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To cite this article: R Fistola *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **949** 012053

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## Augmented reality for cultural heritage: a new dimension for the perceptual knowledge

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**Abstract.** The paper presents an innovative way of conceiving the museum exhibit particularly useful in those territorial contexts in which it is possible to simultaneously show the place of discovery of the exhibit n (contextualizing it through the virtual reproduction of the historical scenario) and the find itself adding to this the possibility of narrating one's own history and characteristics. The entire meta-project is designed for the Pietraroja site in the province of Benevento which would acquire considerable cultural interest thanks to the potential of augmented and mixed reality. The main idea is to use this new technology to involve the user (observer) by rebuilding the environment and the peculiarities of the finds. The perception of the augmented elements will be possible by design a specific application for smartphone that everyone gets in its pocket.

### 1. Paleontology as a key segment of the cultural heritage

The paleontological heritage is increasingly becoming an important component of the cultural heritage. Over the years we have gone from a purely static-conservative conception of the protection environmental heritage that put everything under protection and that only allowing the contemplation of the good. From this dimension we have moved on to a more dynamic conception, oriented towards an experiential involvement of the public; this is because the landscape and cultural heritage are increasingly considered no longer as a heritage only to be protected but as something destined for public enjoyment and therefore experienced as a tool of cultural and economic growth of society.

But when and how a paleontological or naturalistic site emerges from the shadows and anonymity, that the knowledge of a few experts assigns them and manages to enter in the collective cultural heritage, shared and recognized as a good with undisputed value and of which each citizen is a proud holder? In other words, what are the processes that need to be implemented because the promotion of a paleontological site, but also of a concept, a behavior, become effective and permanent and allows for a cultural growth? While it is more immediate to understand the importance of protecting a forest or an animal species, it is not yet sufficiently widespread the awareness of the geological heritage protection, often constituted by non-renewable resources as a waterfall, a cave or a fossil level.

The use of geological heritage, particularly paleontological heritage, as touristic and educational sites, is everywhere an advantage for the local population and promotes scientific knowledge and



education. In this study, we highlight a unique paleontological site in world that can significantly contribute to the education and development of geotourism.

Moreover, the paleontological site of Pietraraja (Fig. 1) could be an example for all the other paleontological sites of using technological innovation and augmented reality as tools for promoting cultural heritage.



**Figure 1.** Pietraraja - "Le Cavere" site: the location where fossil fishes and *Scipionyx samniticus* were discovered

### 1.1 Pietraraja a field of knowledge: Ciro's home

Pietraraja is a unique fossiliferous location in the world. The site is known since the 19th century for its perfectly preserved fossil fishes. The first to point out the richness of the outcrop was Scipione Breislak in 1798 and, subsequently, Bassani [1] and Costa [2], [3], [4], [5], described the succession of the "Calcariad Ittioliti di Pietraraja" known for their fossil fishes. The age of these limestones was the subject of debate until the end of the nineteenth century, when Bassani [6] re-examined the fossil fishes collected by Costa and confirmed their Cretaceous age.

The site was later studied by D'Erasmo [7] and D'Argenio [8]. The discovery of *Scipionyx samniticus*, the fossil friendly called "Ciro" (Fig. 2), took place thanks to the discovery by a collector, Giovanni Todesco, who brought it to light in the spring of 1981 [9], [10]. Subsequently the University of Naples "Federico II", in 1982, in collaboration with the Museum of Natural Sciences of Turin, carried out excavations [11], [12], [13] and subsequently the specimen was studied by researchers of the Museum of Natural Sciences of Milan [14], [15], [16], [17]. *Scipionyx* (fig 2) has been classified as a member of the compsognatidae family, a family of small carnivorous dinosaurs, characteristic of the period between the upper Jurassic and the lower Cretaceous (150 - 115 million years ago).

According to Dal Sasso and Maganuco, the body of *Scipionyx* was no longer than 50 cm and the specimen was probably less than three weeks old at the time of its death. This datum is derived from a series of juvenile characters, such as the presence of the fronto-parietal fontanelle, the large and round orbits, the short snout, the replacement of the teeth not yet begun, and finally the presence of a space void in the pelvic area which suggests the existence of a yolk sac.

