GENETIC ALGORTITHM ASSISTED DECISION MAKING FOR DATA BASED RESIDENCE ROOF TRUSS SYSTEM

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Abstract. The design of the truss system has its characteristics for different designers. Therefore, hiding knowledge between designers limits the design diversity of different truss system in the real world which will make building has a lower construction budgets has lower possibility to develop a more stable structural system. This research is about to design a shared database that stores different truss information and use the genetic algorithm to identify which system is the best solution under the pre-set restrictions by the user.
Genetic algorithm runs by the population pool which created by multiple solutions. The algorithm is developed from the natural principle that better genes will provide individuals better living situations under particular environment and genes will carry from parent to offspring. Ideally, each offspring should be genetically better than their parent due to the evolutional process otherwise the offspring will have the possibility to be eliminated by nature. By applying genetic algorithm, designers will have more confidence about whether the truss system is the best result according to gene pool.
In this research Algorithm Design and Analysis (ADA) method is applied. This method is used to reduce the repeatable analysis process and it could be used on a different scale just by applying the same algorithm. In this research genetic algorithm is used for analysing the best structural performance from the existing database. This research should return the best solution generated from the database and the output can be further input into structural analysis software such as Karamba to ensure the performance achieves reality standard. The advantage of this research is it provide structural diversity in structural design thus designers could learn from others designing and develop are better structure system. Besides, it provides a more reliable structure by cross-referencing from the existing designs. However, it still has some limitations such as the genetic algorithm requires a long period to process and it could reduce the ability of the designer's creativity. This research could be further implemented to larger scale design instead of residence building and sharing of other building information.

Keywords. Genetic Algorithm, data-based structure information, algorithm design and analysis, decision making in truss structure

1. Introduction: (Research context and motivations)

The new era of data visualisation makes the architecture industry absorb the idea of sharing information and reused it in a certain situation. However, instead of widely application on geological data processing, designers are ignoring or in some perspectives avoiding to share the real data in their project such as truss structural information. According to Epstein, the definition of knowledge is abstract and elusive, but it led to the arguing of what counts and what does not in the reality world (Epstein,1996). However, the sharing of the knowledge may well be constituted to be exploited at the intersection (Styhre, A 2011 p.51-52). This research is about to explore the possibility of how could algorithm been applied in databased roof truss structural generation in residence building by creating a database system that stores structural data and inputting into the genetic algorithm for generation. This process will return the best situation according to the reality limitations the user has previously set.

Genetic algorithms are inspired by nature and further being developed as optimising method to solve real-life issues. These algorithms are designed to solve complex problems and return results in an iterative manner. The algorithm runs by the population pool created by multiple solutions. Like in reality environment each generation has its own characteristic, this algorithm chooses the best result under the condition set by the user and returns the best generation when the criterion has been achieved (Shukla, Tiwari and Kala, 2010 p.59-64). By applying it in this research, the generation would not change the origin design dramatically therefore it will keep the design process more human designing instead of machinic processing.

Moreover, structural analysis is another focusing part of this research. By having the information on structural performance stored in the database, the algorithm will have a process domain to generate under a certain structural allowance. Therefore, structure performance information will indicate the stability of the structure. By doing so, the user will have more visual evidence of whether the generated truss system is applicable in reality.

This research is trying to find the connection between different truss designs and to show the evidence of the sharing of the truss system will not lose the personal characteristic. Oppositely, it will provide more diversities in truss system design and development which could allow more truss types to appear in the future. Moreover, this research showing how open-source databases could be widely applied not only in geological perspective but also in more detailed building information data sharing.

2. Research Aims

This research aims to identify the relationship between the algorithm generation and databased storing and to explore the application. Additionally, this research is to find the possibility of sharing structural information in the architecture industry and the benefits of different designers using the open-sourced structural database in truss system development.

3. Research Question(s)

The key research question is how to generate a new truss structure according to the existing structure information with the restriction the user set before the algorithm processing and how does the structural performance apply as a parameter in the genetic process. Moreover, whether the generated structural more reliable than the original design and what is the range that this method could enhance. Secondly, how the genetic algorithm applied in a structural generation and what are the advantages and limitations of this method.

