# CAD-BASED TOOL FOR AUTOMATED PANEL CUTTING OF PREFABRICATED FACADES

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**ABSTRACT**: The development of prefabricated facades, using architectural concrete panels or GRC panels, starts by cutting facade maps included in the architectural project. The aim of the architectural department is creating a design of the panels, taking care about the viability in terms of dimensions, weight, location, etc, and also looking at the cost of the execution.

With this aim we develop an ad-hoc tool to automate the process. The software, based in AutoCAD, allows the architect to obtain the maps for the final panels and its locations using a graphical interface.

The interface prompts the user for all the geometry of the facade selecting it from the drawing or creating it at the moment, including: frameworks, pillars, structural lines, design lines, expansion joints and no paneled areas (windows, doors, etc.). These will be the input data for the cutting algorithm that defines the geometry of each panel.

To run the cutting process, the architect must input some parameters about the panels, such as maximum size, type, etc. The algorithm divides the surface of the facade into the smallest units that can be considered and generates the micro-panels layer. By using these micro-panels, the algorithm decides which ones should be together to conform the final panel planning, attending some criteria: viability to fix the panel to the structure, weight, dimensions, total number of panels, number of similar panels, etc. When this process is finished the interface shows a detailed resume of the costs, as well as the panel's drawings.

***Keywords***: *Computer-aided Design (CAD), Precast Facades, Concrete Panels, GRC*

## 1. INTRODUCTION

Architects has multiple options to design buildings, new systems, modern materials and innovating methods, the selection of the building technology will depend on the complexity and the needs of the project.

One of the most leading fields in the construction industry is the use of prefabricated panels for the enclosure, not only because the fast building methods, but also for the superior construction quality.

The construction activities involved in this process are divided in two main groups: off-site and on-site. On site processes are more relevant and form what is considered the typical construction work, i.e. building, but these activities are the most difficult in relation to automation, mainly because of the highly complex and variable environments in which they take place.

A common off-site process is the manufacturing of prefabricated facade panels [1] that are later assembled on-site [1].

Actually, the aim of the architectural department in manufacturing process involves the following steps:

1. Cutting the facade.
2. Generate the maps for the panels.
3. Generate the maps for the moulds.
4. Fabrication planning according to the building plan.

Usually those processes are not automated [3] and require a tedious work by qualified staff in this field, spending lots of time and resources and generating a bottleneck.
The traditional material used to build the panels is the concrete, but one innovative material used in this kind of industry has been the Glass Reinforced Cement (GRC). Rapid design is a limiting factor in the production of GRC panels as well as for concrete panels.

**2. OBJETIVES**

The objective is developing an ad-hoc tool to automate the panels design process [4]. The tool must allow the architect to obtain the maps for the final panels and its locations ensuring the size and weight restrictions.
The specific objectives of the tool can be grouped into the following three:

- Save time in the definition of the project. Allowing potential users such as architects, technical architects and draughtsman, get a first proposed solution to the facade, without the intervention of the architectural department, and almost immediately.
- Cost saving in project definition. As project information is already available in the appropriate format for the architectural department defines the project details and needed less time and resources in its execution.
- Savings based on a significant improvement in quality due to the elimination of human error in the definition of the facade.

**3. DESCRIPTION OF THE TOOL**

The tool we developed is an AutoCAD Architecture 2010 [5] add-on that can be downloaded in .exe format from the project web. The user installs the add-on by including in the loading of AutoCAD application the extension that the executable file extracts on the user disk, this file is a dynamic library developed in C sharp using the Microsoft .net platform.
The add-on attaches in the user's AutoCAD application the necessary commands to execute all the steps of the panel design, the user interfaces to access to the commands.

The first step to design the final panels is defining the geometry of the facade, with this purpose we use different objects like:

- The outline of the elevation in the facade in study.
- The frameworks.
- The pillars.
- Design lines.
- Structural lines and expansion joints.
- The carpentry elements of the building.

All of these objects are defined as AcPolylines whose are closed when necessary.
The second step is to run the cutting algorithm using the available information and attending some criteria imposed by the manufacturing system on the plant.
The final step is the visualization in the web, where the architect can see the final facade panelized, as well as a resume of the cost, number of panels, etc.

