18].

Focusing on the egocentric viewpoint limitation, Fig. 3(a) illustrates the necessity of changing the user's FOV to access more information outside the screen. In MR, to complete certain tasks, it is necessary to modify the user's position to see the scene from a different viewpoint. The solutions to the egocentric viewpoint limitation challenge might also provide improvements to some of the other above-mentioned SV challenges, as it is necessary to deal with more information to create new viewpoints. Finally, tackling the egocentric viewpoint limitation could also enhance user experience and safety, because the user can see more and become more aware of the surroundings. Taking this into account, it is obvious that solving or mitigating this challenge can have a major impact on several situations like, for instance, on the lives of people with mobility difficulties (visiting monuments without passing its entrance), or in maintenance activities (inspecting a particular machine from unreachable positions).

III. LITERATURE SEARCH METHODOLOGY

The literature review was performed using the following methodology based in three phases: parameter calibration, the search process itself and the analysis of the outcomes. In the search calibration phase, the research question was defined as "*what kind of techniques can be used to overcome the egocentric viewpoint limitation challenge?*". Electronic databases were defined ensuring coverage of books, journals, conference and workshop proceeding articles, between 1996 and 2020. The used databases were Web of Science (Clarivate Analytics) and Google Scholar. Specific keywords were selected for the search and Boolean logic was applied to further refine initial search results and obtain a more manageable number of publications to analyse.

IV. RESULTS AND DISCUSSION

Using the mentioned methodology 32 publications ([1, 16 – 18, 20, 25, 27 – 36, 38 – 53]) were identified. It is possible to say that the application areas of the analysed articles are botanic [1], architecture [16, 17, 18], maintenance [18], document management [20, 50], tourism (or navigation) [25, 29, 31, 33, 35, 38, 40, 41, 43 – 47, 52], manufacturing [27], education [28], inspection [30, 36], urban planning [32], health [34], environmental monitoring[39, 42], project management [50], analytics [51] and public-utility sector [53]. Regarding the device types, most of the studies use devices of the mobile-based device group [16 – 18, 20, 25, 30 – 36, 38, 39, 41 – 47, 52, 53]. The research work presented in [1, 27 – 29] is in the video-see-through-based device group, while [40, 50, 51] is in the computer-based device group. Concerning the techniques to extend the egocentric viewpoint of the user in MR applications, the search's results showed that there are six (6) different techniques: multi-perspective renderings, transitional interfaces, off-screen visualizations, zooming and focus + context, overview + detail, and combining maps and sensors with the egocentric MR view. Fig. 4 shows the distribution of publications according to the used techniques.

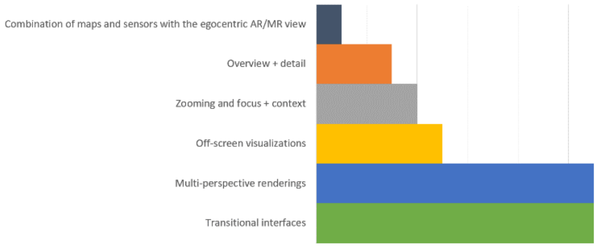

Fig. 4. Distribution of publications according to the used techniques to deal with the egocentric viewpoint challenge in MR.

As can be seen in [18, 27 – 33, 39, 41, 43], transitional interface technique offers the users a seamless way to switch from the MR egocentric viewpoint to other relevant virtual reality (VR) viewpoints of the same elements without altering their position. This technique also delivers spatial indications that permit the users to mentally map the viewpoints. To accomplish the transitions, annotations or visual links are usually used to mark where real and virtual views are similar. The first transitional interface used in AR, in the context of a collaborative workspace, is presented in [27]. It used continuous motion cues to avoid user's disorientation. Another example of the transitional interface is the Magic Book [28] that supports smooth transitions between AR views and immersive VR scenarios. As mentioned above, the work presented in [41] shows that it is possible to shift to a VR exocentric map view to give an overview of the neighbouring points of interest (POIs) according to the users' position but, as usual, it is not possible to change the viewpoint around a chosen object. The work presented in [39] and [43], as in most of the systems using these techniques have a limited number of available VR viewpoints to switch to. A typical transitional interface technique complements the egocentric viewpoint with a world-in-miniature (WIM) [29]. The WIM can have copies of real-world objects, but, usually, these interface items are only designed for head-mounted display frameworks (and not for handheld devices). Bane et al. [30] present a WIM interface, in which a user can switch to a virtual occluded room and interact with it. The transitions are made considering the specificities of the actual user's tasks or goals and supported by some intelligent algorithms based on a pre-defined semantic (for instance, the scene semantics), referred as smart transitions. The smart transitions can be used, for example, to create more immersive MR games, allowing the player to follow virtual characters that otherwise would disappear behind geometry, or can be used to switch to a virtual viewpoint to validate urban structures, detecting undesired occlusions from certain viewpoints. Others transitional interfaces use the Object-Centric Exploration (OCE) that allows users to look/interact with an entire computer-generated replica of the real-world object without moving from their position, as can be seen in Fig. 5(a). In OCE techniques, the transitions between virtual and real content appear to be enough to keep users oriented when switching between modes [18]. However, this approach might not take into account the actual goal of the user (in this situation smart transitions might be preferred). The OCE techniques proposed in [31] and [32] allow a complete examination of a real-world object, including overviews and zooming operations without physically changing the user's location as they use virtual copies of the real-world object. The transitions between the AR and VR views are based on the task and scene's knowledge meaning that the system suggests appropriate VR viewpoints according to the task [32]. The techniques were assessed in urban settings, as can be seen in Fig. 5(b), and produced design recommendations for OCE interface's development [18, 32].

