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# Application of digital 3D models on urban planning and highway design.

L.A. Hernández & S. Hernández
*ETS de Ingenieros de Caminos, Canales y Puertos, Universidad de La Coruña, Campus de Elviña, 15071 La Coruña, Spain*
*Email: lahernandez@etsiccpc.udc.es*

## Abstract

Several advantages of producing 3D digital models of civil engineering designs and the way this advanced tool overcomes drawbacks inherent to the conventional design process is explained in this paper. Three cases, namely, a two level road junction, a new highway and a new university campus are included to emphasise the feasibility of 3D digital models in real life projects. Several advanced visualization techniques have been used in the examples presented, which correspond to real practical problems

## 1 Digital 3D models and civil engineering design

During the last decade, CAD techniques have been progressively implemented in areas of urban design. Urban planning, construction, facilities layout, transport and traffic management are actually fields in which projects are made over a computer techniques basement. Along those years, processes and algorithms for 3D representation of digital models arose and consolidated, although the degree of implementation on each field of sciences and techniques varies.

In this sense, the presence of methods for tridimensional representation in the topics of roads and transport systems has been mainly sparse. Nevertheless, they appear to be a very powerful tool to be applied in every stage of the project-construction-finished work process. The following paragraphs will be devoted to ilustrate this idea when applied to real design problems.

Digital 3D models feed the project with an extra amount of information that is not available in traditional computer tools (2D-CAD, GIS). This advantage produces some new benefits that could be related to two main categories connected to the visual features of the finished work and the virtual construction of the project.

## 1.1 Visual features of the finished work

### 1.1.1 Appearance

Most of the objects involved in urban design are made not only to be used but also to be seen. Their appearance is difficult to describe solely by using technical drawings, and many visual features such as material types, lightning, or even meteorological effects are easy to implement on a 3D visualization of the object.

### 1.1.2 Visual impact

Many times, the environment where the object is to be built becomes as important as the new construction. Studies dealing with environmental impact can turn a big profit from the simulation of the future of the areas affected by new projects.

### 1.1.3 Visibility checking.

This feature is specially important in projects related to road and rail networks to assure a correct visibility in crossings, junctions, slope changes and signs to prevent risk of accidents and black points.

To simulate such perception by the use of 2D drawings is a difficult task, considering that tridimensional vision along with perspective effects are involved.

### 1.1.4 Simulation

Recreation of future trajectories gives a worthy amount of information for urban transport projects. Inclusion of a virtual camera moving along future paths following the expected velocity curves, makes possible to evaluate many important features of the design

## 1.2 Virtual construction of the project.

### 1.2.1 Geometrical coherence

Experience in 3D modelling of projects gives the evidence of the difficulty to reach a geometrically correct complex design when represented only by using 2D drawings. Plans, elevations and cross sections make a limited set of representative projections of the future design and do not contain the full geometrical data of the object itself. Thus, it is easy to find areas not defined, ambiguities and even mistakes caused by the lack of a system capable to verify the tridimensional coherence of the design by putting together and comparing all the data contained in the drawings.

On the other hand, a 3D model is a geometrical clone of the object itself, fully defined in its three dimensions inside the computer. From this model plans and views can be obtained in the same way the designer drafts the plans from the object in his mind. The difference resides in the fact that the

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model compared with the imagined object is geometrically complete, without undefined parts or ambiguities.

### 1.2.2 Hidden mistakes and error detection

From the above mentioned , It could be inferred that traditional projects contains a grater number of mistakes as their geometrical complexity increases. Projects related to communication facilities and road networks fall in such category for they involve sets of shapes with very different properties that are to be assembled together (roads, terrain, pipelines, buildings, structures, underground tunnels, mechanical objects, vegetation, etc.)

The generation of a 3D model is by itself a good system of error checking for it represents a virtual construction of the design using the drawings as an initial source of data. The budget devoted to correct such mistakes by making a 3D digital model is several orders of magnitude lower than if detected during the construction works.

### 1.2.3 Volume analysis

3D models are very suitable for mathematical analysis. That feature makes easy to obtain volumetric data to be processed as needed. Volume of excavations, inercy and other mechanical parameters, interference and collision detection and any result concerning with volumes can be easily achieved.