4. Methodology

4.1. METHOD DESIGN

4.1.1 Design background

The existing design process for residential roof structure design is lack of evidential results to prove the structural reliability comparing with other options. Also, regarding the truss system as part of the design privacy, construction designers are unlikely to share their experience. Therefore, it is important to design a system which is capable to record all the existing truss structure system into a database and use the algorithm to assist the analysis process which helps the identification of whether the generated design is better than previous designs. This system should ideally reduce the design period for each structural engineer and make the truss system applied to the building more efficient and meet certain reality restrictions.

4.1.2 Method Inspiration

There is similar research has already been done previously on both roof optimisation or using genetic algorithm to assist the process. The application of multiple-constraint genetic algorithm used in house design accelerate and improve the quality of the result. Self-crossover operation is executed, which means only the fitness value under the constraint in chosen to carry out to the offspring generation. As a result, in one thousand generations the first one hundred schemes rapid change the arrangement patterns and after one thousand reproduction the offspring maintain certain characteristics (Narahara and Terzidis, 2006). This method provides the experience of using genetic algorithm in reality situation and rapid offspring pattern changed to increase the mutation diversity.

4.2. PROCESSING STEPS

The overall method to approach in this research is a software called Grasshopper which could export truss into either points or lines information and further be categorised in a plugin called Slingshot uses simplified SQL language to create a database system. This information inside the database will be further processed under genetic algorithm analysing. The implementation of GA requires elements such as the mutation operator, fitness function, selection operator and the offspring generation. The quality of the results is also influenced by the elements been input (Guerrero, Lera and Juiz, 2017 p113-135). Therefore, the algorithm will return the

best result from the genetic database with reaching the requirement users pre-set such as which truss system has better structural performance. Galapagos is also applied as genetic algorithm machine in Grasshopper which requires the input of generation variable and the fitness function. The setting of both variables and function allows the algorithm to recognise the best generation form the offspring generation pool under a limited mutation period.

5. Background Research/Literature review

5.1 LITERATURE REVIEW

This review is the preparation for the furthering research about in what ways can genetic algorithms be applied in residential roof structure analysis and generating. In the architecture industry, lack of sharing information about different truss systems limits the possibility and diversity of easier, material-saved and solid truss be applied across a variety of designers. Therefore, this research is about to provide a sharing database to combined with genetic algorithm analysis to generate the most suitable solution for the limitation the user has input and return it as a recommendation to the user which will not make the entire design process lack personality.
The focusing of this research is on how does the genetic algorithm generates the best solution and returns it to the user. Secondly, does the generated roof structure have the best performance under pre-set environment and further how could it be applied in residential buildings. Moreover, can the generated structure be re-test under structure analysis software such as Karamba in grasshopper.

5.1.1 Research Purpose

According to the research purpose, the research criteria in this research are developed. The sources are considered in this research is focusing on the introduction of the concepts of genetic algorithm and the reason for choosing this algorithm in this research. In addition, similar research about applying the genetic algorithm in architecture structure to reference and inspire how this research could be further develop based on previous experience. Furthermore, it provides reliable experimental evidence from other perspectives.

5.1.2 Genetic Algorithm

Genetic algorithms are inspired by nature and further being developed as optimising method to solve reality issues. It has been applied widely in building performance analysis to find the best generation of the design with the pre-set performance request. Software such as DesignBuilder has already applied the genetic algorithm to generation building detail generation to enhance the building performance. Therefore, it is important to explore the further ability of whether the genetic algorithm could be applied in other perspectives of the design process such as generating the truss system.

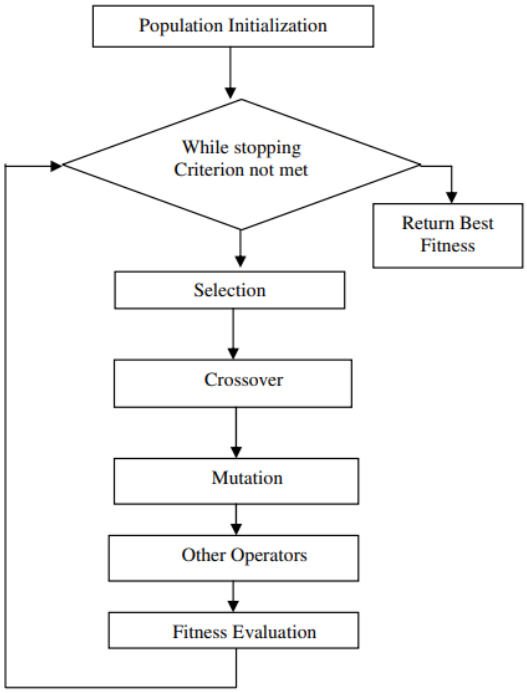

Figure1: The genetic algorithm diagram (Shukla, Tiwari and Kala, 2010)

