Cavia: Computer Aided Visual Impact Assessment

César Otero, Cristina Manchado, Rubén Arias
Dept. of Geographical Engineering and Graphical Expression Techniques
University of Cantabria
E-39005, Santander, Spain
{oteroc,manchadoc,ruben.arias}@unican.es

Abstract- This paper offers a complete summary of MOYSES, a modelling and computer graphics application for helping civil engineering designers evaluate their designs for environmental and landscape plan approval. MOYSES is an application capable of geometrically defining scenes where maximum visual impact is important. This article refers to the scientific basis of the process, explains the algorithmic foundations and describes the process steps of the generated tool. Lastly, an explanation of the tool's functions post-processing is given, an operation that is related to the virtual representation techniques of land and civil works.

1 Introduction

Visual Impact Assessment (VIA), as an integral part of Environmental Impact Assessment, is a required component in the majority of public administrations when guaranteeing the sustainability of infrastructure or public service works. The specific problem of visual or landscape assessment is the difficulty of determining which scene or scenes are representative (that is, from where and towards where they are viewed) of the alteration produced by the work in question. Moreover, the set of representative scenes has to be reduced so that it is actually operative.

Determining each one of these scenes involves a geometric problem with a simple solution (find the Camera point and the Target point to generate a realistic visualization of the land) with considerable geometric and computational complexity, since all the points of the area where the work is located are potential Camera points and, from each one of them, all the points are once again potential Target points. Firstly, it refers to a complexity problem $O(n^4)$ that can result in an enormous amount of solutions. From the solutions that turn out to be inevitable, the "Camera-Target" pairs have to be chosen in a way that offers the most descriptive result of the alteration that is going to be produced.

A very operative method from the computational standpoint consists of performing a spatial analysis of those pairs of "Target-Camera" points that satisfy the criteria of maximum effect on the landscape and maximum impact to the observer, measured first in qualitative terms and then in quantitative terms [4]. A "Target-Camera" pair must be considered as a solution when it guarantees that one looks at an area with maximum landscape trauma and from a point where the amount of potential observers may be the highest. The exploration of the land in search of such conditions

can be adequately carried out using GIS (Geographical Information Systems) techniques.

Under these optimization conditions, a Computer Graphics application called MOYSES [9, 10], able to assist the designer during the design process, has been developed. In short, MOYSES is an application to compute the Target point-Camera point pairs under the conditions set out in the paragraphs above.

This paper offers a complete summary of the foundations and the operating capacity of MOYSES. Section 2 sets out the computational approximations (including GIS) relevant to the problem of visual impact assessment. Section 3 introduces the MOYSES v3.0 application while Section 4 describes the process followed for carrying out an evaluation of the magnitude of the impact from each "Camera-Target" pair selected. Section 5 illustrates the natural post-processing that the application makes possible: the appreciation of the impact intensity and its realistic simulation.

2 GIS Approaches to the Computer Aided Visual Impact Assessment

Different approaches to the problem of visual impact assessment can be found in the literature; GIS and Virtual Reality environments are arguably those offering a more specific and direct solution, whereas other approaches (such as the decision-making or genetic algorithm support systems) consider the problem in its more global context, relating the visual and environmental aspects to economic ones or execution and project management aspects.

A good approach relative to the treatment of the tools for realistic representation and Virtual Reality environments for impact simulation can be found in [5], which contributes to defining the technological support required by the problem; an integrated treatment of the subject within the global design process in engineering can be found in [7], based on technologies for decision-making support systems and in [8], in this case incorporating genetic algorithms into the scientific and technical visualization process.

The more classic GIS spatial analysis methods are used in [1] in order to create a specific procedure for the information process that the authors call "precision conservation", whereas [2] reports some experiences focused on the Visual Impact assessment strongly associated with the geomorphologic characteristics of the area and with spatial analysis techniques. This last reference is supported by case studies in order to communicate the experiences carried out; it

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presents the idea of combining numerical (measurements) and graphical (simulations) factors related to the more representative viewpoints of the projected intrusion. The application of MOYSES is based on the conclusions stated in that paper.

3 MOYSES V3.0.

3.1 The real goal of MOYSES

In this third section, a description of the MOYSES application and an explanation of how version 3.0 was developed is given. It is particularly important to distinguish what the application does and what it does not, since the natural tendency of the reader (or the application end-user) is to think that MOYSES is a generator of realistic images.