The uniqueness of *Scipionyx* lies above all in its perfect state of fossilization which preserves a unique variety of internal organs and soft tissues. External soft tissues are represented by horny claws. Internal tissues include ligaments, pieces of cartilage, neck muscles, part of the trachea and esophagus, part of the liver and other blood-rich organs, but the intestine is the most complete and most visible internal organ of *Scipionyx*, of which it is still possible to appreciate the loops of the duodenum and the folds of the mucosa. Thanks to the exceptional conservation status of *Scipionyx*, within its digestive system, the bones of a lepidosaurus reptile were found in the region of the stomach, remains

of a lizard in the duodenum, fish scales in the rectum and a variety of small remains in different points of the intestine.



**Figure 2.** *Scipionyx samniticus*, friendly called “Ciro”

The quantity and the detail of the informations obtained from this single specimen make Pietraraja a unique fossiliferous location in the world. Furthermore, the Pietraraja site shows an extraordinary biodiversity and in addition to fishes (Holostei and Teleostei) and *Scipionyx*, microfossils (radiolarians and foraminifera), sponge spicules, plant remains (conifers, ferns and possible leaves of angiosperms), Mollusks (gastropods, bivalves and ammonites), starfish and crustaceans, Tetrapods (amphibians and reptiles) have been found in the sediments outcropping there.

What was the environment in which *Scipionyx* died? On this point there is no agreement between the scholars and three distinct models have been proposed. According to some authors [8], [18], the Pietraraja sediments settled in a very shallow lagoon environment that was often isolated from the open sea but subject to the influence of tides and occasional storms. Other authors [19] believe that the deposition of the sediments that emerge today in the area of Pietraraja took place in a coastal strip that ran between the edge of the platform and the deeper sediments of the basin.

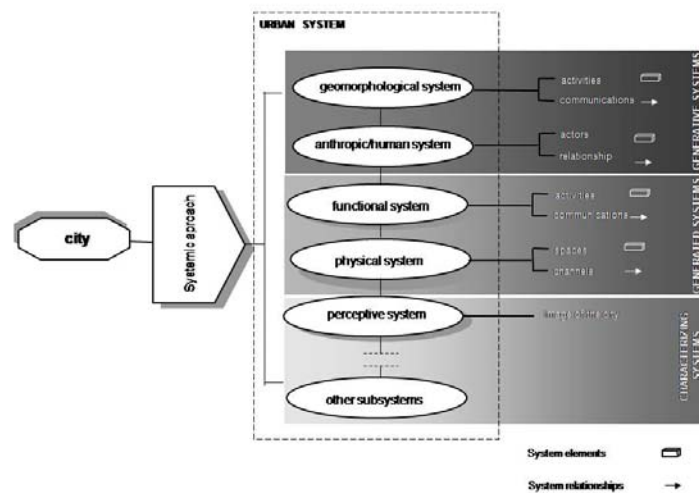
A third model has been proposed more recently by other authors [20], according to this model the sequences outcropping in Pietraraja would have been deposited in a submarine channel and *Scipionyx* was buried in a single, rapid event by a turbid current. More recent studies, carried out through the analysis of sedimentary facies, suggest that the depositional environment of this succession refers to an area perhaps a few hundred meters deep, where the sediments coming from a shallow lagoon accumulated rapidly [21]. Other studies, also based on plant remains, favor a deposition environment with relatively low and open sea waters [22], [23], [15]. What was geography like in *Scipionyx's* time? In other words, how were continents and oceans located in those days? Paleogeographic and paleobotanical data [22], [24] support the hypothesis that *Scipionyx* and the other terrestrial fauna of Pietraraja inhabited temporarily isolated lands, surrounded by large shallow lagoons bordered by cliffs, which rose in the Tethys, a large ocean present in these places during the Cretaceous. These lands were part of the Adria Plate [25] or they were a promontory of the African continent.

