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ABSTRACT

As one of the presentative novel technologies in recent years, Augmented Reality (AR) has gotten the ROC government’s attention, and thereby the AR-related applications have been taken into official account in facilitating citizen life. In this research, first, a sort-out of the definitions and the scope of three types of Realities—AR, VR, MR—will be offered to tell the much more realistic dimension of AR. Under the official road excavation context in X city via observation method, second, specific AR applications will be proposed by illustrating it in the pre-excavation, the excavation, and the post-excavation phases, respectively. By cross-referencing between the official road excavation system and public infrastructure pipeline databases, third, the related data of pipeline maps could endow the current AR positioning with better accuracy and directionality.

Keywords: Augmented reality, observation method, road excavation, public infrastructure pipeline databases.

INTRODUCTION

With the pioneering combination of the physical environment and virtual squares, “The Sword of Damocles” proposed by Sutherland in 1965 is widely regarded as the first AR application (Sutherland,1965). Nowadays, AR applications have been extended to various domains. For example, Boeing uses AR to reduce both the error rate and the operation time of wire deployment, which indeed brings out improved safety and the lower manufacturing cost of airliners (DIGITIMES, 2021). Similarly, the head-mounted display (HUD) adopted by the military is an AR device, integrating aircraft information and physical space, which enables fighter pilots to make decisions faster. Possessing the click-and-mortar nature, noticeably, AR shows up in not a few interactive games like EyePet (launched by Sony) or Pokémon Go (developed by Niantic). In comparison with such flourishing commercial AR applications, the ROC governmental AR applications still remain the initial stage. Even though one of the municipal governments, X-city, has tried to figure out a proper AR application to engineering planning that might alleviate the disturbance of traffic jams and inconvenience resulting from road excavations, it is actually an initial scheme with sparse content. Therefore, a further detailed scheme of the AR applications to the engineering planning of road excavation would be the main idea of this research, thus improving the engineering quality of road excavation as well as eliminating the excavating disturbance to citizen life.

Considering the inextricable linkage among all the underground pipelines, including wires, gas pipes, water pipes, and telecommunications pipes, any forms of road excavations, such as emergency repair, major disaster, new construction, even the establishment of a national freeway, should draw up a prudent plan before each engineering in case of any possible false excavation. Since the image of the underground pipelines presented by AR could offer a larger dimension of visibility, from 2D to 3D, it reaches a more concrete and precise simulation of excavating engineering planning. In this case, the scheme of AR applications to excavating engineering planning will be separated into three phases as follows: pre-excavation, excavation, and post-excavation. Before road excavation, AR will present the corresponding location of the underground pipelines to achieve an ideal deployment; during road excavation, mis-digging could be avoided by applying an AR device inter-comparing with the physical environment; after road excavation, 3D pipelines shown by AR in checking pipeline collisions could validate the correctness and the rationality of the pipeline information. In addition, the data gathered by cross-referencing between official road information systems and public infrastructure pipeline databases will enhance the current AR positioning with better accuracy and directionality.

Basically, in the second part of this research, we discuss the definitions and examples of AR and other realities; the third part is methodology; the AR applications to road excavation are illustrated in the fourth part; the final part is the conclusion.
dings production process.

LITERATURE REVIEW

Augmented Reality (AR) is an imaging integration of virtual objects and the real world. Azuma (1997) argues that AR consists of 3D, instant interaction, and the combination of virtual reality and physical reality. So far, AR has been widely applied in different industries. In the medical field, for instance, AR serves for surgical simulation, while in-game industries, certain interactive AR games, such as Father.IO designed by Proxy42, a First-Person Shooting (FPS) game integrating reality and virtual weapons, have been launched by swarms of game companies.