However, the generation of realistic land models (with or without superposed virtual elements, such as civil works, parks and other urban elements) is a mature technology that is already in use today in almost all the engineering offices that design large or medium-sized infrastructure works. In fact, MOYSES is an automatic calculator that provides the data necessary (Camera point and Target point) for generating the realistic images that simulate the intrusion at the points where its effect (i.e. visual impact) is maximum. In simple terms, this application allows the user to know from where and towards where he should look so that there is clear evidence that the generated image shows the greatest effect on the landscape and is seen by the maximum amount of viewers. All of this is based on objective data.

Once such points are determined, MOYSES is able to measure, in terms of area, the percentage of the alteration. By contrast, we rely on commercial software tools from here onwards for the generation of realistic images, such as those shown in this paper. The only thing remaining is the development of an optimal automatization process of the data flow, an issue that has an unquestionable technical, but non-scientific, value.

3.2 The algorithm

The initial spatial analysis algorithm was designed to be developed in vectorial format [9], although version 3.0 has modified the entire treatment and solves the problem by using raster modelling [10]. Both conceptions have been published in previous articles. To be consistent with the development of this contribution, the process will be detailed next. The figures from previous publications are omitted here but are available in the original sources. The initial data required for MOYSES are:

1. DTM (Digital Terrain Model) of the zone,

2. NMDM: layout of the new motorway as DTM on top of the one belonging to the area,

3. GIS Entities: Scenic units; Geomorphologic map of the zone; Land-use map,

4. CAD basis cartography: Roads, population nuclei, rivers; Geographic DB (databases) with population data; Data on the size of another relevant infrastructure of the zone; Examples of known visual intrusion, for comparison.

From the stated data capture, the following layers of graphic information are obtained:

1. DTM: Digital Terrain Model of the zone,

2. GM: Geometry of the Motorway,

3. PD: Areas in the zone, classified according to Population Density,

4. RB: Zones Areas, classified according to their proximity to other roads (Road Buffers),

5. LU: Landscape Units. Notice that in an initial process, the DTM and GM data are obtained directly. The other layers are obtained by several spatial analysis commands.

A second processing leads to the following intermediate results:

1. GVE: Areas of Greater incidence or Visual Effect, obtained from PD and RB, combining their geometries and calculating the sum of their relative weights for both criteria,

2. MSLU: Motorway's sections in Landscape Units, obtained from GM and LU, by means of the inclusion operator. CMSLU: Centroids of the MSLU sections,

3. VS: Viewsheds for each CMSLU centroid. In general, the viewsheds for several centroids can overlap,

4. SVI: Areas of great Visual Impact in Viewsheds, obtained by the relation of inclusion of GVE within VS.

Each VS viewshed for a CMSLU is used to determine, in association with the GVE polygons, the SVI maximum visual impact zones. Let us consider the CSVI (SVI's centroids); these points can be considered as representative VIEWPOINTS for the zones from which the observation of the motorway proves to be more traumatic on the landscape. In fact, CSVI centroids belong to zones of higher population or passerby density, while CMSLU centroids represent stretches where the motorway passes through zones of high scenic value.