**3.1. USER INTERFACE AND AVAILABLE COMMANDS**

As we said, the AutoCAD interface is modified adding a context menu which allows to the user to access easily to the following commands:

- INSPECT: Using this command the user can get all the information relative to a drawing object that belongs to the add-on, like type or surrounding elevation.
- FACADES: Shows a window were the user can view the state of the project in the current drawing with a resume that includes:
  - Number of facades.
  - Elevations per facade.
  - Objects of each type per elevation.
- NEWFACADE: Create a new facade by creating a new layer with the name and color that the user inputs.
- ELEVATION: Create a new elevation in the current facade, selecting it from the drawing or creating it at the moment drawing a new polyline that must be closed.
- NOPANELLED: Creates a new carpentry area where the final panel will have a hole, the "*no*

*paneled area*" must be inside a elevation totally or in part, in case of the "*no paneled area*" was placed in part outside this part will be subtracted from the original area.

- FRAMEWORKS: When the user selects this option a new window shows that allows the user to create automatically the frameworks areas selecting a base point, the base point of the next framework and the thickness. Another option is to introduce each framework as a closed polyline. Also this window allows marking the frameworks as projecting frameworks.
- PILLARS: Similarly to the frameworks this option shows a window to introduce the pillars automatically or one by one using polylines.
- DESINGLINE: Using this option the architect can create a design line that will be in the final structure, in a decorative manner or being the joint of two panels, depending on the final panel planning.
- STRUCTURALLINE: This option, defines a line in the elevation that must be the division of two or more panels, in example because it's an expansion joint.
- PANELIZE: Once the region that must be panelized is defined, as you can see in Fig 1, this command initiate the cutting algorithm. To start this process the command prompts some final data:
  - Maximum size of the panels.
  - Panel positioning direction.
  - Panel type.
  - Color of the new panel layer.
  - Scale.

After user accepts this form, the algorithm starts, generating a new layer with the name of the facade layer that includes the final panel planning.

- VISUALIZE: When the cutting algorithm has finished the user can visualize the final design in the project web. This command allows the user to input the user and password information, once it's confirmed, AutoCAD sends all the information needed to the server in XML format where it's stored according to the national law in terms of privacy and using SSL encryption. This data includes number of panels, size, volume, number of similar panels, etc.

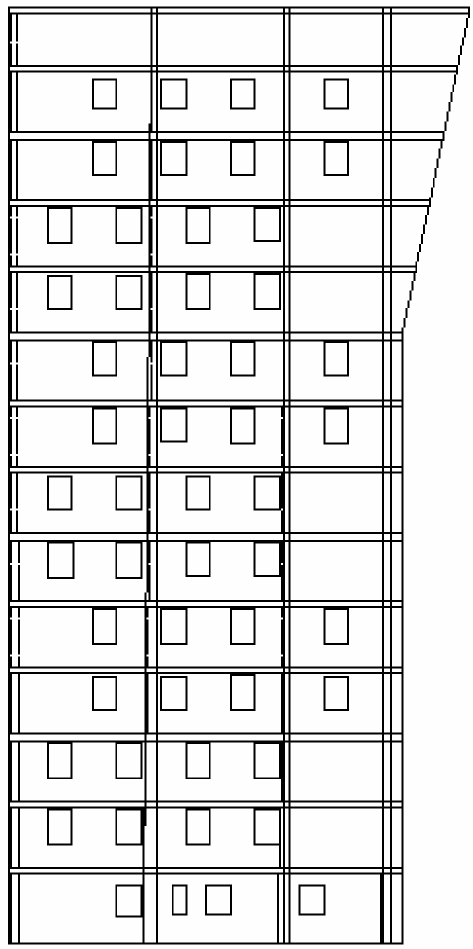

Fig. 1 Input geometry of the façade.

**3.2. DATABASE TRANSACTIONS**

The information stored in the drawing is a compound of AcEntities that define the geometry of each facade including the input data of the algorithm, Fig 1, and the output data.

Each entity has attached some additional data that is stored as Extended Entity Data in a 16Kbytes buffer that includes:

- A general code indicating that the entity was created by the add-on.

- The code of the surrounding elevation as a 16bit integer.
- The code of the type of entity.

This Extended Entity Data is used by the commands to identify the entity, picking out from other entities in the current drawing and from other entities created by the add-on.

