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Courtyard house solar parametric design

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***Abstract*—this study offers a parametric architectural design method to improve the solar potential of the courtyard house, in need of rehabilitation or to design a new solar courtyard house. The parametric model design is developed by converting of a set of mathematical equations into an algorithm. To do this, we have chosen Grasshopper parametric design environment. Ladybug has been chosen to finished and complete simulation process. Results showed that, developing of parametric architectural model makes architectural design easier.**

***Keywords*— courtyard house, Solar design, Architectural modelling, Parametric modelling, Algorithm.**

I. INTRODUCTION

Architectural design methods are extremely diverse and vary, from simple to complex. Depending on tools used, two methods can be distinguished: Mathematic and digital. Digital methods use numerical modelling software while the mathematic one are based on mathematical equations. The focus of this study is to facilitate the process of architectural solar design of the courtyard house by translation of a set of mathematical equations to a digital model; by using computer software such as: Grasshopper, and Ladybug.

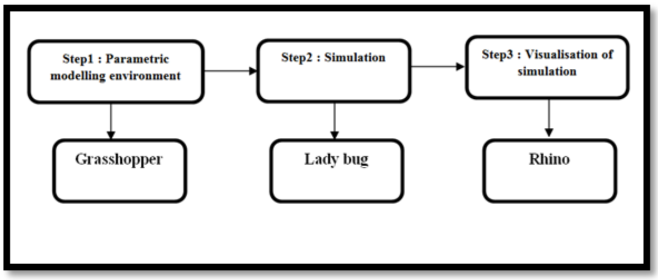

Fig. 1 Work steps.

II. THE GEOMETRY OF THE STUDIED ARCHITECTURAL MODEL

This research study is based on previous master study results, wherein we have established a set of mathematical rules that determine the size and the main dimensions of the solar courtyard house (tab.1) to improve its solar potential. After that, the solar potential of the generating model was evaluated using Ladybug plug-in. The results showed that, the new design method allows the sun rays to penetrate to the ground floor rooms in winter; and it should ensure an acceptable level of solar protection in summer.

Our studied model consists of two parts, each characterized by specific geometry and dimensions. The first one is the lower part which is an equal height mass surrounding the courtyard. While the second one takes often U shape. It is composed of a built mass and a terrace which faces the sun. The dimensions of this part are calculated according to the azimuth interval (-30°, 30°). All dimensions of the studied model are determined according to the sun positions. So the lower part geometry is shaped in order to provide good winter comfort. While the upper part geometry is shaped in order to provide good comfort during the summer months. Indeed, all mathematical rules as we shall see in the next section are derived from the trigonometric law. The following table shows the main solar dimensions of our courtyard architectural model:

TABLE I
ARCHITECTURAL MODEL DIMENSIONS

Model parts	**Solar dimensions**		
	Planar dimensions	height	**law**
The lower part	30° azimuth width: it was considered t hat the (-30, 30) azimuth interval defines the best geometry according to the duration of sunshine. It depends on the site zise.	The height : it is defined by a law which is derived from the trigonometr ic law	H=tg Hs* A30°
	North-south width: it depends on 30° azimuth width. It also determines all the	Ws-n=cos30*A 30	H=tg Hs* A30°

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	other dimensions.		
	Est. west width: it depends of the two previous planar dimensions.		
The upper part	wings extension : this part provide solar protection in summer	**The height:** it's calculated using the same law of the lower part height but using the summer solar height	

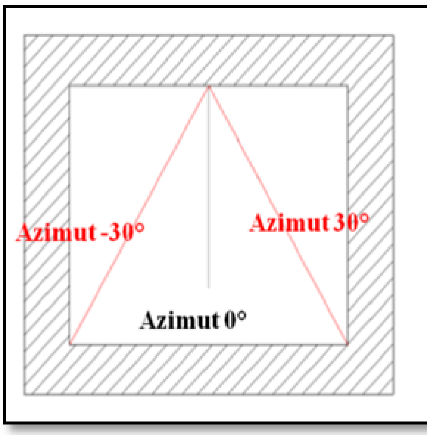

Fig. 2 Work steps.