As a result in this algorithm each centroid PTi of the CMSLU has generated a more or less reduced set of PCj centroids in CSVI. In brief, a simulation of results can be attained automatically considering all the realistic visualizations that arise from considering each PTi centroid in MSLU as a Target Point and all PCj centroids in SVI as Viewpoints from which the corresponding visualizations are generated.
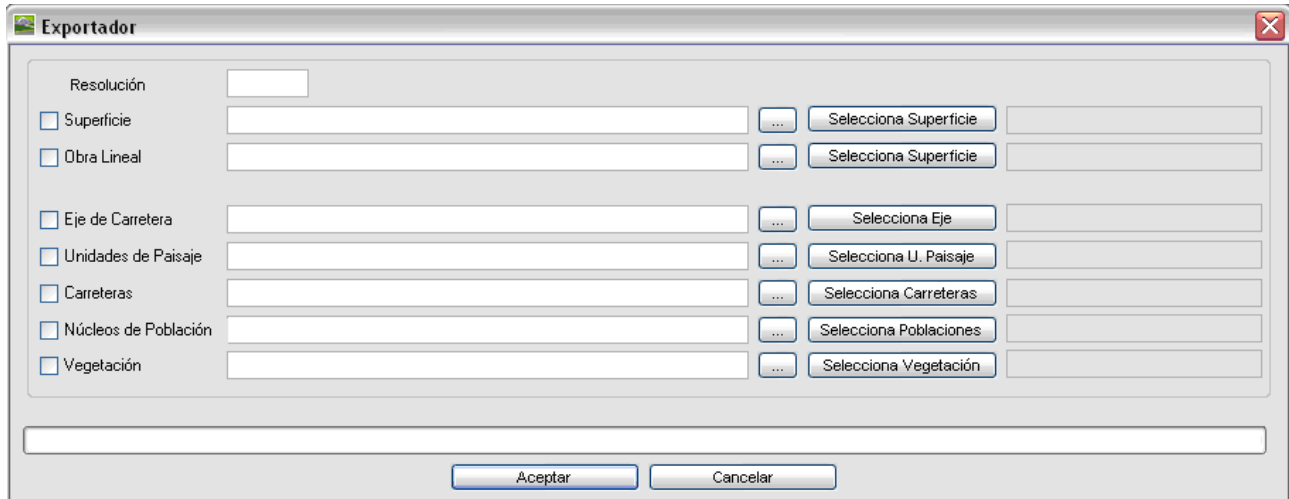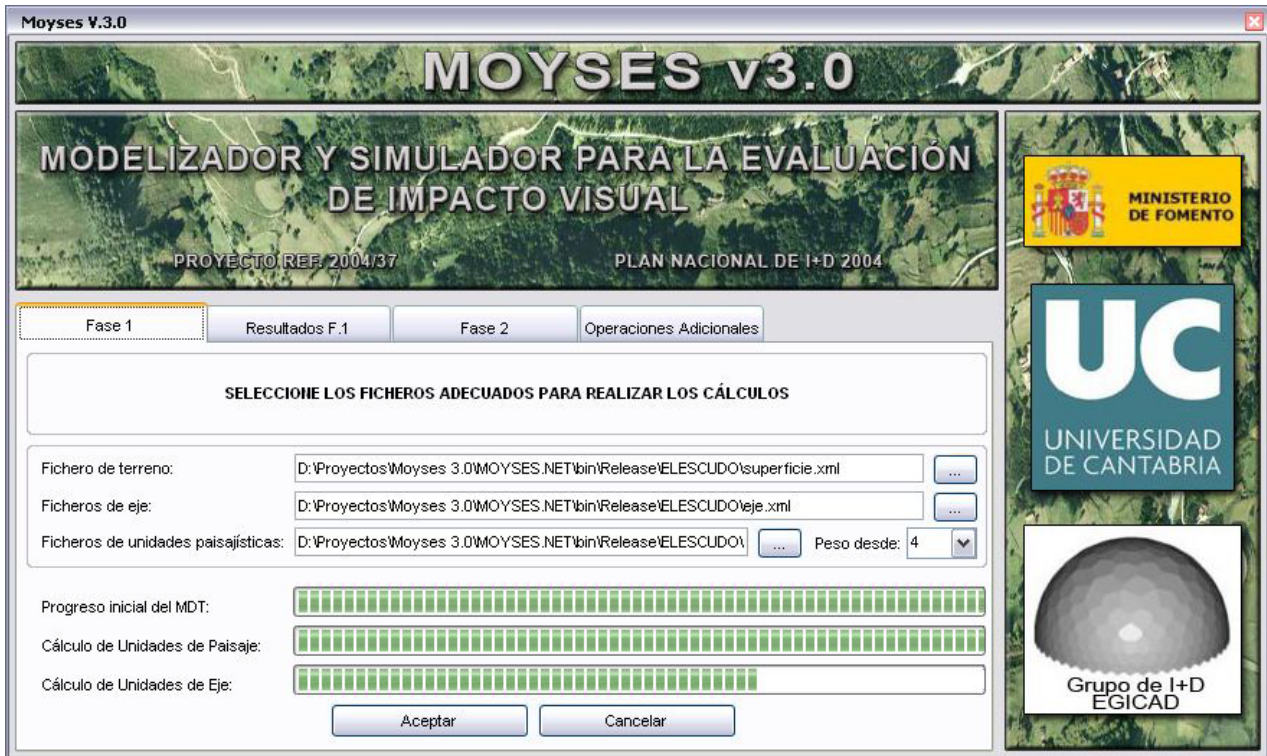
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Figure 1: Exporter of MOYSES v3.0

Figure 2: Target Point calculation sheet

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CSVI Centroids are viewpoints and CMSLU Centroids are target points. The images obtained simulate the visual impact produced by the motorway on the landscape. The result obtained is a catalog of Realistic Visualizations (RV) obtained from considering all PTi as Target Points and, for each one of them, all corresponding PCj like Viewpoints. This catalog simulates the worst effects of the motorway on the existing landscape.

Moreover, this algorithm, as hereby described, includes two important issues:

1. The effect of vegetation when calculating Viewsheds.

2. Those points of view most relevant to the site along with those vantage points known (by tradition) to offer a high quality view. Both can be easily included in the process: Forest areas can be incorporated into the DTM by weighting each triangle in relation to its mean vegetation height. This value can be added to the mean triangle elevation when calculating the viewsheds. On the other hand, those vantage points belonging to the ACSVI catalog can be merged into the CACSVI centroid collection.