## **2. A technological innovation and "perceptual sharing" of knowledge.**

Today the digital revolution can no longer be considered an exclusively "technical" revolution but must be placed among the "ethical" revolutions, those that are able to modify the actions and the interactions of individuals within the anthropized environments. This reflection has long been shared among scholars who believe that technological innovation represents an evolutionary determinant capable of "driving" anthropic systems, and its components (social, functional, economic, etc.), towards new evolutionary structures. In this sense Schumpeter already states: "In a free and capitalist society innovation can impact certain sectors so intensely that they force the societies that belong to it

to evolve, under penalty of extinction" [26]. It seems particularly interesting, in the desire to define a methodological reflection on this subject, to consider the systemic approach to the study of the city and the territory [27]. This approach considers the territory as a complex evolving system; thanks to this modeling it is possible to identify a series of component sub-systems (Fig. 3): the geomorphological one (constituted by the physical substratum of the territory), the socio-anthropogenic one (represented by the human component that adapts the natural environment and establishes its functions there); the physical one (directly represented by the urban artifact); the functional one (consisting of the functions that take place within anthropic contexts) [28].

Furthermore, there is another sub-system to be considered among the others and it is the psycho-perceptive sub-system that considers the mental image that each citizen constructs within himself through the perception of the space around him. Starting from this approach, it is therefore possible to state that the urban subsystem most impacted by the Innovation Technology (IT) is currently the one attributable to the social component of urban settlements.



**Figure 3:** City as a complex system with the different sub-systems

The new technologies: widespread, pervasive, invisible, portable, wearable (soon also "implantable"), drive actions, dictate behaviors, run movements, characterize relationships.

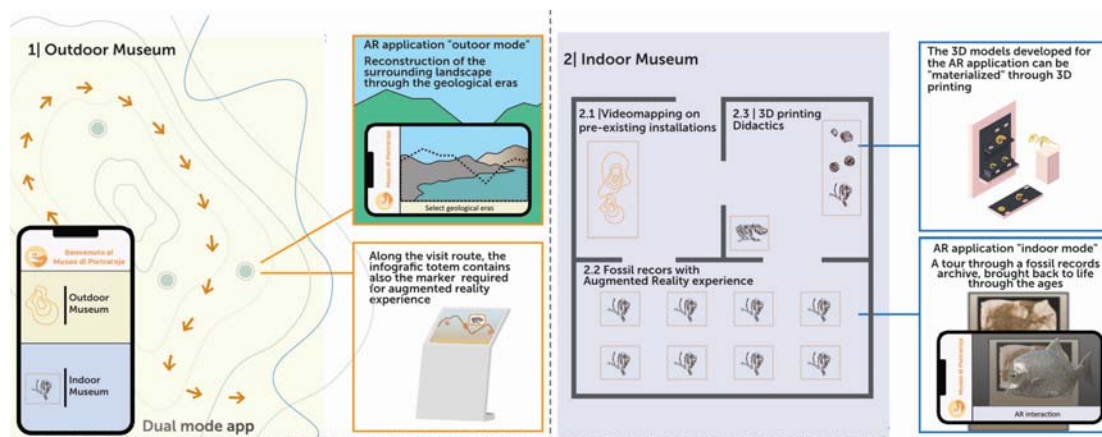
The "liquidity" of society [29] finds in its fluid and diffused technology, its ideal context, its breeding ground, the most fertile territory of development. Among the urban subsystems most impacted and modified by technological innovation, it is no longer primarily considered that of the functions of the city, which made use of the technological means to completely or partially re-engineer the process of supplying the service to urban users (contributing to modify the "weights" of the activities on the territory), but probably one of the generative systems of human settlement: the socio-anthropogenic one. The transformation is no longer only in the adoption of advanced technical tools for the production of services, but it is in the producers themselves that modify their behavior as a consequence of the introduction of new technological dimensions capable of reconfiguring the relational systems of the citizens and their way of acting and interacting in the city.

As recently noted, the revolution is not only "digital" but probably "mental" [30]. There is now widespread awareness that new technologies have the potential to intervene and implement processes of modification of human perception through wearable devices and dedicated software. The possibility of creating an immersive environment in which the user sees, feels and relates to the external reality

"added" with alphanumeric data, information or digital objects (plugged in its perceptive context), is the technological innovation currently of greatest interest for all research fields and human operations. Here we will not enter into the specific description of technology that goes under the name of "augmented reality" or "mixed reality", but it will describe its potential use in the field of what could be defined: "perceptual sharing of knowledge". Wanting to provide a definition of this new field of action we can say that the perceptual knowledge, implemented through augmented and mixed reality techniques, allows information content related to a specific place, context, object or subject to be transferred to a gifted user of a perception device. In other words, the knowledge content is conveyed, using the new technological potential, through a direct, simultaneous and non-conventional perception of the user.