Fig. 5. (a) OCE method, from [18]. (b) Smart transition method using scene semantics in an urban planner task, from [18].

In [18, 34 – 43], multi-perspective renderings technique is used to add extra views of the real-world into the current MR user's egocentric view, extending the user's FOV and giving a general overview. This technique truly extends the egocentric viewpoint because users do not need to move from their location to visualize all the relevant data around them. The main weakness of multi-perspective renderings technique is the difficulty for the users to change the viewpoint of the added renderings because these new renderings are usually static (specifically calculated for the needed situation). One way to obtain the viewpoint extension is to strategically introduce mirrors in the MR process [37]. Each mirror is equivalent to adding a camera positioned in its location. [34] introduce the concept of a virtual mirror in laparoscopic surgery to present information that faces away from the users. [35] verified how mirrored views from a live video simplify orientation in urban environments and [36] uses virtual mirrors in combination with a camera to spread the MR viewpoint and to improve the interaction by showing distant elements in a zoomed render. Deformation procedures can also add supplementary views into MR users' current view on occluded or out of view scenario elements. [38] used radial distortion and melting methods for uncovering occluded POIs, mixing reconstructed models and projected video images. However, with these procedures, it is impossible to have real-time viewpoint changes for investigating remote POIs, because the deformation computations are very time-consuming and must be pre-processed. These deformations could affect both virtual and egocentric MR views, as can be seen in [39], where a VR exocentric view was seamlessly integrated into the egocentric AR view to provide an overview over a large area. Finally, another possibility to integrate several views in a single egocentric view is panorama renderings. Panoramic rendering is the seamless collage of several rendered images, each one obtained by rotating the camera at a different angle, starting from its initial position. The panorama rendering could go up to a full 360° view of the horizon. An assessment of diverse panoramic representations of the users' environments is presented in [40]. In [41], the users' FOV is enlarged by zooming out on a panoramic image of the environments. This work could also be categorized as a transitional interface technique because it is possible to shift from the egocentric view to an exocentric map view showing different POIs according to the users' position. In this fuzzy categorization, the transitional interfaces presented in [42] and [43] create a multi-perspective rendering with the images of the available views in the real-world. Their work intended, respectively, to communicate existing views of the environment and deploy digital content in AR. This proves, according to [18], that in conjunction with transitional interfaces, multi-perspective renderings may be employed as an overview visualization for additional interaction. Fig. 6 gives examples of the multi-perspective renderings methods.

Fig. 6. Multi-perspective renderings techniques. (a) Deformation procedure, from [38]. (b) Virtual mirrors, from [35]. (c) Panorama renderings.

As can be seen in [25, 44 – 47], off-screen visualizations try to reduce the impact of the limited MR display's size or FOV when important data is scattered in an area whose size is considerably larger. The concept behind this technique is that the MR display is just a window into a larger space, as is illustrated in Fig. 3(a). The method's objective is to make the user aware that the desired information might not be visible at a given moment because it is out of the camera's FOV. To help in the navigation task, directional or neighbouring indications are shown in the users' current egocentric view, using arrows – as can be seen in Fig. 3(a) – or halos (circles around off-screen objects that intersect the visualization display's border) – as can be seen in Fig. 7. Nowadays, the trend in the use of off-screen object indicators is 3D. The off-screen indicators can be applied to represent more than the POIs direction or neighbouring data. Off-screen visualizations still need the users to alter their viewpoint (moving to new locations) to be able to explore the desired information because it only delivers spatial cues. However, according to [25] this technique may reduce the task conclusion time and the perceived task load.

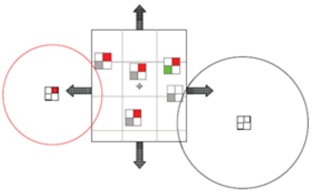

Fig. 7. Representation of an off-screen visualization using halos, from [45].

