Experimentation of a Web Database for Augmented Reality Apps: the case study of ruled geometries

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Abstract. The growing field of Augmented Reality Apps is an indication of greater interest, by private markets and public institutions, towards immersive visualization and those tools that can enhance cultural content through user involvement. An often underrated feature of this digitalization lies in the smart language with which the notions are shown, in quick synthesis based on schemes, slides, lists, images, and comparisons. But the continuous input of data in an app can cause various problems, both on the hardware and software front: from the obvious weight gain, not negligible for pocket devices, to the continuous updating of scientific knowledge, that risks leaving behind all those theoretical contents that are not controlled or renewed. To this is added the problem of the constant maintenance of mobile devices for what concerns software, operating systems, security protocols, and systems for decoding existing data, especially for AR Apps that use audio and video devices. With this in mind, and in order to optimize the performance of mobile tools, a digital archive in the form of an open-source site is useful, providing centralized and pre-cataloged data specifically for use in the AR App. In this way, qualified users can contribute to the knowledge presented through a client-server upload system on the site, properly filtered by semi-automatic security checks. The experimentation of the contribution investigates the advantages and possibilities of such a structured system, setting the case study on the theory of ruled geometries, and the architectures corresponding to them.

Keywords: Architecture, Augmented Reality Apps, Immersive visualization, Ruled Surfaces, Database.

Introduction

Augmented Reality is now well suited to teaching, as an auxiliary tool in different fields, as engineering, chemistry, medicine, and including geometry and the study of architectural forms. In the latter area, the state of research offers ample opportunity for in-depth study, as well as the spread of immersive tools in the national academic and cultural overview. Added to this is the current difficulty in finding advanced models and information in open source spaces, which can be assets (models that make up the contents of software) for apps with educational features. Therefore, the study intends to propose and experiment with a useful content base in the form of a website, an information aggregator that can be easily linked and able to feed itself through the users, aimed at visualizing three-dimensional geometries and comparing them with existing architectures. Through this process of experimentation, we can carry out a selection of the case study geometries, the ruled surfaces, are propose various methods of communication between users and websites for data transfer, and the issue of the digitalization of 3d models is addressed, catalogued in order to provide a digital archive useful for app development.

1 State of the art

1.1 Geometries

The ruleds, those surfaces described by the movement of a straight line in space, represent a complex section of three-dimensional geometry, for the many properties they have and for their application in architecture and design.

A fundamental characteristic of their genesis is the fact that they are always led by three leaders, who guide the movement of the generator line, which in turn generates the rift. The guidelines can be curves, straight lines, or improper lines (director planes), and the combinations of these three types give rise to a wide variety of surfaces, with specific properties and are sometimes recognizable in other families of geometry, such as quadrics or cubics, and this fact has forstered the interest in these surfaces, in history of design. That interest is shown by the many applications that the ruleds have found and still find today, in the field of architecture and design, just considering the use of these surfaces in the science of cutting stones (stereotomy), in the construction of gears, or in the realization of helical staircases and ramps [1]. Ruled surfaces have been studied by many mathematicians, but their systematization, in the form in which we know them today, is due to Gaspard Monge, who described their properties in "*Geometrie Descriptive*" [2], and in several other memoirs published during the years of his teaching at the *Ecole Politecnique,* and is due the contributions of the students of his school too, as Jean Nicolas Pier-re Hachette, author of significant works such as "*Traité de géométrie descriptive*" [3], in addition to other memories of those years. The study of surfaces was approached by Monge and his students by combining the synthetic description of the form with the analytical one. At the turn of the nineteenth and twentieth centuries, the synthetic approach to the study of ruled

surfaces was reflected in the contributions of several mathematicians such as Otto Wilhelm Fiedler [4], Michel Chasles [5], and Gino Fano [6], well as many other.