### 1.2.4 Broadcasting

The fact of having a built version of the project, even a virtual one capable to be assigned with realistic attributes allows the designer to produce pictures and animations of the future works. Such media can be used to advertise the project on TV, press and exhibitions, giving an undoubtedly added value to the 3D model.

## 2.- Accuracy and digital models

It is necessary to clarify the concept of precise digital models. 3D computer graphics are now part of almost any production on the film, video and multimedia industry. Many times any model with realistic appearance is considered a valid one . This assertion could be true is such above mentioned industries where visual appearance is all, but for a model to be suitable to be used in technical tasks the level of accuracy has the same or greater importance that realism.

It is possible to generate a 3D model to produce realistic pictures of a design by substituting geometrical elements with other visual effects of similar appearance (one of such techniques consist on the application of photographs over a very simple geometry to avoid modelling the details in the form of texture mapping). That approximation must be used with ultimate care, for it avoids to appreciate the real shape of the objects in a close analysis. A digital

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model to be used for design requires an accurate and full description of every object, otherwise, the results can be realistic but deceitful.

It is obvious that the level of accuracy will be according with the size of the model and the relative importance of its parts. As an example, the computer visualisation of a highway can have a precision of a centimetre in the road and several meters in the simulation of the satellite view of the geographic area where it is located. This can be achieved in a unique model to be used for both purposes.

## 3.- Examples of application

### 3.1 Urban road networks. Application to a two level junction project.

This example will show the application of a digital 3D model in the design phase of a future road intersection in a highly consolidated urban area.

#### 3.1.1 Social considerations

Urban roadworks usually generate social debate, making that kind of projects to be evaluated by the citizens with very faultfinding spirit. The political cost can raise to be specially important because, although they are promoted to improve the conditions of the area or the city as a whole, they also carry inconveniences that affect exclusively the zone in which the works are going to take place in the form of radical changes in the aspect of the area, sometimes with demolition of houses and dislodgement.

The digital 3D model may serve to take decisions related to this items, since it will help a lot to appreciate the real visual impact, and to verify the real need to demolish buildings. Representing the area using computer models allows to incorporate the future project in the actual area. Thus, computer images can be made from any target viewpoint and then compared with actual views. Morphing techniques can be applied to accentuate the magnitude of visual changes and their effect over the urban environment.

These techniques provides easy and comprehensible documents that can be displayed to the affected citizens, and can be also used as a reference for complains that have to be presented in front of this computer generated views of the area, avoiding disagreement often based upon suppositions mostly produced from a bad understanding of technical drawings that only inspire to the inhabitants an uncertain future for the zone.

#### 3.1.2 Description of the model

The works related in the study are located in an urban area inside the city of La Coruña, in the Northwest of Spain. The zone was to be redesigned due to the heavy amount of traffic. Therefore, an existing avenue was to be converted into a two levels junction. For obtaining that, some existing buildings should be demolished allowing room for widening the avenues, to build a roundabout in the lower level and a bridge for the upper one.

To recreate this urban assembly it was necessary to model the façades of 42 buildings, several garden areas, the roads and roundabout themselves, and the bridge. As starting point data, initial drawings of the project (later modified), topographical and GIS data of the zone, and photographs of the buildings were used.

The kind of objects present were specially assorted, so several different modelling techniques were used: Direct polygon meshing for buildings and urban accessories, Krieging techniques for the terrain, sweeping and lofting procedures for the bridge and geometric simulation with texture mapping for the trees, signs and other accessories.

Each of the different parts of the model where generated individually, and then put together in the global model. It was take into account that any part should have enough detail to produce a consistent picture in a close visualization but not so high to saturate the global model over the capabilities of the machines that were to be used to render it.Several versions of the most important parts were made, such was the goal of the model for its use on the design process.