Overview + detail and zooming and focus + context techniques were used to level the viewpoint restriction of users when the workspace is larger than the screen size. These approaches can be used in conjunction with off-screen techniques. A comprehensive review of these techniques is given in [48]. In overview + detail, the current view of the user is seen as the detail, while other visualizations offer an overview of the neighbourhood. For instance, to give an overview of the entire relevant information to present, [49] creates a movable field-of-view box to control the contents of the detailed view. In contrast, the zooming and focus + context technique establishes the detail view as a focus and then delivers the overview as a context that includes, seamlessly in most cases, the focus area. It uses geometric and semantic zoom. These methods "freeze" (or "lock") the image, interrupting the real-time scene visualization, and apply different degrees of zoom according to the user's interest. Geometric zoom only scales data size, while semantic zoom varies the size of visual elements and the number and type of details shown (resulting in the possibility of displaying elements differently depending on the semantic zoom level) [50]. In the visual analytics area, analysts need summaries of large amounts of information, which becomes a challenge when dealing with non-numerical situated information. The semantic zoom visualization could provide an interactive overview of the data combined with a detailed view of entities contained in it. Any subset of the data can be semantically zoomed to show increasing detail as the zoom level rises while keeping surrounding documents visible to supply context [51]. It is hard to advocate which of the two techniques (overview + detail and zooming and focus + context) is better because their results differ significantly depending on the task and the implementation. However, zooming and focus + context techniques can give the user, with the same viewpoint, an overview of the information and more specific detail of data, being all a matter of zooming and definition of the information to be presented [46].

The combination of maps and sensors with the egocentric MR view could require little changes in the user's location to cover the entire map and to allow the exploration of all the desired data. In [52], while the handheld device hovers over the map, personalized information, such as distances between places, is displayed on the screen. This is not a real egocentric viewpoint solution because the entire information can almost fit in the user viewpoint and the user is not physically walking through the areas that are presented on the map. This technique may implicate disconnection from the real-world, occasional lack of smooth interaction and split focus between the two tasks (scan the map and analyse the virtual information).

V. CONCLUDING REMARKS AND FUTURE WORK

When specifically thinking in SV based on MR, the solution for the mentioned challenge becomes much more imperative. The solution could pass not only to find new and different viewpoints, but also to present important data related with the environment where the user is. So, the relevance, amount and source of information that can be used might be crucial. For instance, from the literature review [9] and the obtained results, the mobile devices are the most used in MR. Knowing that this kind of devices come increasingly with more built-in sensors and cameras, an interesting topic of research might be to consider the use all the sensors to create the biggest panoramic viewpoint that the device could have, overriding small FOV limitations or to improve a multi-perspective renderings technique. Another possibility is to change the viewpoint or the information to present, using the knowledge of where or what the user is looking at. To add pertinent data to the existing situated information is to think beyond the visible graphics and annotations and consider other kinds of information such as user's profile, other types of context data or even multimodal information (as haptics or audio). The multimodal SV is an interesting area that needs further investigation. All of the mentioned must address critical issues like the size of the devices' display (small to large), the processing capacity of the used device (limited or not), and the possibility of having interactive tools for multimodal situated analytics to give the user a better experience and sensation. These potential research work must deal with additional challenges of how to retrieve, combine, synchronize and present all the gathered data and if it is possible to have it all done in real-time.

A specific research opportunity is to investigate the possibility to combine transitional interfaces and multi-perspective renderings techniques (usually applied separately [18]), as a mean to extend the viewpoint of the user.

All the mentioned opportunities will become more effective if combined with artificial intelligence.

The semantic zoom technique is a big opportunity due to the spread of the artificial intelligence. Semantic information might be used to strategically present relevant viewpoints according to the user's current task and context, considering, for example, smart transitional interfaces that detect and adapt to undesired occlusions, from certain views. The intelligent search for answers of how to combine MR and VR views and the transitions between them should also analyse when it is more advantageous to use MR or to use VR and if all the process could be done in real-time. The new VR views could be generated with the knowledge of the 3D reconstruction of the scenario and the MR camera's parameters.

Possible solutions to the egocentric viewpoint challenge might require the adaptation of the scene. [18] expresses the conviction that there are valid application cases, such as poster showing augmented content or table-top applications, where interferences between content should avoid occlusions. The scene adequation and modification could be thought, for instance, as the same application used in completely different situations or just an adequation related to the change of the user's profile/condition – presenting the information with different detail or in a different way – or the degree of sensitivity of the information – preventing (if in public) or not (if in private), the appearance of sensitive data.

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