Today, the introduction of new methods of digital representation offers renewed opportunities for experimentation on form through the synthetic method [7], operating in virtual space, and showing geometric properties with new declinations. One of these, in fact, is augmented reality, which still offers much material for the study of surfaces, although it still operates on an approximate display of the shapes (expressed by a finite number of viewable meshes), therefore many potentially interesting features are not sufficiently deepened or disclosed, making them less known and sometimes difficult to understand. Moreover, the cataloging of ruled surfaces is now consolidated and established in a theoretical-literary form [8] but has not yet achieved a communicative evolution in a digital or immersive environment, and it is on this point that virtual archives can contribute.

1.2 Immersive visualization

Since the first experiments on immersive reality, we ca identify the factors that most contribute to effective communication, including today we recognize the sensory experience, which is maximized thanks to various devices, such as the completion of perceptual impact with tactile inputs, the masking of artifacts such as targets, or multimodal feedback such as vibrations and sounds [9]. Despite these insights, the immersive factor is difficult to define concretely, but today remains a fundamental principle in many professional and non-professional fields [10], from the more generic visualization of data [11], to disciplines such as marketing, finance, healthcare, physics, engineering, up to architecture and education [12].

It is therefore no coincidence that many studies have confirmed the advantages of immersive access, useful for laboratory environments typical on architectural design, that can reduce loads of study and instrumentation [13]. But, if on the one hand is recognized to these a didactic effectiveness, on the other hand, the devices themselves involve various implications and challenges, starting from their learning, to the commitment to show them [14] or, again, the motivational and emotional load that they involve with the perceptual experience, which certainly requires further investigation [15]: this makes the development of virtual environments a multidisciplinary work [16] that with the width of the users base also increases its criticality.

It is therefore the training field that receives the greatest benefits from this new media [17] [18], both for the large amount of specialist information [19], and, in more restricted cases, for the representation of forms at the level of primary education [20]. The geometries tested with positive results, in fact, go from the two-dimensional ones (although the AR appears as an optimized tool for 3D visualization) [21], to the more complex three-dimensional mathematical forms, although immersive functionality is still considered poor in design tools, advanced interactions, or interdisciplinary (e.g., communication to BIM exists only in experimental cases). And that's why research is moving in that direction [22].

Moreover, Augmented Reality, beyond the educational sector, is effectively suitable for the representative cases of problem-solving, since the basic and unique forms of elementary geometry are effective both for a general decrease in mental workload [23], and for the simplified learning proposed in universal design [24], where the playful aspect covers a fundamental and profitable character [25]. As for how these forms are presented, the standard lies in predefined static models, but sometimes the parametric system is also used for a more controlled and defined visualization, although it is necessairly restricted to specific experimental forms [23].

Augmented Reality is therefore a medium with a high expressive potential also in the geometric field, and its combination with the archives of easily accessible shapes could make easier and faster the diffusion of this knowledge. In this context, the research aims to fill its needs and observe its potential.

2 Experiments-trials-testing

In order to meet the needs identified, the testing of a website that can act as open-source content support for Augmented Reality Apps has been started.

The website creation platform used is “https: wix.com”, and the address chosen for the web experimentation is https://researchdatatry.wixsite.com/datatry (Fig.1).