5.1.2 Algorithmic Design and Analysis Method

Different truss system has different characteristics and also has different performance under pressure. Algorithmic Design and Analysis (ADA) is a method to automate the performance analysis. This method allows the computer to automate adjusting the existing modeling operations which contain the information required by the analysis tool. Moreover, it simplifies the process of analysis and able to analysis of a set of designs and allows analysing in different scale which makes it can be used in reality scale (Aguiar, Cardoso and Leitão, 2017 p35-36). This research could be referred to as an idea of how to generate all the structure information in the database and provide the foundation of how to further applied in genetic algorithm. Another article discussed the different approach of the rod behaviour. In addition, it provides the formulation of the lack of liner structure of the configuration space and provides structural evidence of how does the structural response to the existing truss roof based on Cosserat rod theory *(Miśkiewicz, 2018)*. According to figure3 and figure4 which provides structural evidence of how does difference truss structure could have the potential to affect the over structural performance. And provide evidence of why the research of optimise the best generation of the truss system is important.

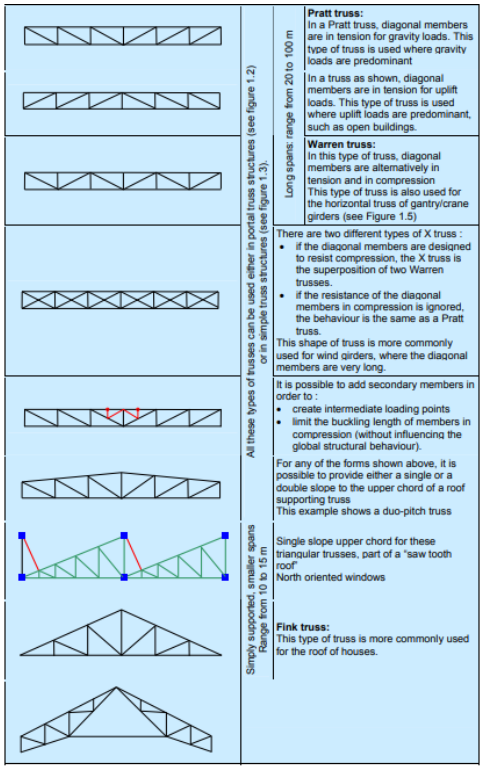

Figure2: Different Truss System (Träger and Mittal, n.d.)

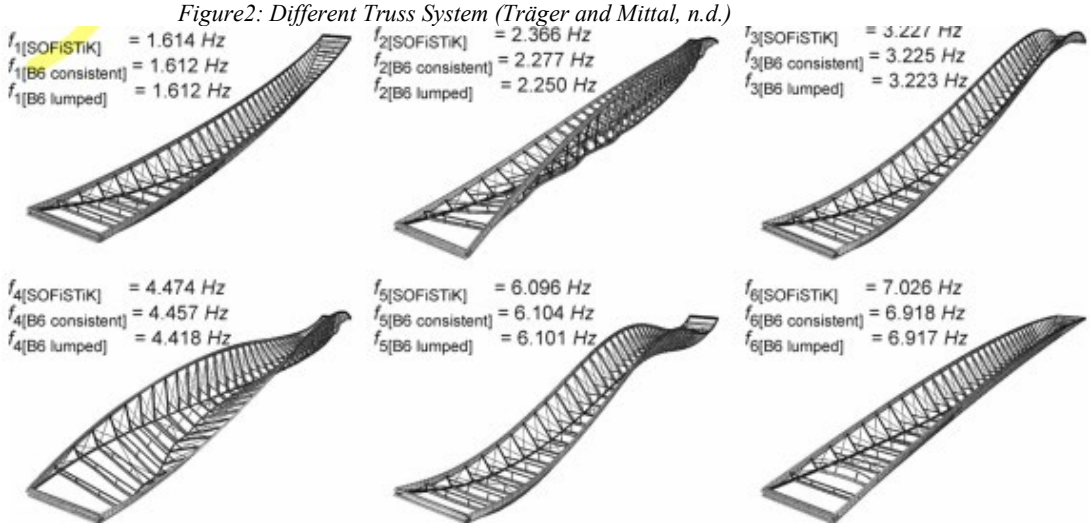

Figure3: Single lenticular girder, numeric result (Miśkiewicz, 2018)