North-south width = A0= Ws-n =cos30*A30

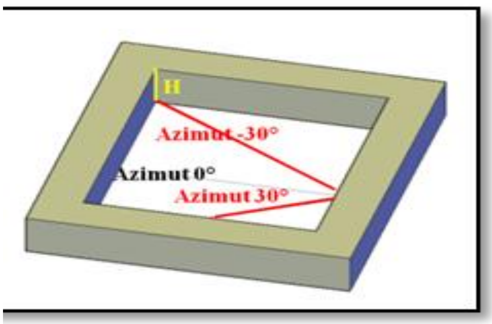

Fig. 3 Work steps.

The height= H=tg Hs* A30°

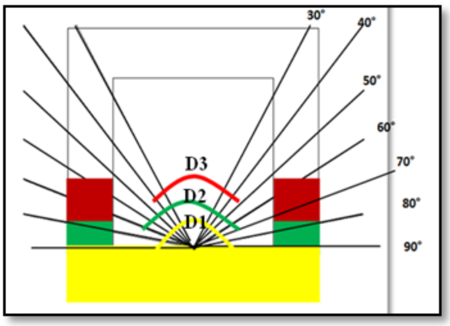

Fig. 4 Work planar vue of the upper part.

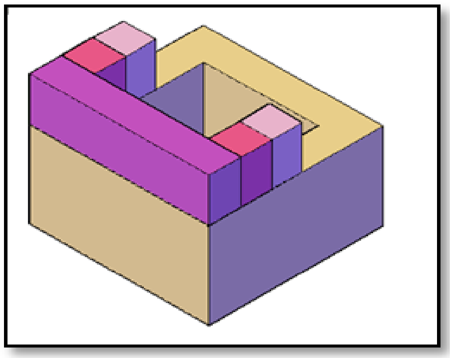

Fig. 5 3D vue of the upper part.

III. The Parametric Modelling

This research is classified as a simulation and parametric modelling research. Grasshopper software has been chosen as parametric modelling environment. We will see below the many stages of developing the algorithm mainly established by translating the mathematical lows. After developing the algorithm, we have used LADYBUG software which allowed us to evaluate the solar potential of the generating architectural model.

A. Modelling stages process

In modelling we have attempted to simplify the geometric aspect to reaching the desired objectives. So, we have worked with software commands witch use points as input. Our work was based on simple plane surface creation then we have extruded these surfaces according to the mathematic rules (the height).

The first stage: must be to define the planar dimensions of the courtyard. So simple commands have being used to generate the three-dimensional rectangular shape of the courtyard and the lower part. Which are defined according to two dimensions: the est-west width and the A30° width and by applying the mathematics lows.

The illustration below shows the transcription of the mathematics equations into a generative model algorithm. So we have to introduce only the red values to generate the courtyard three dimension solar shapes. The est-west width and the A30° width are defined according to the lot dimensions. As regards the courtyard height is defined according to the minimal solar height (in winter 21 December). So as it's shown on the illustration the output of this stage is the three-dimension courtyard and the lower part of the model house studied.

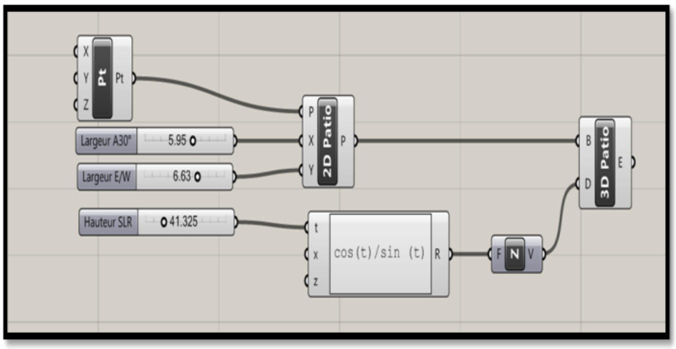

Fig. 6 Algorithm generating the three dimension courtyard

- **The second stage: (**generation of the upper part of the model): in this stage we have generated the three dimension shapes of the three parallelepiped rectangles of the upper part of the house model.