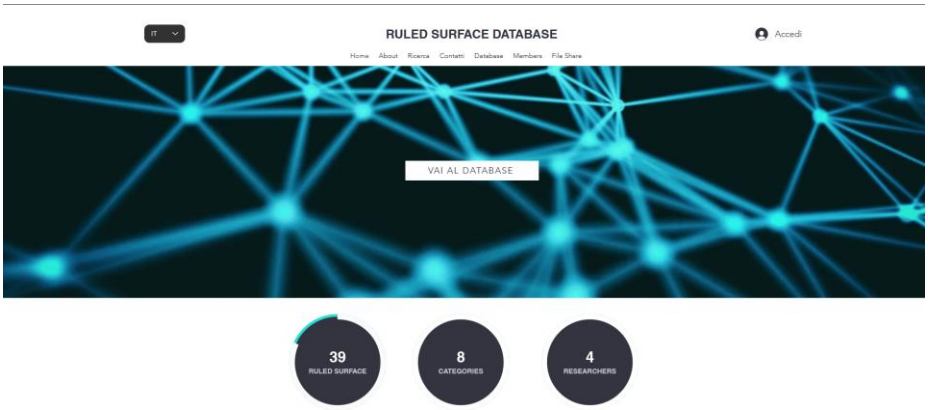

Fig. 1. Home page of the website “https:///researchdatatry.wixsite.com/datatry”, the database containing the ruled geometries, Thomas Guido Comunian and Simone Porro (webmasters).

The site had to offer enough space for uploading, a layout containing information data on geometry and the availability of downloads in various formats and in various 2D and 3D previews.

The development process was divided into several phases, starting first from the choice of a sample content of geometric type, which has been identified in the web cataloging of ruled surfaces (Fig. 2). The classification adopted for the archiving and presentation of the models derives from a hierarchization of the geometries inspired by

the work of Gino Fano in the collection "*Lessons of Descriptive Geometry at the R. Politecnico di Torino*" [5], in which he proposes a basic classification of the ruled surfaces, based on the combinations of directrixes:

Ruled with a straight line:
- *Biais passé*
- Triangular thread screw
- Director plan ruleds

Ruled with two straight lines:
- Rectangular thread screw
- The surface of the entrance vault of a round tower (similar to the generic conoidal surfaces)

Ruled with three straight lines:
- Striped quadrics

An extensive survey was therefore carried out aimed at building an implementable repertoire of models, capable of describing the relationships that exist between the different combinations of directrixes and the final shape of the surfaces in space. These models can show some notable properties of the lines, such as the genesis, the degree, the Gaussian curvature, the symmetries, and the implications that these have in applications to real models.

Starting from this selection of geometries, the results were compared with particularly significant modern contributions such as those by Krivoshapko & Ivanov [8], and later by I.A. Mamieva [26] in a classification of over 50 types of ruled surfaces divided by Gaussian curvature and other properties which, however, unlike the hypothesis assumed in this research, are oriented more on the section profiles of the shapes to distinguish their classes, and less on the genesis through the combination of guidelines.

Therefore, together with this contribution and in the context of a broader research on ruled surfaces, the following classification into five categories is hypothesized:

- Generic ruled surfaces (three curved lines)
- Cylindroid (two curved and one straight directrix, proper or improper)
- Conoidal surfaces (one curved and two straight directors, one of which is proper or improper)
- Quadrics ruled (three straight lines, one of which is proper or improper)
- Planes (two directorial planes and a straight line, proper or improper)

This last category is still the subject of debate today [27] [28], as it is of less interest than the more complex morphologies of the ruled surfaces but is included in the framework for greater completeness.

This division is therefore derived from that of Fano, and contemplates every possible combination of directrices, since being three different types they can be ap-

proached in 10 different combinations, which in turn depend on the positions of the curves, branching the repertoire into a complex and articulated variety.