3.3 The Computer Aided VIA Tool: Pre-processing

The algorithm described above has been implemented so that it works directly with all the data (road networks, population centres, landscape units, etc.) already expressed in raster numerical values. In this way, each one of the spatial crosses described in the algorithm of the previous section involves a simple operation with the weights at pixel level.

In order to obtain this, it has been necessary to create an exporter (whose interface is shown in figure 1) capable of discretizing the data; this provides another important benefit to the application, since it makes possible that the data capture process (always dependent on the CAD or GIS system in which these data are given) becomes independent from the MOYSES process itself.

From the development point of view, the data discretization process is generally based on two classic algorithms (Bresenham for the discretization and geometric search of points in areas) combined with the typical library functions of extraction of numerical data in CAD systems (generation of selection sets, set paths, acquisition of the object data of a graphical element and extraction of its geometric data) combined in some cases with the extraction of associated extended data (such as for extended GIS data which determine the landscape quality, the population density or the vegetation typology). These last resources are part of the APIs provided by the CAD/GIS software manufacturers, and its use is important even although it does not have any scientific relevance. The same happens to the land Surface Model, which is a relevant piece of information that may not be numerically defined in the CAD System; if that is the case and the terrain comes defined as a TIN (Triangular Irregular Network), its conversion to raster is made

through an exploration function $z = f(x, y)$ which is generally provided by the system manufacturer's API.

Even more interesting is the discretization treatment of the axis of the motorway of the new simulated project: Whenever such axis is represented by straight line segments, circular arcs and clothoid arcs, a numerical problem of specific parameterization arises. This problem has been analyzed, for example, in [11]. This issue has also been addressed by the authors in a simplified way and will be the subject of a specific publication.

MOYSES v3.0 has its own exporter for data output written from the AutoDESK environment (AutoCAD and Civil3D) and has total functionality. Moreover, its interface allows the user to select the layers or objects embedded into the data (surface of the terrain, motorways, axis of the project, etc.) and inserts them into specific XML files subsequently addressed by the application kernel. In this way, the system is already constructed independently on any commercial software.

3.4 The Computer Aided VIA Tool: Processing

The tool for calculating the maximum visual impact points has been developed in .NET environment; it is issued with a user interface that has 4 sheets, each one associated with a block of operations:

- The sheet called "Phase 1" (see figure 2) is responsible for dividing the axis of the motorway into sections for each landscape unit that it crosses, rejecting those sections associated with units of low landscape value (set by a minimum acceptable value threshold) and creates the representative centroids of the non-rejected sections. Each one of these centroids is considered a useful Target Point for the simulation.

- The sheet called "F.1 Results" (see figure 3) shows the X and Y coordinates of the obtained centroids, their landscape value and a validation option, that allows the user to reject some of the calculated solutions for various reasons (for example, because of the proximity between points, which can cause almost identical results). On this sheet the user can select one of the Target Points, a condition necessary for advancing to the second process, which is activated from the button called "Calculate View Points".