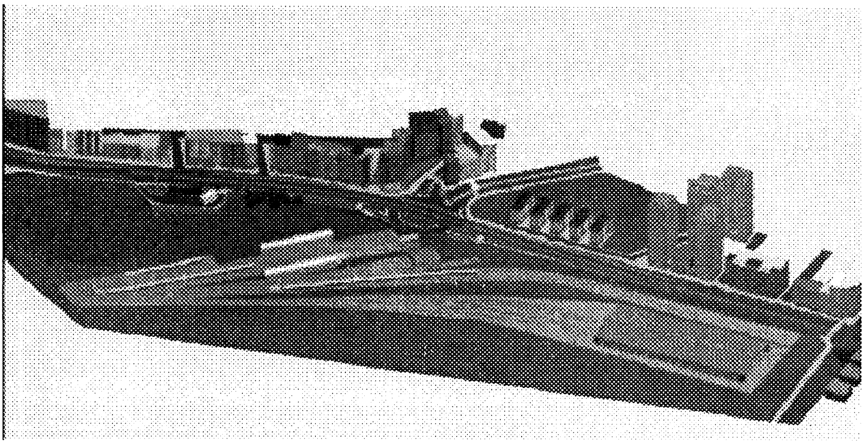


*Figure 1. Digital image of the area studied*

**3.1.3 Timeline connection between model and project.**

This model was created to support the project in the design stage. In this sense, once the urban environment was modelled the first version of the project was located on it. This was the time when the first profits appeared, and several modifications were made on the construction project based upon the results of the geometrical building of its digital twin. This modifications were again carried to the digital version, then checked and so on.

Process lasted until the final decisions of the design stage were made up. The following list contains several major aspects that were worked out and improved by the use of the digital model:

**3.1.3.1 Detection of geometric local problems:** The 3-D model of streets and roads allowed an easy identification of excessive slopes in the intersection of roads with very different inclinations.

**3.1.3.2 Definition of bridge cross-section:** Several shapes, up to a number of five, of candidates cross sections of the bridge where checked up trying to achieve high aesthetic quality of the bridge. Many models of bridges with distinct total length, and relative span lengths, were also compared in the digital model in order to find out which produced better visual impact. Also, geometry of the pillars was decided upon trying a set of different shapes.

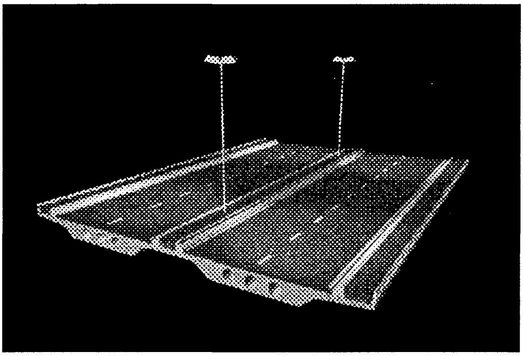
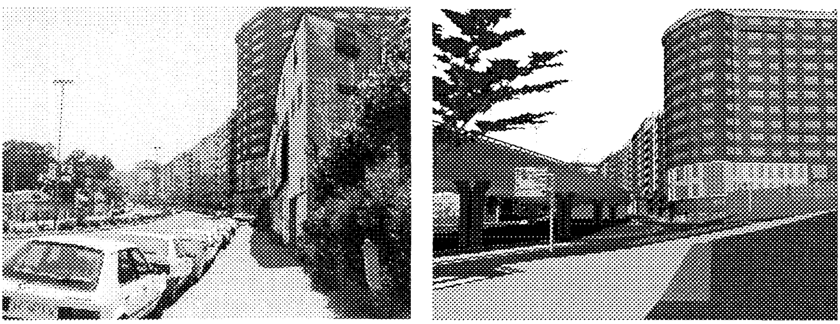


*Figure 2. Final design of bridge deck*

**3.1.3.3 Visual consistency of new and old constructions:** After completion of the digital model of the new planning, a set of digital images were rendered from the same point of view than the existing pictures. Then a few sequences showing the perturbation from the existing situation to the future one were simulated by morphing techniques.



*a) Actual view* *b) Future view*

*Figure 3. Morphing from actual to future view in Avenida del Ejército*

**3.1.3.4 Visual impact from moving objects:** Having into account that the drivers were the intended users of the two level intersection, it seemed to be necessary to check the quality of the design when observed from objects in motion. To achieve that, several paths along the intersection were defined and computer animations to visualize the overall design were created. More than 4500 simple frames were made to obtain animations of each trajectory. Such amount of frames, subtracting test animations and previews, provided with 3 minutes of computer animation.