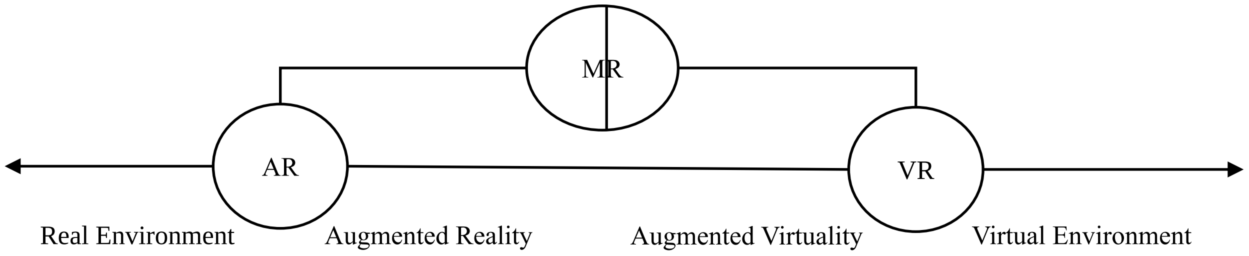
Simulated by a computer system, Virtual Reality (VR) itself is a 3D virtual world providing simulated senses of sight, hearing, and touch to users who can accordingly grasp immersive and realistic experiences. With the 3I characteristics of Immersion, Interaction, and Imagination (Burdea & Coiffet, 1994), VR accentuates the leading role of humans in virtual systems. That is, the information processing model of humans toward computer systems has evolved from external observation to internal immersion. In the virtual world of Second Life (developed by Linden Lab), for example, Users can create characters, called residents, who can not only walk around, socialize with other residents but also participate in individual or group activities and transactions.

Integrating physical sensation into a virtual environment, Mixed Reality (MR) has brought out the interactive coexistence of the real and the virtual objects. For example, the flight simulator provides a simulated cockpit of equal proportion, including a real flying setting, a virtual sight, and hydraulic or electric driven systems to achieve the reenactment of piloting sensation as genuine as possible (Milgram & Kishino, 1994). Signifying single or multiple episodes, Substitutional Reality (SR) is a visual imaging projection of existence belonging to an arbitrary moment, no matter virtual or physical, past, present, or future. Compared with AR and VR, SR need not follow the linear timeline; instead, it could refer to single or infinite timestamps simultaneously.

Generally speaking, AR is a technology based on the real world's photographic image upon which computer information is superimposed; it aims to provide specific sensory information at a specific time and place, that is, augmenting virtual data in physical reality. Oppositely, VR is a virtual space generated by a computer system in which physical reality is duplicated and represented. Via the movement and interaction operated by the controller or keyboard, the VR users easily immerse themselves in the simulation.

Assimilating the real and the virtual, MR creates a new world with new visibility where physical objects and digital objects can be coexisted and interacted in real-time. To a certain degree, MR has expanded the comprehensive application of reality and information. Bathing in the MR environment of multi-dimensional information by equipping various sensors, users meet their expected perception and recognition through the simulating interaction directly with MR settings. Different from all the others, SR is neither based on specific reality nor accommodated specific dimensional objects. Referring to non-specific time or space is the unique feature of SR that sets it apart from other realities. All the realities mentioned above are sorted by their dimensions and shown in Figure 1.

In summary, the characteristic that AR attaches utmostly to the physical reality is geared towards the official need of real-time integration of virtuality and reality. That is the reason this research proposes applying AR to the engineering planning of current road excavation.



Source: Revised from Milgram & Kishino (1994).

Figure 1: Types of reality.

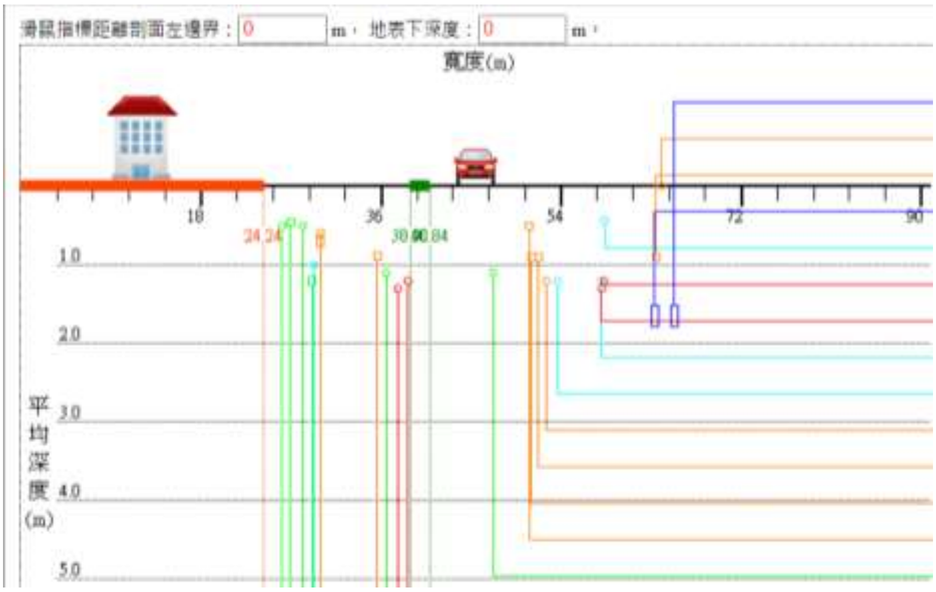
METHODOLOGY

Compared with the interview method, that restricts the imagination of the interviewees because of the interview questions. Therefore, if a system analyst designs the system based on the opinions collected from interviews, the system creativity is very likely to be limited, without the significant innovation or inventive ideas. As Henry Ford said, before a car is manufactured, when he asked people about what kind of transportation they need, almost everyone's answer is a faster horse. Therefore, the observation method is adopted to determine the AR application in the official road excavation system.