- The sheet called "Phase 2" (figure 4) asks for the accurate data to calculate the viewshed associated with the Target point selected in the previous step and to determine what motorway zones and population centres belong to it. Based on this process, which can whether or not take into account the wooded zones for visibility and even allow simulation of different tree heights, the solution areas are obtained as an aggregate of points (pixels).
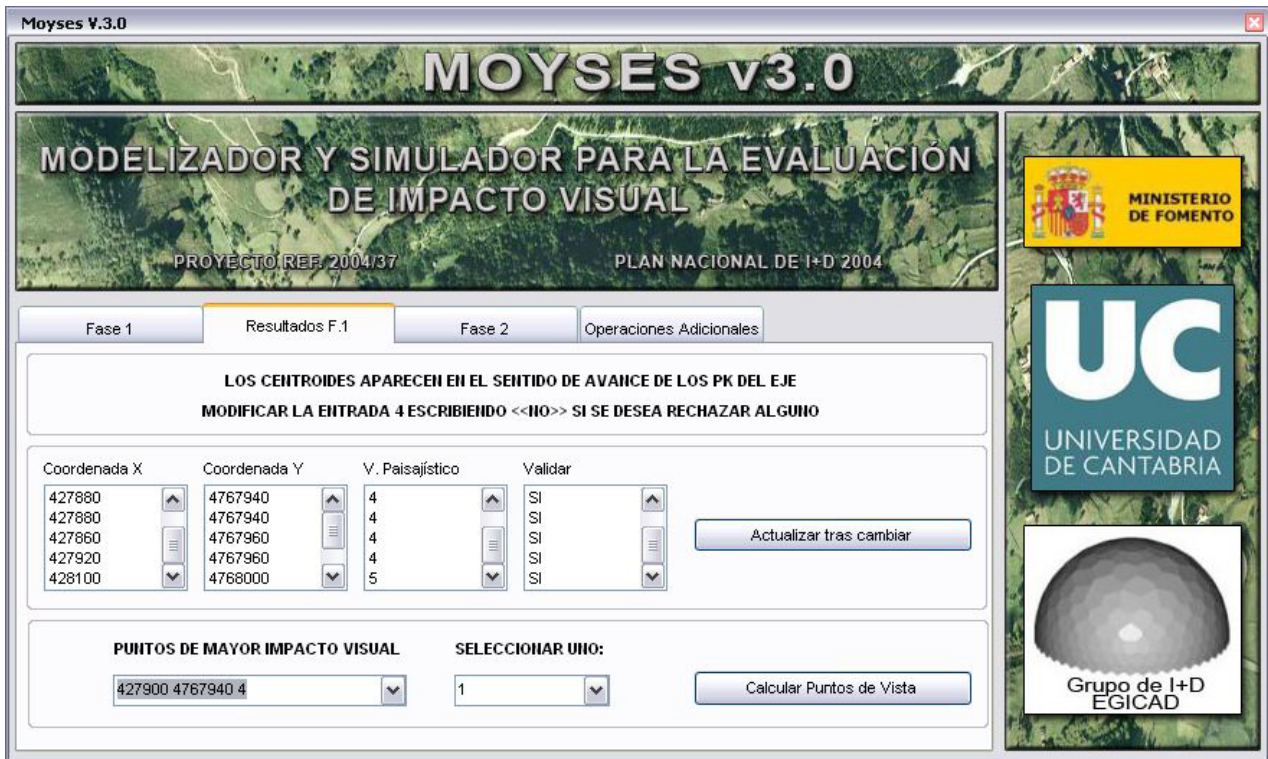
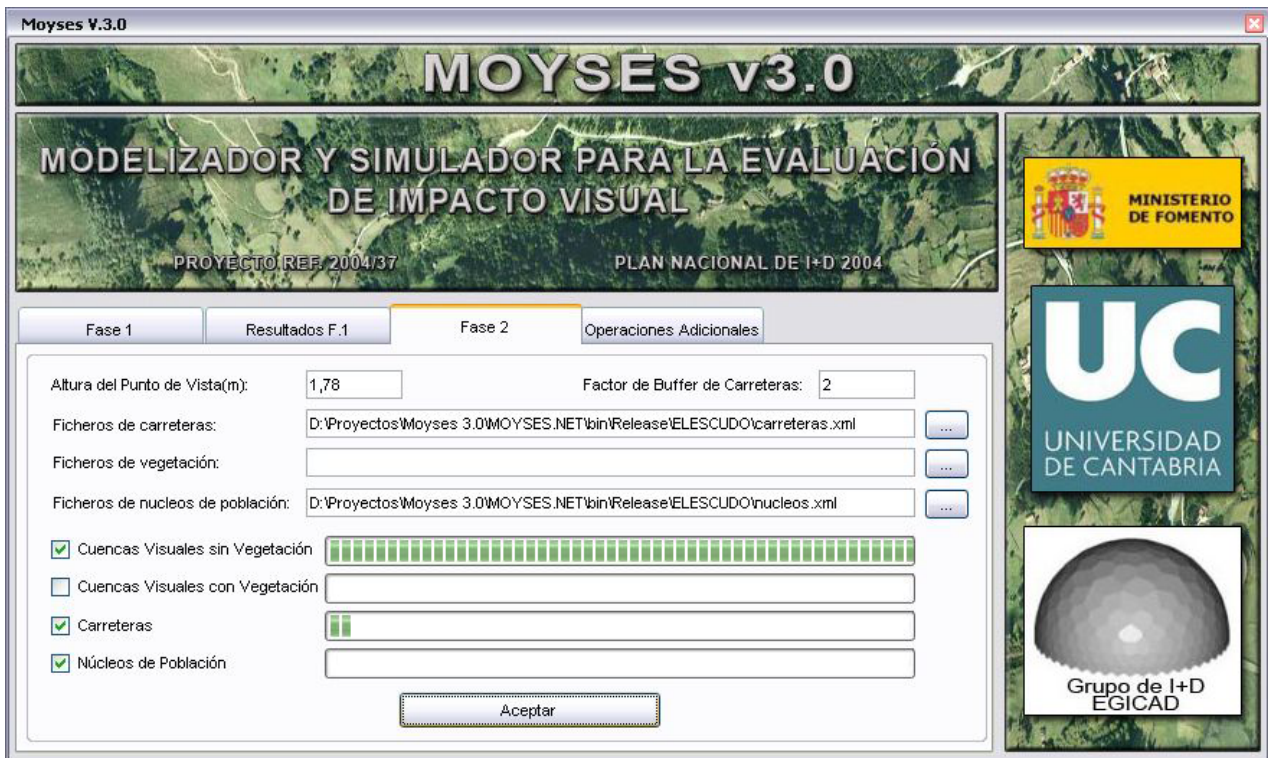International Journal of Computer Information Systems and Industrial Management Applications (IJCISIM)
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Figure 3: Phase 1 results sheet