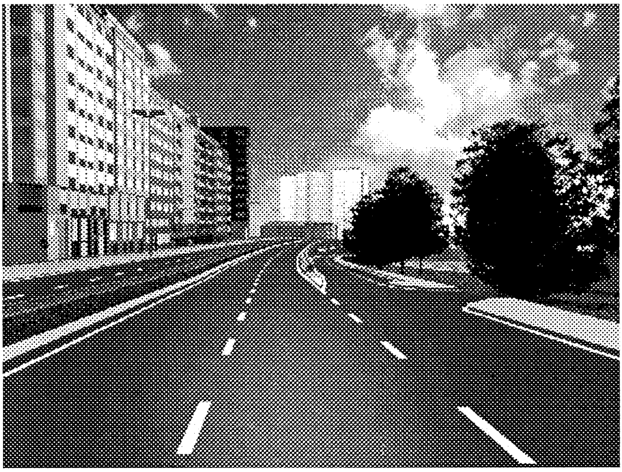


*Figure 4. Single frame along animation path*

**3.2 Interurban road networks, Visualization of a highway.**

A new track measuring 35 Km., presented together with several main road links connecting secondary lanes and a large amount of upper crosses is the case of study. The main course was defined by a wide variety of cross sections running along a rough terrain and an assortment of bridges of short to medium size.

In this case, the aim was to visualize a project already finished in order to validate it from a geometrical point of view, and to check its environmental impact. Such a large facility made necessary to use a tool to get a global view of the project in order to verify through a virtual walkthrough the environmental impact in the landscape, and to find multiple details and possible defects that could have been remained hidden in the 2000 blueprints of the project.

**3.2.1 Description of the model**

From the numerical data used to define the axis and cross sections of the main trunk and each of its branches, a model of the platform and the structures on it were made. Such a model was embedded in the 3D model of the adjoining terrain obtained from aerial photogrametry data. Terrain levelling was then recalculated and compared with theoretical results. The last step consisted on mixing this model with the province 3D mesh that was obtained from a dataset available at the IGN (National Geographic Institute). The mesh was then mapped with LANDSAT satellite images. The presence of two dissimilar terrain meshes made necessary to generate a transition mesh between them.

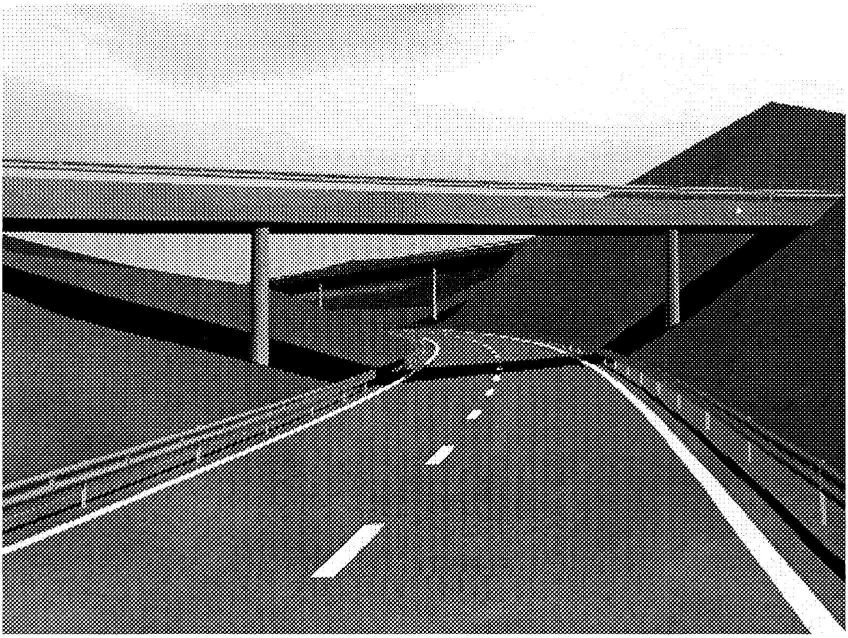


*Figure 5. Virtual walkthrough along the digital model*

**3.2.2 Timeline connection between model and project**

The model was used to check the original technical project in any possible way. Once the necessary corrections were found, the final version of the whole project included all the modifications, and it was not considered useful to port them again to the digital 3D version. Several benefits can be identified:

**3.2.2.1 Early detection of geometrical problems.** Many problems, specially in the main junctions, related with the unions of the different road branches were encountered, also unexpected slope discontinuities and undefined parts were detected.