Ciesielska *et al*. (2018) classified the observation method into three categories as follows: (1) participant observation: researcher immerses himself in a specific culture for a long period of time; (2) non-participant observation: researcher keeps being as an outsider while acquiring what is needed; (3) indirect observation: researcher relies on the observations done by others. An important principle of participant observation is that researchers do not only perform observations but also need to participate in the organization in some way as their roles. By carrying out the participant method over two years, this research attains the anticipated collection of the observation data gathered from different special municipalities. In this case, data collection itself involves daily routines and special events, including road excavation systems, policies, self-government ordinances, and standard operating procedures.

APPLICATIONS

Traditional pipeline maps are presented in the form of 2D overlooking perspective, rooted on the electronic maps, which has its limitations in the context of road excavation. For example, due to the flat view angles, it is not easy to show the spatial distribution, obstacles, and conflicts of pipelines in the 2D modus. Even from the point of side view, as shown in Figure 2, the spatial structure and the direction of pipelines cannot be presented. In addition, because the 2D presentation only gives the partial and specific information of pipelines, the global and spatial analysis is hard to achieve, which makes it difficult to observe pipeline obstacles and resolve pipeline conflicts properly. In order to provide a holistic perspective of pipeline spatial structure in the real environment, AR comes into being. Compared with the 2D pipeline maps, AR could be applied in the actual environment to show the spatial structure of pipelines in the 3D modus, which could present pipeline distribution, pipeline obstacles, and pipeline conflicts properly. Moreover, the AR application in underground pipelines may give feedback on the correctness and the rationality of public infrastructure pipeline databases.



Source: This study.

Figure 2: Side view of 2D pipeline maps.

In the pre-excavation phase, first, AR can be used to present the current distribution of the underground environment, especially the complexity and the danger among crowded pipelines (e.g., oil or gas pipelines), as shown in Figure 3. Superior to the conventional planimetric sight, the stereoscopic image formed by AR offers larger visibility to the construction units that can make better engineering planning through a more sophisticated calculation—cubic meter by cubic meter—to get more convincing constructing costs and schedules.

Source: This study.

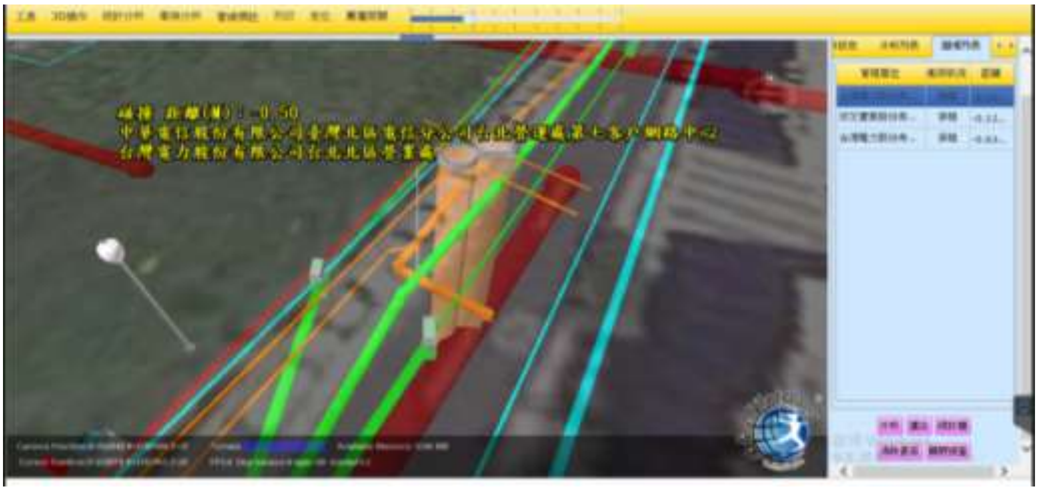
Figure 3: AR applied in the pre-excavation phase.