Figure 4: View Points calculation sheet

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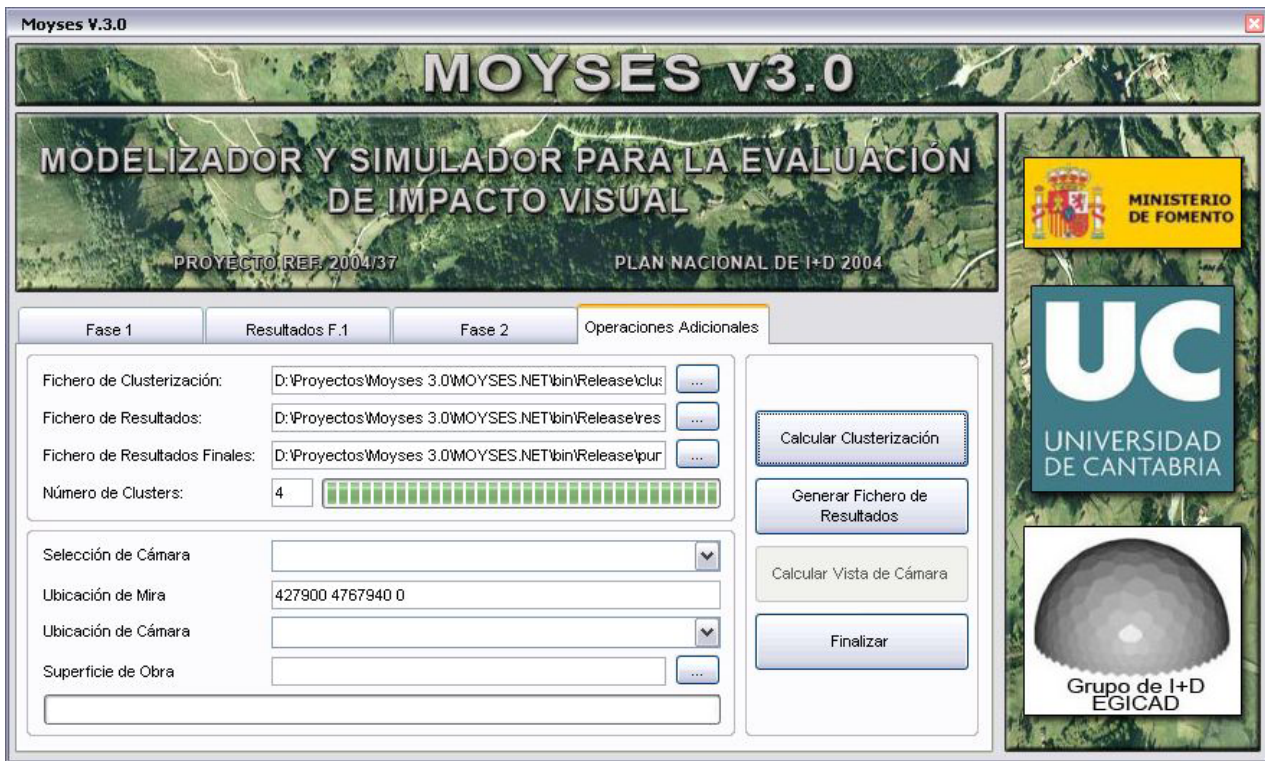Selected Papers from CGGM'2007 Workshop