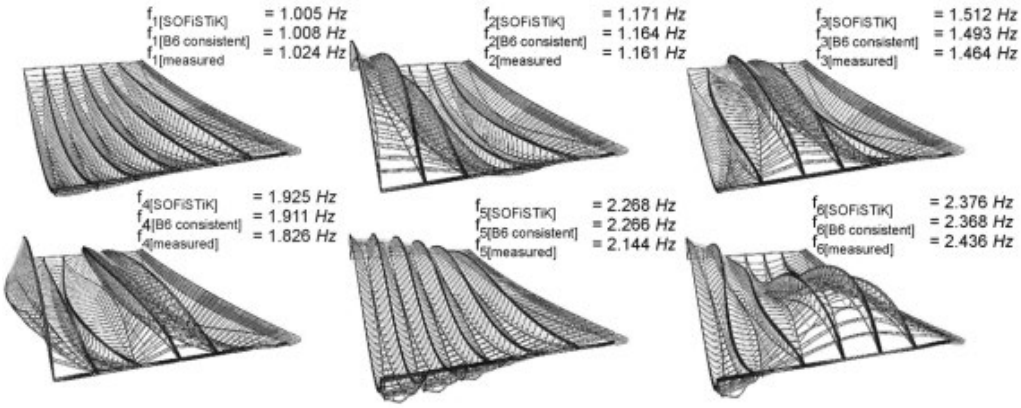

Figure4: Natural frequencies and modes of the roof (Miśkiewicz, 2018)

5.1.3 Roof Optimisation Using Algorithm Assisted

There is some case study that has already been done previously on both roof optimisation or using genetic algorithm to generate the best outcome of building design. The first research is about how multiple-constraint genetic algorithms could apply in housing design. In this research, it provides a refined genetic algorithm approach to accelerate the process by using self- crossover operation which only carries out the fitness genes and neglects the poor one (Narahara and Terzidis, 2006). However, it reduces the genetic diversity by eliminating the poor population and thus limits the possibility of gene mutation. (research about gene mutation) The second research is about how the genetic algorithm could apply to generate the roof design for the airport under solar analysis. By setting the objective such as minimise the energy consumption, provide sufficient natural daylight and using modular roof elements. Also, multiple climatic conditions for multiple space typologies are considered in this research. And after the generation, the result was put into energy analysis software again to ensure the accuracy of this research (Ensari, Kobaş, and Sucuoglu, 2017 p140-148). This research provides evidence of how to generate the roof pattern to find the best result under certain constraints in reality projects. Similarly, research has also been done in the stadium truss structure system and the results show the optimisation enhances the performance of the entire structural system and provides proves of how these methods could be applied in a curved truss system (Sofotasiou, Hughes and Ghani, 2017 p8). 5.1.4 Conclusion These previous researches provide this research solid foundation and structural perspective evidence. Also, according to the result in these researches, it provides mature methodologies for this research to begin with. However, there are still some perspective has not been tested in these researches which leave space for testing such as how does genetic algorithm could apply in structural information stored in database and applied on generating residence roof structure. Overall, based on these researches, my research will use multiple-constraint genetic algorithm and to generate the best result of certain constrain for the existing structural database to investigate how does the roof structure been changed under different optimisation stages.

6. Case Study

6.1 DESIGN WORKFLOW

In this research, all the data are processed in grasshopper to achieve the same data format and reduce the risk that crosses software data reference. The plugin called slingshot is used to categorise different truss structural data. Firstly, in this research seven types of truss system have been stored in the database which is generated in the grasshopper plugin called lunchbox. In this research, the structural difficulties are not considered, therefore there is any need to create a unique structure. After that, identify the attribute that different tables will have is important to this research due to easy reference and classify the key value that should be stored as key structural information or further appliance in genetic algorithm analysis.