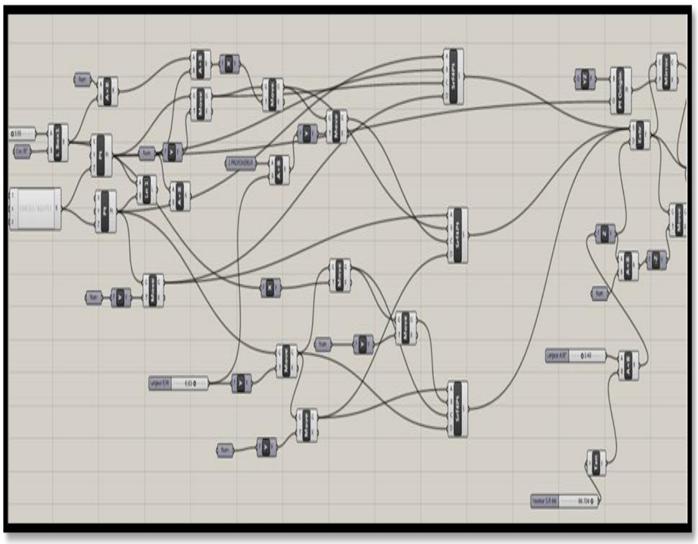

Fig. 7 Algorithm generating the three dimension upper part

IV. SIMULATION

All this work is intended to show how the combination of mathematical and digital methods makes the early stage architectural solar design more easy and simple. After algorithm development we have introduced the weather data as it's shown on fig.8 which has defined the location and the latitude. On the other hand, the site size is a very important factor in determining the courtyard solar potential. After developing the algorithm we have use ladybug plugin to generate solar radiation analysis. The first thing to do was to import the weather data which is an ewp. file then, visualise the solar path. After that we have to adjust simulation parameters.