Figure 6: Clusterization of the visibility areas to obtain the Camera Points
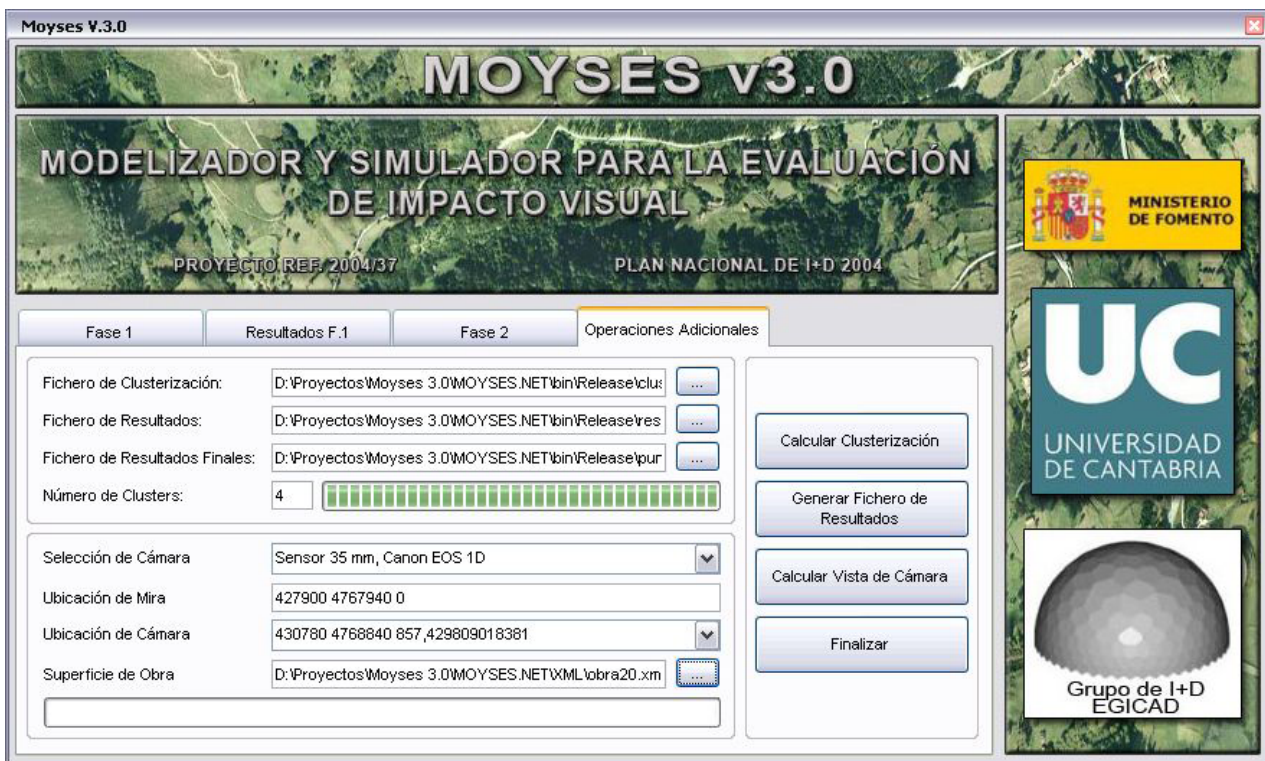
Figure 7: Measurement of the intrusion magnitude. Quantitative assessment of the impact

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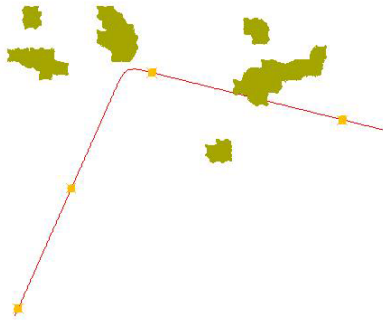Selected Papers from CGGM'2007 Workshop

Figure 5: Result of the phase 2 process. Clusters of solution points

- Of course, the aggregate of pixels referred to in the previous paragraph associate in clusters, each one representing every one of the areas of the land where all the optimization criteria are satisfied (see figure 5). The most common situation is that in each one of these areas, with any cluster point chosen as the Camera Point, the perspective obtained is virtually the same. For that reason, in the sheet called "Additional Operations" there is the possibility for the user to carry out a clusterization process of the solution points. This process is performed by using the K-means method, where the number of clusters is specified beforehand by the user. Once the clusters are obtained, a function is provided that computes the centroid of each cluster; if the centroid falls outside of the cluster, their points are covered and the one closest to the outside centroid is chosen as the solution centroid. Each one of the centroids thus obtained is a definitive Camera Point associated with the Target Point that closes the entire processing.

4 Measuring the Magnitude of the Visual Impact

A recommendation reported in the literature is that the generated Impact has a quantitative measurement in terms of the percentage of altered surface [3, 12] regarding the visible land surface, but measured from the visualization in perspective (not in plant). Since the Target and Camera data points are known, the problem is defined geometrically and is well suited for computer simulation.