**3.2.2.2 Areas of unacceptable design.** The original project was been made using a special software for road design. This program made automatically many decisions that were technically and geometrically correct but unacceptable from the viewpoint of the quality of the design, as an example, a simple visual inspection of 3D model displayed zones of excessive terrain slopes and remanent pieces of terrain that should be removed.

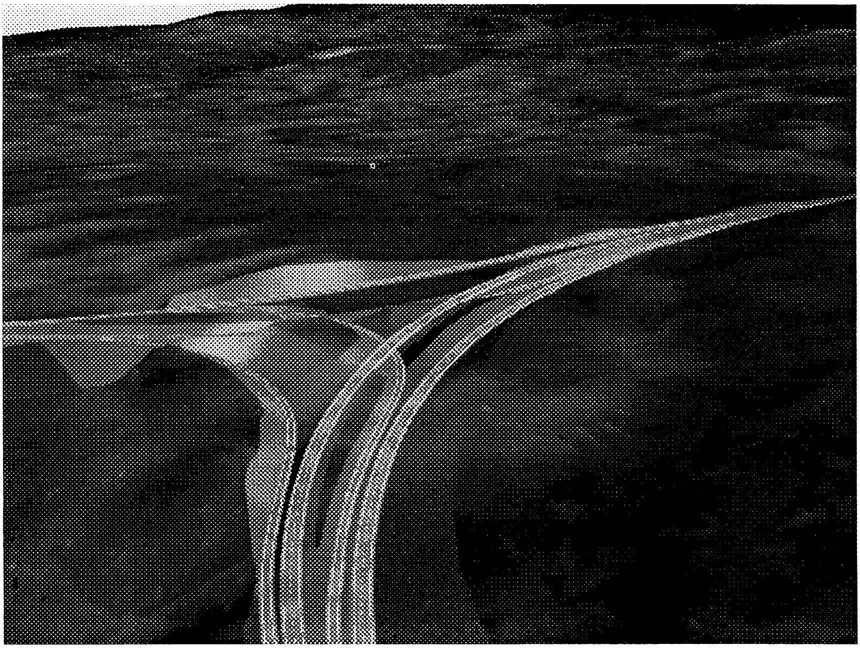


*Figure 6 Aerial view of one of the main roadjunctions.*

**3.2.2.3 Visibility and environmental impact check.** The 3D model made easy to visually test de project from the inside to check for reduced visibility areas that could influence on the traffic safety. The model also proved to be useful to get a good idea about how invasive the new highway was going to be in relation to the adjoining environment.

### 3.3 Visualization of new urban areas.

The next example is introduced as an application of 3D digital model to the visualization of new urban layouts. It relates how a new university campus is constructed simultaneously in the real world and inside a computer. The project spreads over a 3 Ha where four new buildings were to be added to the three existing ones, while the whole urbanisation was to be modified and completed.

#### 3.3.1 Description of the model

The interest of this work is related to the use of a single model in which all the different projects coming from different architects were to be reflected in a common actuation. Such a large work was digitally built, and served as a meeting point for the various design teams involved.

The model included a very precise description of the geometry of the buildings, roads, terrain and urban accessories on a global mesh composed of 250,000 polygons. Many different modelling techniques and rendering strategies were used to generate it in such a way that the model could be rendered as a whole by using personal computers.