### 2.1 Augmented reality and new territorial dimension of the Pietraraja site: an innovative configuration of the museum

Through the design and implementation of specific "environments" of augmented reality it is possible to add the spatial reality with contents of different nature. This procedure takes on particular relevance both in the open spaces in which finds, objects and remains of specific historical and scientific importance are located, and in the museum containers for which it is possible to create specific digital models of the exhibit capable of interacting with the visitor. In the case of Pietraraja, the contextual conditions allow a global prefiguration of the museum site while the presence of finds both at the territorial and more specifically museum level. From these considerations comes the idea for the creation of a perceptual "external/internal museum" (Fig. 4) for the Pietraraja cultural site through a technology that allows a digital-three-dimensional reconstruction of the context, grafted onto the spatial elements actually existing *in situ*[31]. As previously highlighted, the characteristics of the territorial and exhibition context of the paleontological museum lend themselves to a meta-project of a system of interest.



**Figure 4:** A concept sketch about the external/internal museum

As regards the external museum, which can be built near the fossil deposits, contextual elements, typical of the Cretaceous territory, could be virtually added, capable of defining a digital scenario that allows the environment to be perceived in an immersive way, through the smartphone, to the contour. At the same time, it will be possible to present data, measurements and readable information through the device by framing the specific find. This is technologically possible using markers that the device can recognize and that could also be represented by the objects present in the site properly detected

and digitized. The necessary condition is that there is the possibility of receiving a data signal and being able to activate a specific application on the smartphone that will be appropriately implemented.

Moving later inside the museum container and using the same application, it would be possible to reconfigure the exhibition route by considering, as AR marker, the individual display cases containing the fossil finds or the other finds showed. In this case the marker would become the find itself which could, once framed with the smartphone, come to life and start a narration of contents related to its own story.

### **3. Mixed reality and the movie of the of the Ciro's home**

At present the practices of mixed reality can be compared to the first historical manifestations of film art, in which the simple use of the new instrument of the camera was the primary factor of interest and novelty.

The short film of fifty seconds of the Lumière brothers "The Arrival of a train en gare de La Ciotat" (1896) to our eyes does not arouse the amazement and wonder that could arouse the viewer of the epoch, this because the primary characteristic of that work consisted precisely in being a cinematographic work, a technology then unpublished. Today augmented reality operations are often based on the simple act of superimposing a digital element in a given context, the next step could be to search for the peculiar elements of this technique and structure them in a more complex "narrative".

Having the methods and experiences of cinematography available we can derive initially a first path to follow, just as the cinema started from the theater and literature for then develop its own peculiar language. Before proceeding with the presentation of the "Pietraraja" meta-project it is necessary to pay attention to the general framework of the new digital technologies and to understand that, as far as now fragmented and sectorialized in a variety of specific techniques (video mapping, interaction design, virtual reality, augmented reality, 3d printing), are actually different outputs of the same signal, the 3D modelling. Orchestrating and bringing together the different forms within a single project is definitely a way to get the maximum expressiveness from this new revolution digital within the museum site. A possible digital enhancement intervention in the context of Pietraraja could be exposed in a way inspired by the film writing.

#### *3.1 The subject and the screenplay*

The fulcrum of the "augmented" setup inside the Pietraraja site is certainly Ciro, our ancestral protagonist, around which we discover the great path of scientific research. Imagining the museum as an illustrated story, in which the visitor can interact freely, it will be necessary to find the elements of dialogue between man and museum, between exhibit and observer.

Unlike the cinematographic medium, augmented reality belongs to an interactive and dynamic environment, which is encoded in real time, thus able to change, adapt and react to various types of inputs.

#### *3.2 Art direction and production design*

The ways in which all this can be orchestrated are many and there are many companies already active in this field of the revaluation of the cultural heritage. Starting from the most interesting experiences it very important to pay attention to all those operations in which much emphasis was placed on narration. It's also necessary to make an in-depth study of what has been done and which elements were critical or successful on the public. The main task of the director in this context is to create dynamics and involvement, also through elements of game design. Currently the latest software developments of augmented reality (as "ARCORE 1.7" open source project released by Google) allow the creation of persistent and shared environments between users, through the creation of "marker" zones that ensure continuity of the augmented experience even in large areas.