Second, the mis-digging of pipes during road excavations has always been an issue that concerns the officials most due to its high risk of resulting in serious damage. Limited to the invisibility of underground pipelines, the previous constructing units relied either on luck or on constructing experience to reduce mis-digging. Fortunately, the public infrastructure pipeline databases of the ROC government have kept on developing and so far reached millions of pipeline maps with transparent data standards (Construction and Planning Agency, Ministry of the Interior, 2020). Derived from public infrastructure pipeline databases, the bountiful pipeline maps confer quite enough foundations where the artful 3D images formed by AR can be embedded in almost seamlessly. Upon specific areas with highly concentrated pipelines, such AR images embedded in the pipeline map matter a lot because they can tell the underground physical environment correspondingly in great detailed width and depth. Synchronously executing during road excavation via an official exclusive App operated in a mobile device, the prudent cross-comparison between the AR simulating images and the solid pipeline spot delivers effectively the real-time information of physical pipelines(shown in Figure 4). Taking advantage of this elaborate AR application in pipeline maps, the danger of road excavation and the inconvenience caused by mis-digging would be eliminated not entirely, at least partially.

Source: This study.

Figure 4: AR applied in the excavation phase.

After road excavation, third, the AR application in underground pipelines somehow could answer to the correctness and the rationality of public infrastructure pipeline databases. Trapped by the flat angle of vision, in fact, the preceding 2D image gave a little guarantee to the accuracy of pipeline maps of public infrastructure databases. As opposed to a 2D image, the 3D image formed by AR indeed constructs larger visibility which allows more latent pipeline conflicts to be found and checked cautiously in a detailed picture, as shown in Figure 5. Likewise, the examination of engineering execution and pipeline maintenance, or the evaluation of underground security, could depend on related AR applications to a certain degree.



Source: This study.

Figure 5: 3D pipeline conflicts.

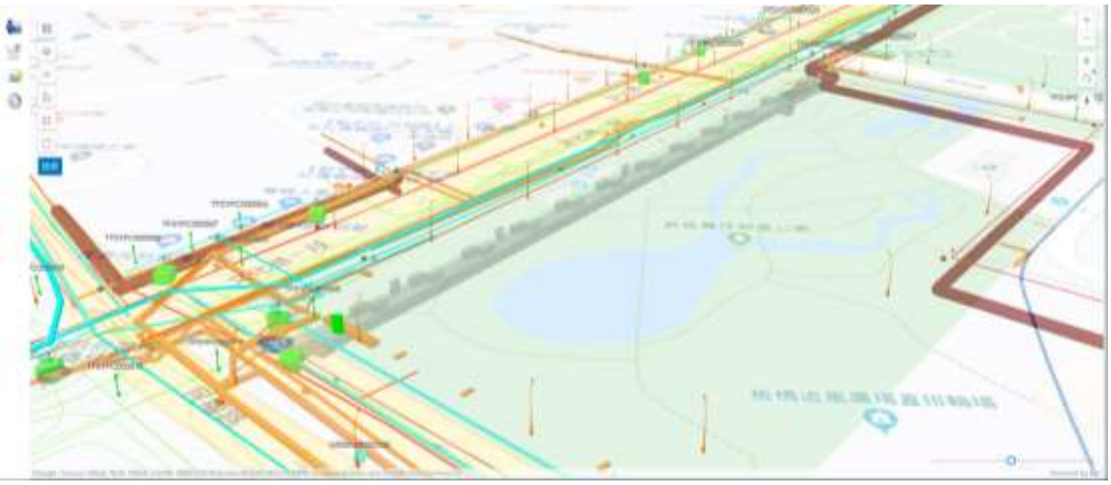
It is worth mentioning that AR positioning hasn't attained entire perfection yet. Actually, there are several meters of deviation of AR positioning now applying to commercial mobile devices GPS, which would be an unacceptable inaccuracy applying in road excavation. Such deviation of AR application in road excavation equals a latent threat. Misled by this deviation, any excavation upon a road with a gap pipe only several meters nearby, for example, is very likely to get a mis-digging. Meanwhile, the uncertain directionality of AR positioning is another issue. Under the static state applied to existing GPS, AR positioning nowadays can only tell the information of physical location without giving further specific directionality. Relying on such AR applications unable to tell specific directionality, even though the constructing units of road excavation indeed grasp physical location, they are somehow incapable of preventing mis-digging and the lurking disastrous consequences. Therefore, with the cross-referencing between the measurement by national GPS positioning and the manual inspection of pipeline data/maps (e.g., the positioning error is acceptable only within 30 cm in X city) as shown in Figure 5, the ubiquitous hole-covers in great numbers could effectively help to point out the precise directionality of pipelines underground. As a suggestion, namely, the identifiable orientation drawn by the horizontal axis between two separated hole-covers is a supplement to the inaccuracy and the non-directionality of AR positioning in road excavation mentioned above.