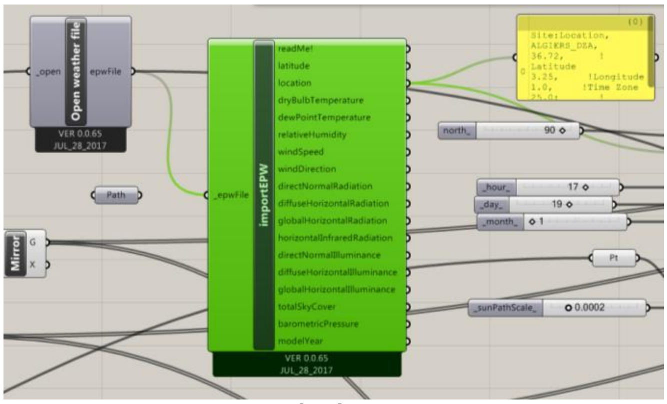

Fig. 8 Weather data component

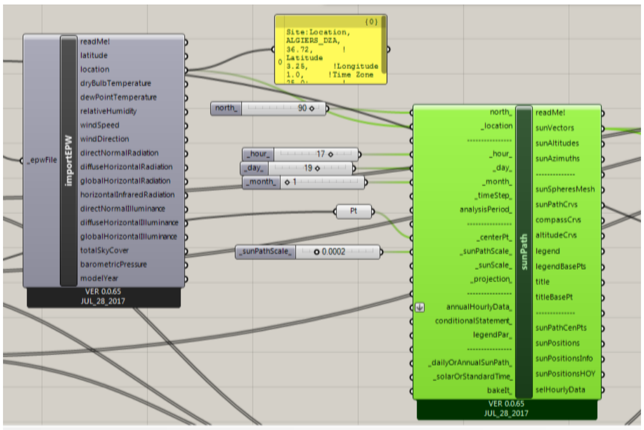

Fig. 9 the sun path component

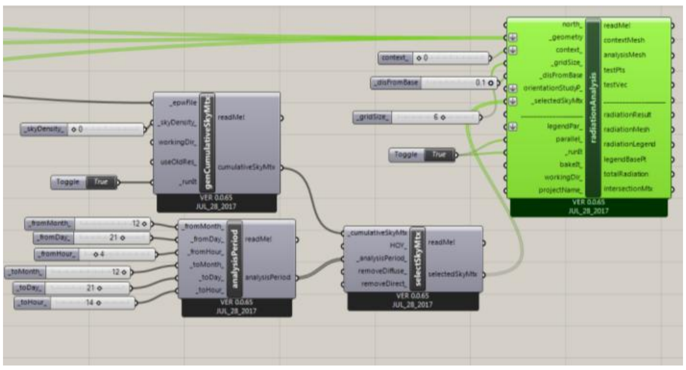

Fig. 10 Radiation analysis component

Then we have used Ladybug plugin in order to effect a simulation of the solar potential of the generated courtyard house model. It contains one tool tray with tools to adjust solar analyses. Rhino visualise the results simulation.

V. RESULTS DISCUSSION

Solar gains estimation

December 21: we note that the solar exposure time of the couryard house during the month of December is important and it falls between 10h and 14h. The highest amount of energy received is estimated 3.02 KWh/m2.

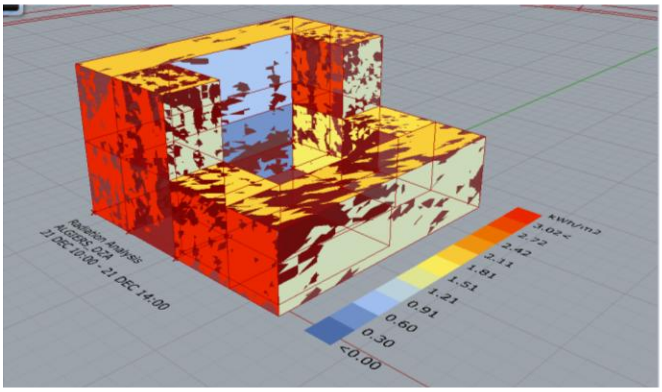

Fig. 11 December solar gains

June 21: The daily mean incident solar radiation is not important du to the solar position and height.

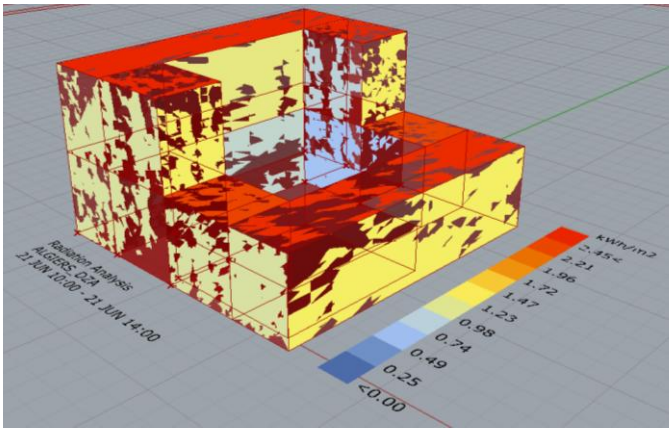

Fig. 12 June solar gains

VI. CONCLUSIONS

This study shows us the role of the parametric graphic modelling in generation architectural design and how it makes it easy and simple. So we can generate an architectural solar design by only introducing a set of inputs. So it merges the various stages of the architectural design process. The algorithm developer in this study represent a good tool for testing the solar potential of courtyard houses in early stage design in order to make the best design decisions.

On the other hand, the combination of three software: Grasshopper and Ladybug merge the modelling and the simulation process. So the simulation also becomes parametric. Indeed, the most complex and efficient algorithms are developed using the simplest geometric component which is point.

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