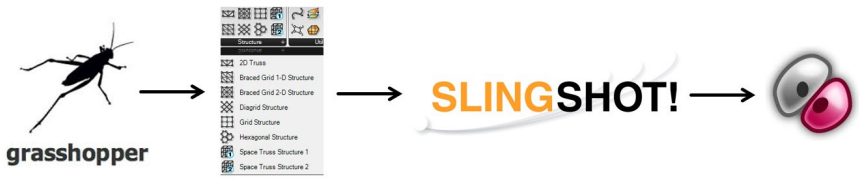

Figure5: The design workflow

6.2 DATABASE TABLE CREATION

In this research, the overall table is named Big brother which stored different trusses name and its structural id as the primary key for unique column value identification. Then the two types of reference tables in named truss1 to truss7 which stores all the truss information as x, y and z coordinate which will help the future algorithm analysis. Another table is named as structural performance which is the key table store all the structural performance data run in karamba and these values will be further applied as a fitness function in the genetic algorithm. Secondly, this research is trying to focus on the appliance of the genetic algorithm. Galapagos is used due to the limitation of the research period and it has the function of quickly set up all the variables that the genetic algorithm required and generated the result that the user could easily understand.

In the first stage of creating a database table, the relational model system is applied due to the wide appliance in business information database creation due to it has the advantage of quick element identification and lookup. Also, this method requires to minimise the elements inside the table. If elements in one table need more detailed information or it required to refer to the unique table for the decreasing of the difficulties in searching and wasting analysis in useless information, the new table will be created and link with the original table to reduce the storage and make the system easier to understand. Using the link method between the different table and applied by SQL language it will make the table easier to process and can set

particular restriction to decrease the unnecessary data.