Simultaneous Localization and Mapping (SLAM) may improve the precision and try to answer the directionality question of AR positioning. The definition of SLAM is the user moves in space, locates his own position or posture based on the observed map features, and uses specific calculation techniques to achieve simultaneous positioning and map construction. For example, Google collected street view data and did the image processing to retrieve multiple feature points of architectures for drawing spatial maps. Therefore, when we use Google street view AR positioning, the images of a real environment are required to analyze, capture, and compare to the spatial maps made in advance. Accordingly, calculating relative angles and distances from the captured real scene image and GPS coordinates to the spatial maps could provide better precision and try to solve the directionality problem of AR positioning, as shown in Figure 6.

Source: Google maps app.

Figure 6: Google AR maps.

However, the street view and spatial maps mentioned above are owned by Google, which indicates another SLAM method should be taken to improve the precision and try to respond to the directionality question of AR positioning. In X city, public infrastructure pipeline databases are maintained by the following SOPs. Firstly, pipeline maps should be checked and corrected very carefully. For example, according to the engineering survey, pipeline owners fill the attributes of pipelines such as diameters, starting points, intermediate points, endpoints, and laying depths. Then the authorities concerned verify the correctness and the rationality of the pipeline information. Secondly, the pipeline maps and the related facilities are converted into RIM (Road Information Modeling), as shown in Figure 7. Different from BIM (Building Information Modeling), which focuses on the construction of 3D models for buildings or architectures, RIM is defined as 3D objects of roads and related facilities that provide management at all stages of the life cycle, including plan, design, construction, and maintenance.



Source: This study.

Figure 7: RIM.

Therefore, with the cross-referencing between the measurement by national GPS positioning and the manual inspection of pipeline data/maps (e.g., the positioning error is acceptable only within 30 cm in X city) as shown in Figure 8, the ubiquitous manhole or handhole covers (as shown in Figure 9) in great numbers could effectively help to point out the precise directionality of pipelines underground. As a suggestion, namely, the identifiable orientation drawn by the horizontal axis between two separated manhole-covers is a supplement to the inaccuracy and the non-directionality of AR positioning in road excavation mentioned above, as shown in Figure 10.

Source: This study.

Figure 8: Public infrastructure pipeline databases.

Source: This study.

Figure 9: Manhole and handhole covers.

Source: This study.

Figure 10: Combination of AR and public infrastructure pipeline databases.

CONCLUSION

Among the compilation of the definitions and the evolutions of AR, VR, and MR, AR finds itself a position attached utmostly to the physical environment. Despite the fact that AR has been perceived by the authorities concerned in Taiwan, it is actually an unfolded application so far in official affairs. Based on its 3D visibility hence, AR is proposed applying to the engineering planning of road excavation, including preview, execution, and review. Conditioned to the context of road excavation in X city, the inaccuracy and the non-directionality of AR positioning can be fixed by cross-referencing the road excavation system and public infrastructure pipeline database.

The application of AR in the context of road excavation brings certain help, whether in the pre-excavation, the excavation, or the post-excavation phases. For example, in the pre-excavation phase, AR could be applied to demonstrate pipeline complexities and obstacles underground to evaluate the construction cost; during excavation, AR pipeline positioning in the actual environment can be used to avoid the mis-digging or tremendous disasters not entirely, at least partially. In the post-excavation phase, 3D pipeline maps generated by AR provide a comprehensive perspective of pipeline conflicts as the basis to validate the correctness and the rationality of the pipeline information.

To sum up, the complementarity between AR positioning and public infrastructure pipeline database embodied in the engineering planning of road excavation in X city, whose bountiful pipeline maps support 3D images firmly, is the main idea depicted by this research. The obsolete approach to governmental affairs, on the one hand, must be upgraded by considering and implementing the ever-changing technology. Other than AR, VR, or MR, that is, any adequate technology should be put into consideration for better governmental efficacy. On the other hand, an ideal model like the AR technology applied in road excavation is what the authorities concerned should try to figure out to ensure the maximum of public welfare. Hopefully, more official attention to the related technical applications in governmental affairs can be aroused by this research.

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