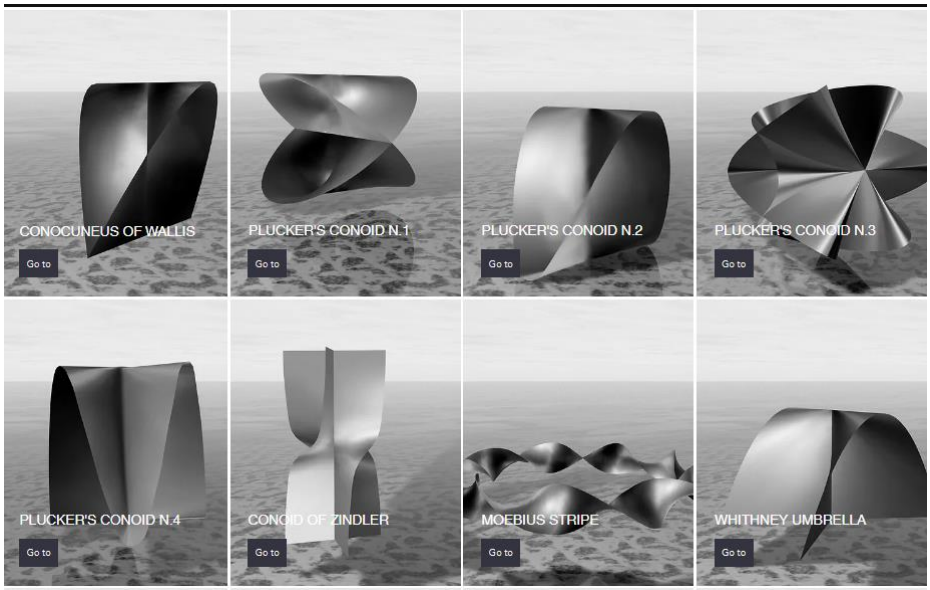

Fig. 2. Some images of ruled geometries included in the database of the web site (screenshot of the website, Alessandro Martinelli (modeling and AR), Thomas Guido Comunian and Simone Porro (webmasters).

For each category, the 3d models of the ruled surfaces included in the web database have been loaded in alphabetical order, and consist of the following typologies: Quadric cylinder, Cylinder, Director plan cylindroid, Generic conoidal surface, Developable tangent, Open generic cylinder, Generic closed cylindroid, Generic cone, Quadric cone, Conocuneus of Wallis, Plucker's conoid n=1, Plucker's conoid n=2, Plucker's conoid n=3, Plucker's conoid n=4, Conoid of Zindler, Möbius strip, Whitney umbrella, Seifert Surfaces Double Ring, Seifert Surface two-edge knot, Moebius Surface, Cayley Ruled surface, Conocuneus, Parabolic conoid, Hyperbolic paraboloid, Normal helicoid open, Open oblique helicoid, Closed oblique helicoid, Right helicoid, Developable helicoid, Sinusoidal conoid, Guimard surface, Milk carton, Oloid, Sphericon, Collar surface, Hyperboloid one flap, Generic conoidal Surface, Cayley ruled surface, Developable tangent [29].

Secondly, as a result of the type of data that has been chosen to be stored on the web and also in function of the diffusion and communication purpose, we chose the type of web platform or website best suited and we identified a template that was suitable for communication and archival purposes, but still simple to use. Thanks to its versatility, although still in the testing phase, the platform can be used both via mobile app and through an ordinary Internet connection made with a personal computer.

The following image (see Fig. 2) shows some of the ruled geometries on the page currently loaded in the website.

The research therefore focused on the potential technical and informative contribution that a geometric database can offer, and three main kinds of use that the members can have with the archive site have been implemented.

2.1 Direct download

The first mode of use is the direct download of the models from the website, after accessing to the archive via login. In view of a possible use in augmented reality, 3D preview display modules have been added. This solution leaves the user room to load into their graphics engine all the models they want in the modes they prefer, defining themselves the user experience of their mobile App. In order to fully test the process, the downloadable clay models, free of assigned materials or textures, will be applied later in the design of an app in Augmented Reality classically set (whose target sparks the appearance of models and the consultation of their properties).

Within the same research, the models submitted are configured to have shape, weight, center and axes suitable for a functional and effective immersive use.