### 3.3. CUTTING ALGORITHM

The cutting algorithm is a process of two steps, the first one, see Fig. 2, starts checking if the panel layer exists and generating it if doesn't exist, after this, the algorithm generates the micropanels in each elevation attending at the input data:

1. The fix lines: These lines are generated by structures that must cut the panel, i. e. the frameworks or the expansion joints, all of this lines determine closed areas of the elevation that must be considered separately to join up the micropanels.
2. The optional lines: Determined by structures than can cut the panel optionally, i. e. pillars or design lines, divides each area created by the division of the fix lines, generating the previous micropanels.
3. The no paneled areas: These areas are in the facade structure as carpentry, i. e. windows, doors, etc., these zones must remain into one single panel, and this is a constructive approach for problems of rigidity of the panels, so cuts should be located at a minimum distance from the no panelled area borders.
   Also some optional lines are generated at this step extending each vertex of the carpentry to the limit of the micropanel surface. This process generates much more micropanels near the no panelled areas that can be group in the following steps of the algorithm generating more efficient shapes for the final panels.
4. Once the micropanels are created, the final step is dividing the micropanels that still being bigger than the maximum dimensions. It happens when there are large areas of the facade without any input geometry.

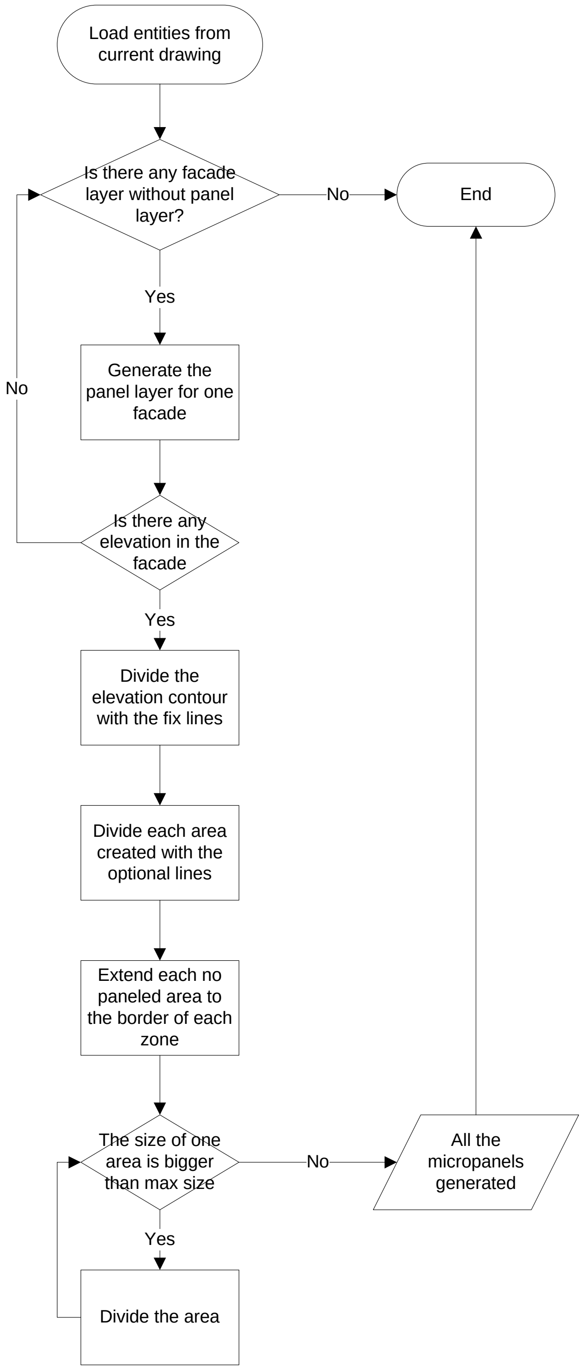


Fig. 2 Process to generate the micropanels on each area determined by fix lines.

The second step of the cutting algorithm is to decide which micropanels must be together to conform the final panel, as you can see in the Fig. 3, the panels are being generated one by one joining up the micropanels that can be together. This process considers only the micropanels included in a zone determined by the fix lines, these zones are processed one by one.

It starts checking the number of micropanels in the zone, if there isn't enough it ends creating a panel with the only one micropanel in the zone.