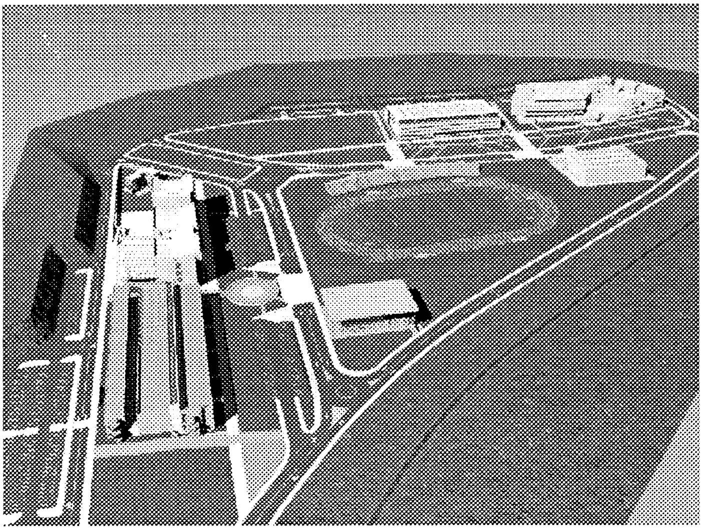


*Figure 7. General view of Elviña Campus*

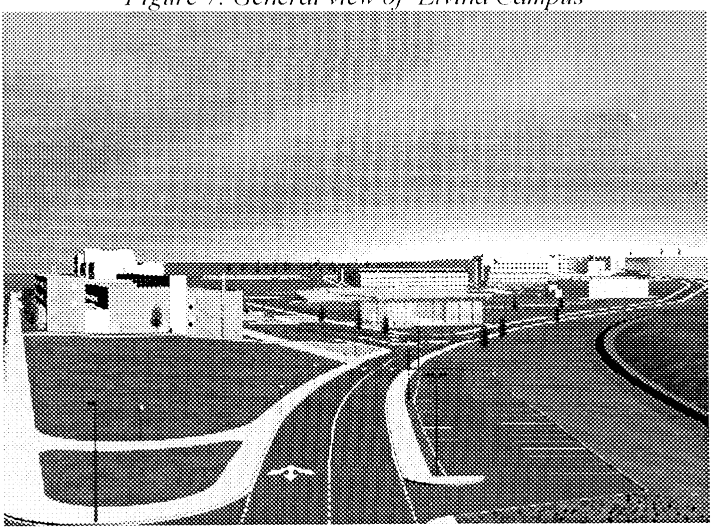


*Figure 8 Partial views of the digital model*

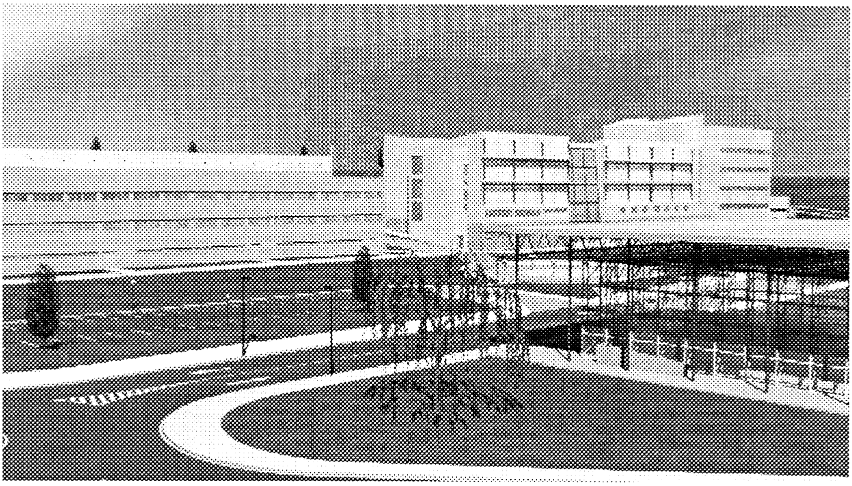


*Figure 8 Partial views of the digital model (cont.)*

### 3.3.2 Timeline connection between model and project

The digital construction of the whole set begun simultaneously with the real world works, and was finished some months before them, so it could be used to advertise the new campus. This model is intended to be useful as a future reference for new projects to be built in this area in the next years, since the authors of the new constructions will have a digital 3D model to evaluate their works in the design phase.

## 4 Conclusions

Several considerations can be concluded:

- Civil engineering projects deal with 3D objects that usually present complex shape and characteristics. Thus, an efficient representation by using conventional blueprints is commonly plenty of chances to produce errors, ambiguities and undefined parts.
- Digital 3D models of civil engineering projects are equivalent to virtual constructions. Therefore they are error free and all the ambiguities and parts not completely defined need to be solved when the model is being made.
- Current improvements on computer technology allows to use personal computers to produce huge detailed models as needed in practical civil engineering applications.
-The set of advanced visualization techniques to be used includes realistic images, morphing between real pictures and synthetic images, computer animations, and virtual reality simulations.
- Any step of the design and construction phase can be improved by using 3D digital models and applications for interactive design, correction

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checking phase and cumulative design have been presented in the adjoining examples.

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