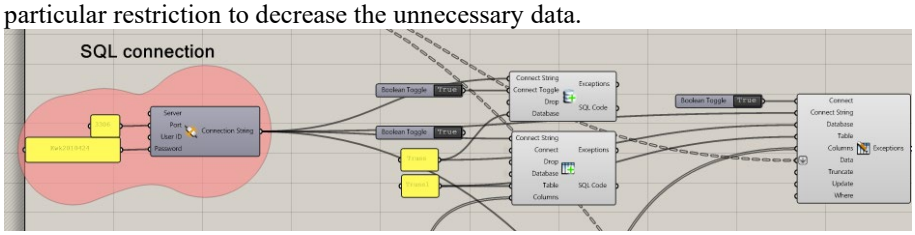

Figure6: The Establish of SQL Database

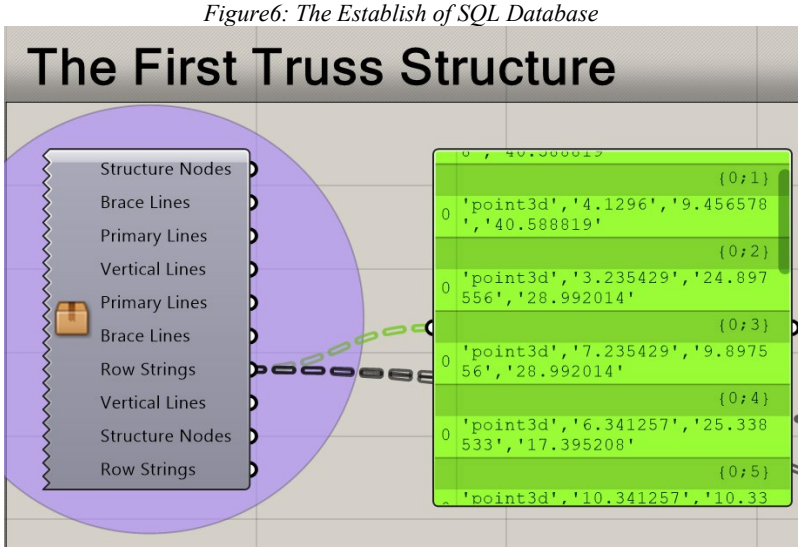

Figure7: Categorising Data into Different Table

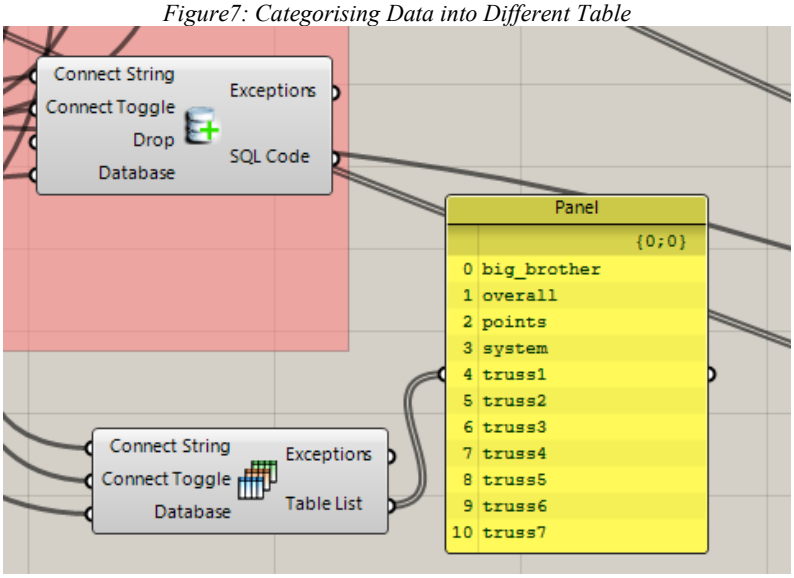

Figure8: Search of Different Table

6.3 STRUCTURAL PERFORMANCE ANALYSIS

The structure analysis is important in this research as it links to both the SQL database from the existing database and acting as a trigger for the genetic algorithm generating. The genetic algorithm is processed by defining whether the structural performance reaches the user setting including the result will be visualised in Grasshopper components for the user to further reference. The legend output has been used by converting into text format and find the subtraction of the first list item and the first item in the reverse list. The positive value and the negative values will be the same due to it only represents the direction of the force. To find the average of the difference will return the first values and could be input into Galapagos as the fitness function.

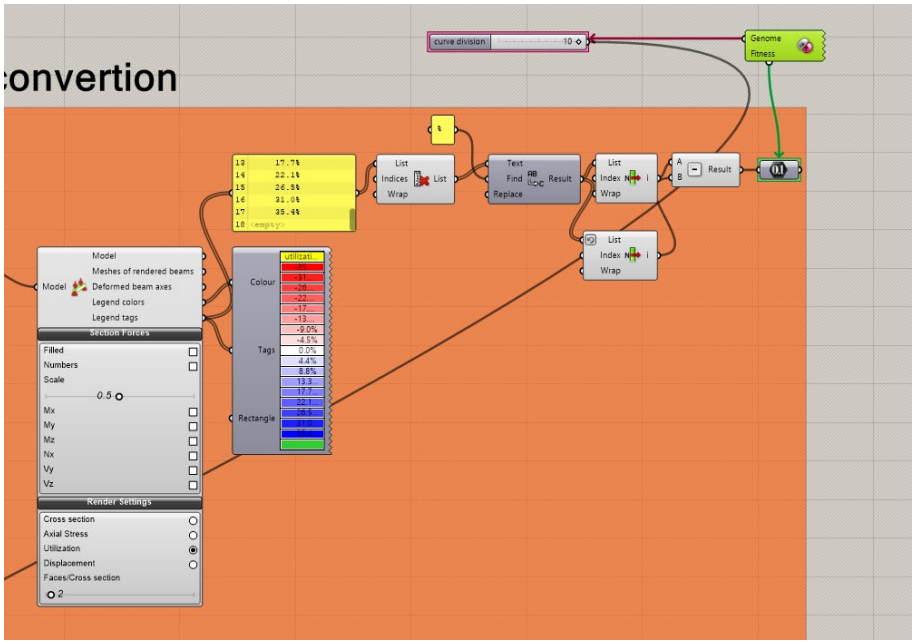

Figure9: Structural Analysis in Karamba

6.4 GENETIC ALGORITHM PROCESSING

The third stage is focusing on how the genetic algorithm is applied in this research and analysis of the generation process. Galapagos is been chosen to exploring the possibility of applying the genetic algorithm in the generation of the truss system. During the process, the result of generation does show that this plugin has the ability to change the number of nodes in the truss and therefore to change its structural performance. Karamba is used as a structural analysis tool to identify the best range of utilisation for the truss structure. Also, it will regard as the fitness function in Galapagos, therefore the structural performance is linked with the genetic algorithm and make the result more reliable to the real situation. According to the result return in Galapagos, it shows the range of possibility of the tested structural truss in graphic and the user has the ability to set what range of values they looking for and the processing period to decrease the risk of over-processing will cause the clash of

the software. Furthermore, it allows inserting new generations to increase the diversity of the population and makes the generation has better results.