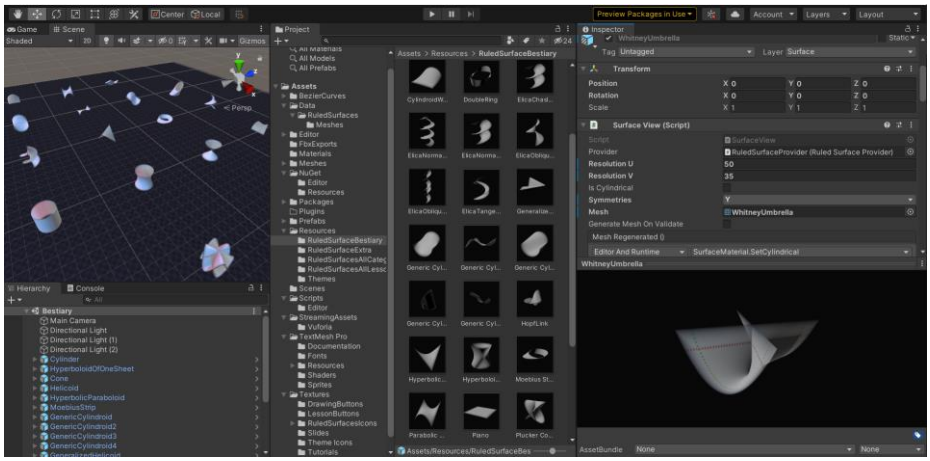

Fig. 3. Example of inserting shapes in the app, using the Unity graphic engine, Thomas Guido Comunian and Simone Porro (webmasters).