If there is more than one micropanel, the algorithm creates an empty group and adds one of them randomly, then adds temporally the adjacent micropanels and checks the availability of the panel made from the group. The checking includes restrictions like:

- Maximum width and height of the panel.
- Maximum weight of the panel depending on the building material.

By iterating this process the final panel is created when it`s impossible to add another adjacent micropanel, joining up all the micropanels of the group in a single closed polyline and storing it in the panel layer of the drawing. The panel is stored as one or more closed polylines depending on the number of no paneled areas content, also an MText is stored in the drawing indicating the reference number of the panel.

The process is repeated until the last micropanel is assigned for all the zones created by the fix lines.

### 3.4. WEB RESULTS

The results of the panelize process is presented to the users in a web page using the command visualize.

When the panel's maps are designed, all of these maps are serialized to an XML document that includes data like:

- Total number of panels.
- Number of similar panels.
- Cost expected.
- Project time-frame.
- Other data.

The application sends the XML document to the server using a Secure Socket Layer, where it's stored.

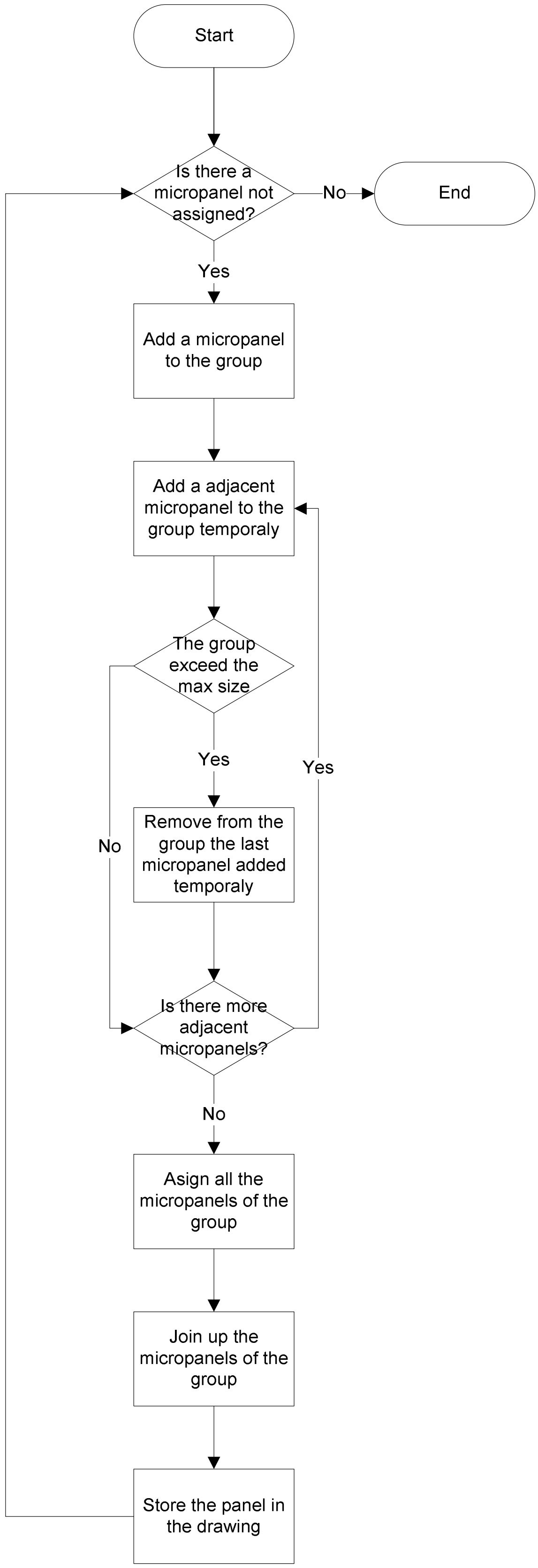


Fig. 3 Generation of the final panels by the union of the micropanels in a zone.

Users can access to the private zone in the web server where they can see all the information mentioned relative to his projects including the elevations and the panel's maps. To show these maps in the web page we use JQuery JavaScript framework.

## 4. CONCLUSION

The developed tool presented allows design the panel maps in the architectural department calculating automatically the map of each panel according to the restrictions imposed by the fabrication and the transportation processes, and imposed by the constructive needs.

Using this tool the cost and the deadline of the prefabricated facades project, even using GRC or concrete, are reduced.

## 5. ACKNOWLEDGMENTS

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