The process begins by numerically creating a new array that represents the sensor of a camera. Then, land's pixels are projected onto camera's pixels by means of a ray tracing algorithm. Since many ground pixels can be projected onto one sensor pixel, the pixel of the sensor is associated with the closest ground pixel, so that the others are hidden by this one. This way, each pixel of the sensor maintains its minimum distance to the land.

In a second step, ray tracing is oriented exclusively towards the new surface (i.e. the one of the planned new work). If a pixel of the sensor now keeps a closer distance to the work surface than the one kept for the original land, this sensor pixel represents visible work in that perspective. It is enough to calculate the sensor pixels that are visible in the work, the sensor pixels at which the total land is visible and sensor pixels in order to solve the intrusion measurement process. This task is strongly dependent on the resolution taken during the discretization of the land.

In Figure 7, the second part of the sheet called "Additional Operations" is shown, where different current use sensors are presented, the new Camera point associated with the Target point (which is meant to be analyzed) is chosen and the file with the already properly-discretized project surface is selected. The result of this execution reflects the intrusion percentage of the project on the land for this specific perspective.

5 Appraising the Intensity of the Visual Impact

However, the bibliography on this subject places much greater value upon technical decision-making, which is called the "Impact intensity" assessment. Unlike the magnitude, this one is related to less numerical and more perceptual factors, in such a way that the expert in impact assessment usually operates by comparing the anticipated situation with other similar situations whose assessment is already known and properly addressed.

It is evident that realistic land representation systems are very useful tools for aiding in the assessment of the impact intensity. For instance, Figure 8 (top) shows a realistic scene of a wind farm that has been modelled in AutoCAD and then exported to .osg format to be analyzed by a freeware visualizer. The work-time process is less than 15 minutes (recall that the land surface and project models are already-existing data). The perspective has been generated with a Target-Camera pair provided by MOYSES and therefore it satisfies the maximum intrusion conditions and maximum number of those affected.

On the other hand, the system provides the user with accurate UTM coordinates so that he/she can place the camera at the exact prescribed position. Summarizing, this last not only involves the desired simulation but also the exact photograph of the real panoramic whose simulation is being made. This gives the expert valuable comparison elements that have, at the very least, excellent metric reliability. Both images, real and virtual, correspond to the same observation of the impact. No time has been lost in the positioning of the images.

Finally, it is important to remark that the output of the points obtained by MOYSES can also be exported to stereoscopic representation devices (figure 9), from where the evaluation of the intensity of the impact may be even easier to carry out.

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Figure 8: (top) Realistic visualization of a wind farm project taken from the Target and Camera points calculated by MOYSES. (bottom) Photograph taken from the same points referenced in UTM on site

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Figure 9: Evaluation of the intensity of the impact from a stereoscopic representation of the perspective generated by MOYSES

6 Conclusions and Future Work

Regarding our future worrk, the tool described under the name of MOYSES is currently being tested and compared using different testing procedures. On the other hand, since its system kernel is platform-independent, it can be integrated into any (either commercial or open source) computer-assisted engineering software.

After 8 years of development, the scientific and technological steps in the tool development process are almost finished. Our current work is focused on technology transfer and the solution implementation in production environments. The feedback from users will enrich the development quality. With MOYSES we have achieved the aim set forth in the applied scientific and technical process: the generation of solutions at the service of society.

Acknowledgments

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About the authors

César Otero (Civil Engineer, PhD in Engineering) is Associate Professor of CAD at the University of Cantabria. He is responsible of different subjects related to Computer Aided Engineering Systems at pre and post-graduate levels in different engineering schools of his University. In 1998 he created the EGICAD R&D Group, mainly devoted to CAD and GIS software developments. His main fields of interest are CAD, GIS and Computational Geometry.
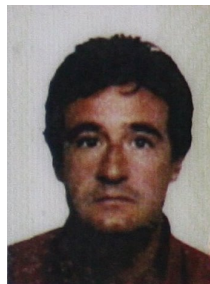

Cristina Manchado (Technical Engineer of Telecommunication) is Assistant Professor of CAD at University of Cantabria. She teaches subjects related to Computer Aided Engineering Systems at pre-graduate level in Technical School of Industrial Engineers. She is also a researcher at Egicad R&D group. Her main fields of interest are CAD, GIS and programming.

Rubn Arias (Civil Engineer) is Assistant Professor of CAD at the University of Cantabria. He teaches some subjects related to Computer Aided Engineering Systems in different engineering schools of his University. He is also researcher at EGICAD R&D group. He is currently pursuing his Ph.D. at the University of Cantabria on Model Development and Application in Civil Engineering.