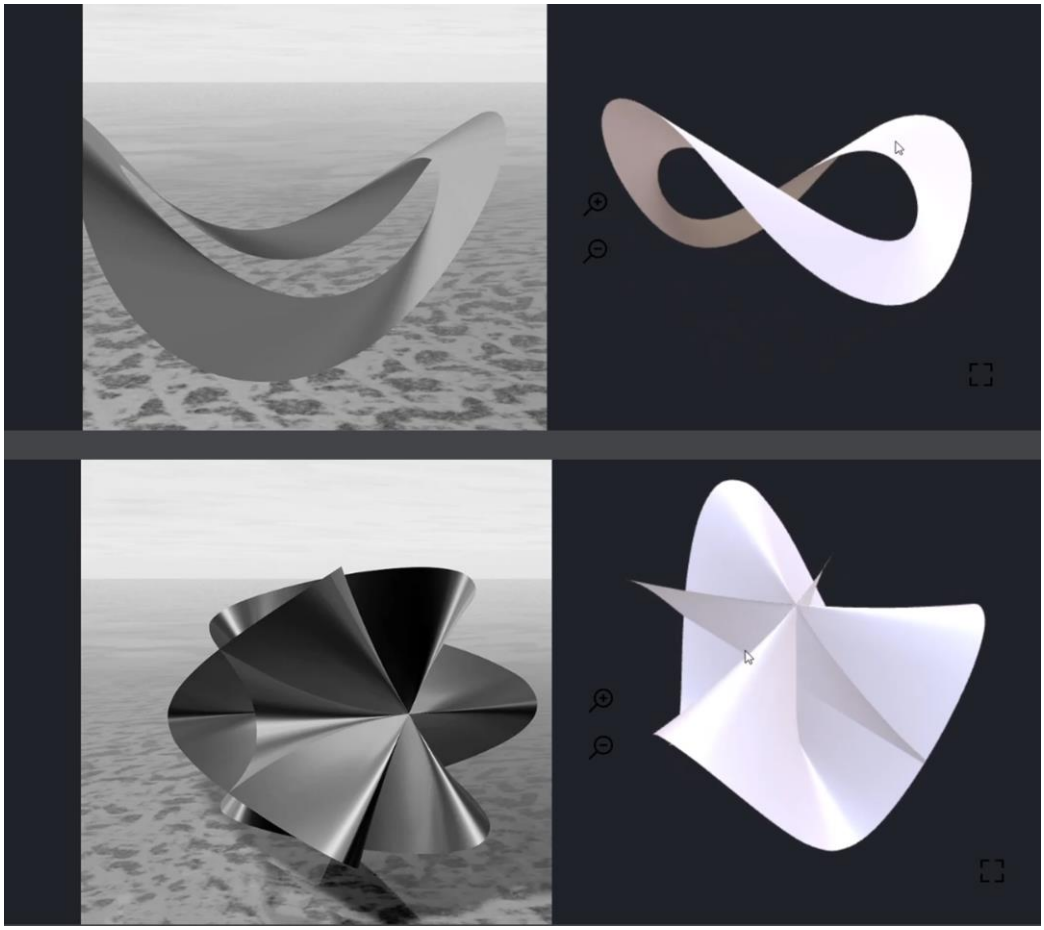

Fig. 4. Web page preview with direct download option, Alessandro Martinelli (modelling and AR).

2.2 Download by link to the launched app

As an alternative to direct download, it will be possible to provide the models stored through a direct link to the app launched (Fig. 5), so that you can reduce loading and processing times and especially in order to lighten the size of the application files that will not have to load the data of all the geometries simultaneously.

For the developed app to obtain real-time web database models during use, it will be necessary to obtain an authorization token from the site itself by creating a specific account with access privileges, such that later in game just launch a request to the site, which will respond by sending the models.

In case the database has a login system, it will be necessary to verify that the library has a public API, not restricted to manual use of the web interface, and that it is also accessible through requests.

It is important, however, that the models are accompanied by the information attached to them (e.g. definition, properties, history, equations), and this is expressed by a JSON text file format, widely preferable to the download of the simple model.

Through this feature, it will also be possible to filter the information to be downloaded, such as "definitions only", or alternatively, "only a certain category of geometry", keeping the communicative compartment light and customized.

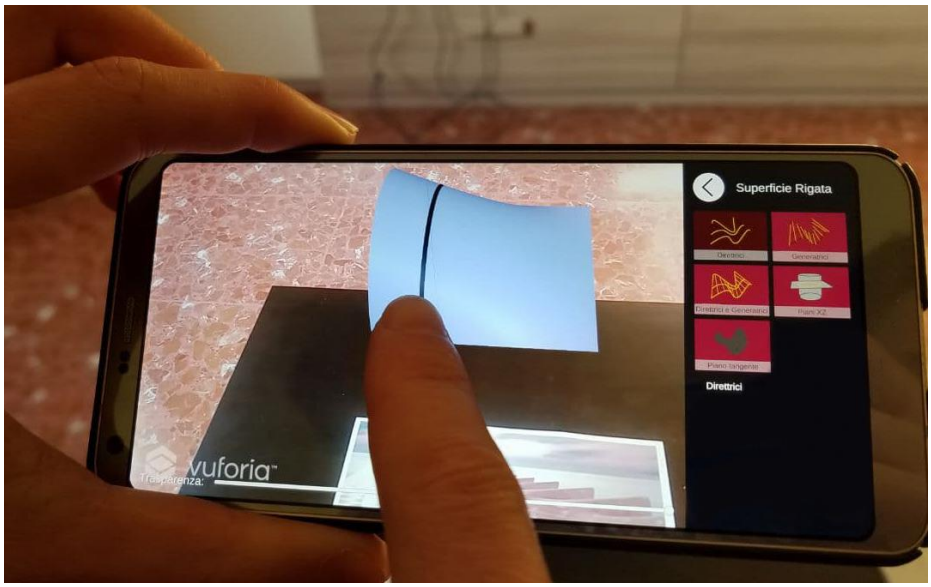

Fig. 5. Example of inserting shapes in the app, using the Unity graphic engine, Alessandro Martinelli (modelling and AR).

2.3 Model uploading

An alternative use of the online database is the possibility to load models by the user (Fig. 6). This operation can in turn be carried out in two modes, which consist in the manual upload on the web, or in the loading through app in case the latter can produce or search for innovative or experimental data.