### 3.3 The cast

From the world of video games, of which augmented reality is an extension and evolution, it comes the state art of the digital character, the digital actor who through a skeleton of animation and a library of movements is able to move in a virtual environment and to be controlled by artificial intelligence. In order to create a CIRO digital avatar it will be necessary to follow a very complex procedure: the first step is to obtain complete information on the anatomical structure of *Scipionyx samniticus*. From this it will be possible to obtain the digital model of the dinosaur through an accurate 3D modeling work.

Subsequently, created an animation system, it's necessary to study the dynamics of movement specific to this species and to generate cycles of animation that will be managed by the AI. Through a scan and digital restitution of the physical space, virtual Ciro can be aware of the limits and obstacles in the rooms where it will be placed. As the main actor of the museum storytelling path, it will be able to move freely in the visit itinerary and mark the events and the key moments in history. The following images (fig. 5) illustrate the 3D model creation process of a prehistoric animal called *plioplatecarpus*. We are making the following reconstruction experimentally to start producing application prototype involving 3D printing and augmented reality. Subsequently, we are going to use this material as a reference to design the virtual Ciro for the Pietraraja meta-project.



**Figure 5:** A low poly model creation (on the left) with correct topology suited for 3D engine and AR applications and the final model (on the right) of the *plioplatecarpus*

### 3.4 The reconstruction process in five steps: from the fossil to a 3d model for augmented reality

Step 1. Fossil record of *Paleobalistum bassani* coming from the Pietraraja site. The rendering of the fossil can be carried out traditionally or using photogrammetry techniques. The impression of the fossil it's used as an activation marker for the Augmented Reality application (fig. 6) .

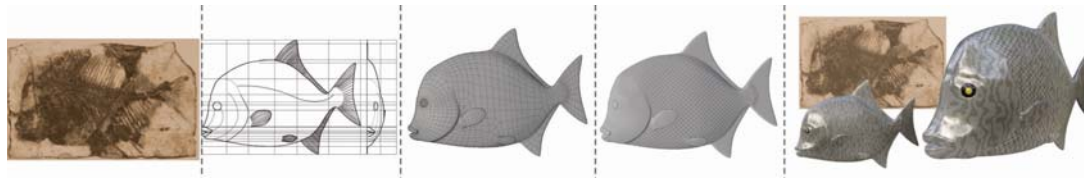
Step2. The fundamental phase of the reconstruction of the living species is the drawing of all the technical tables necessary to describe the shape of the specimen in all its details and with the greatest accuracy.

Step3. On the basis of the generated technical documentation, which includes indications on the shape, color and physical characteristics of the subject, the 3d model is created. The 3d model will be realized in a first step: obtain a light version to be used in real time application. In this phase is generated the animation system and established the texture mapping.

Step4. The next phase is obtain a detailed model targeted to texture rendering. The high polygons model will contain a big amount of data enough to geometrically describe the specimen up to very small scales. All the information contained in a geometric way will be translated in a textures set to be used on the first 3d model. The high detailed model will be useful also in the 3d printing process.

Step5. All the informations converge finally into the animated model that will populate the Augmented reality experience, in which the visitor will be able to see a representation of the living specimen, with which it will be able to interact in the ways provided by the application: informative, technical or involving a gamification dynamic.





**Figure 6:** The five steps of the reconstruction process

#### 4. Conclusion

The paper describes concisely, the capability of the new technologies to build up a different way to share knowledge in a cultural site. The information and data can be diffused, during the visit, both in the outdoor and indoor as well. The Augmented Reality, the digital modeling and other technics can be composed to set up a perceptual knowledge that involves the visitor in a new cultural experience. The force points of this proposal are referred to two main factors: the external/internal dimension of the cultural site, where it is possible to see about the finds in the two different environments; the possibility to see the augmented environment by using a non-dedicated device as a common smartphone.

The paleontological site of Pietraraja seems to be an open laboratory to implement this new exhibition concept which is still a meta-project but could drive towards a new integrated and friendly way to visit a paleontological site. In this site will be possible to “see” the open environment (at the external museum) and a real size animated prehistorical find (at the internal museum) by using a common smartphone as augmented reality device.

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