In both cases, the qualification of an authorized user to upload models through verified accounts is required. In case you configure a direct connection with authentication, as indicated above between web-database and app, the digital archive would not need to have continuous checks and maintenance. This mode of operation would therefore represent the greatest advantage that a digital archive site could offer, in order to encourage the exchange of information and teaching material, currently in transition to immersive reality.

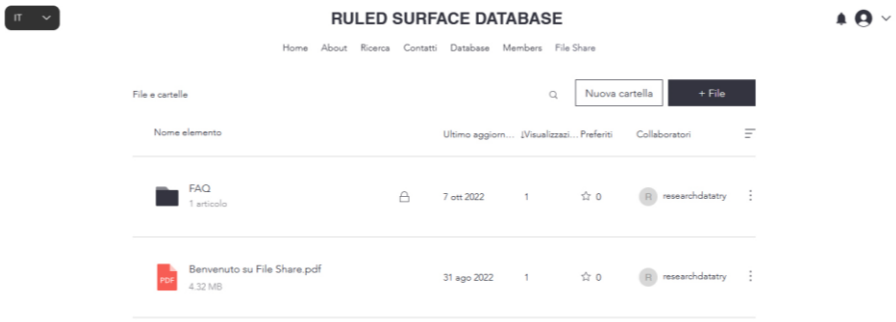

Fig. 6. View of the file sharing page, Thomas Guido Comunian and Simone Porro (webmasters).

3 Potentialities

Any prediction on the potentialities offered by the web database object of this experimental research may seem limiting, for many reasons, such as the rapid evolution of software languages in the computer field, the wide possibilities of implementation of web platforms and the wide panorama of applications.

However, given the scope of this study, which is aimed at addressing issues strictly related to geometric shapes made in the digital environment and, specifically, issues such as the cataloging and storage of 3D virtualization web, it is possible in any case to outline a main purpose of the platform and to assume some of the potential developments that embrace themes of geometric representation, but at the same time different branches of research.

The web database was mainly created with a discloser function, and, as such, the platform could be further developed, firstly by the reference or the link to other websites and digital platforms or mobile apps that have as object the study of the mathematical surfaces and the geometry, strengthening and completing the educational aspect thanks to the virtualizations 3D.

The web database offers the great opportunity not only to enjoy the data in terms of visualization and download of geometric patterns of ruled geometries, but also in terms of loading three-dimensional objects and proposals for integrations designed to directly implement the elements already present, through an exchange activity and interaction between competent users on the themes of the site, and external users such as regularly registered researchers and experts. The creation of a forum-debate to develop new themes of study and disclosure is also a further form of sharing and disclosure itself.

The creation of a section dedicated to further develop other topics in more depth, comparing typologies with architecture.

A further study could be made through the use of a parametric application able to manage in real time the variations of complex surfaces. It could also improve the lightness and agility of the site through shared cloud spaces.

Finally, an interesting potential of this communicative expansion consists in the applicability to new visualization technologies such as the metaverse, a concept recently distinguished as a possible evolution of the internet and digital fruition. The term does not actually indicate a specific technology, and is very relative to social and cultural interpretations: it can mean the physiological convergence of digital technologies towards the use of immersive systems, These include some explorable virtual environments, such as Decentraland, Sandbox, or Axie Infinity, and others under development. Among the various types of assets and avatars that can populate this digital universe, certainly the models described in the database can offer useful ideas of content, making its visualization even more immediate, filling further gaps in the knowledge of the form.

4 Conclusions

The web database object of this research study, containing the three-dimensional ruled geometries, is configured as an online platform with an intuitive interface and practical use, which fully fulfils the main purpose set out in a strictly informative orientation in the digital web of the issues dealt with. The more complex aspects of the geometries collected in the database are made easier to understand, thanks also to the immersive viewing mode and the easy consultation of the app.

The opportunities offered by the site are diversified and designed to be very much implemented also through the contribution of external inputs, for which a special section has been provided that allows the continuous implementation by a network of collaborators and can be extended to further case studies in the field of geometry.

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