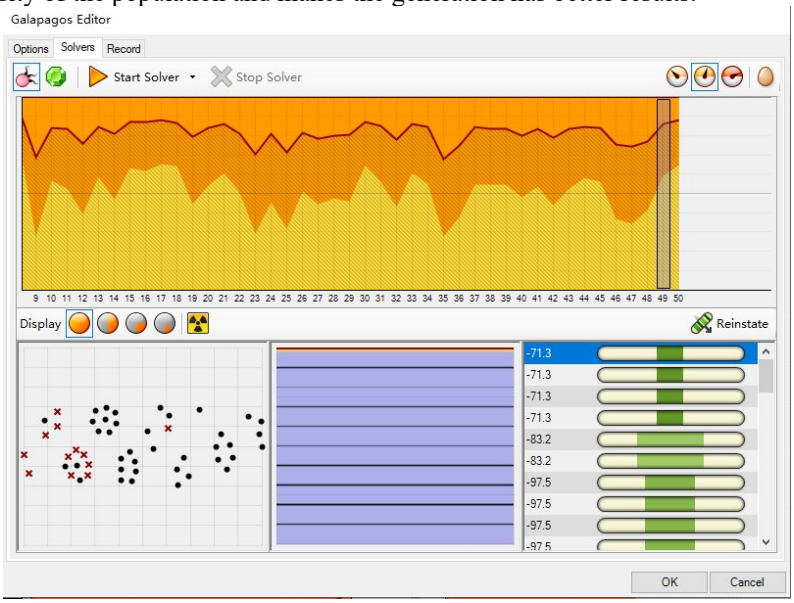

Figure10: The genetic algorithm process in Galapagos

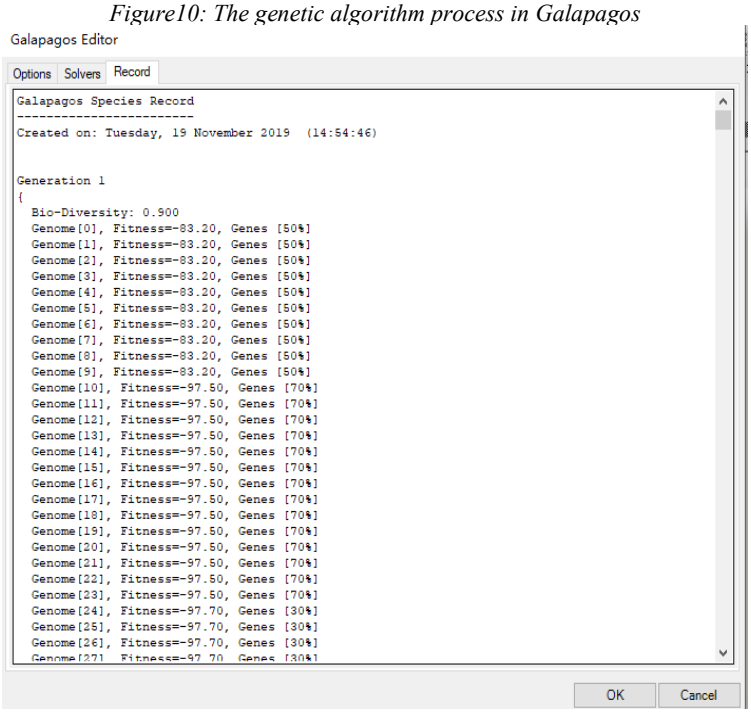

Figure11: The Generation Gene Pool in Galapagos

6.5 RESULT ANALYSING

The result gets in this research is the genetic algorithm has the ability to generate the truss structural system and provide the best population with the pre-set restrictions. Also, the organised database has the ability to store the information and spilled the information as the user required. However, this research does not link the genetic algorithm with the SQL well due to the software restrictions and also Slingshot does not have the function of providing ideally information instead of providing in point and reconstruction it. Therefore, in this research, it is barely to find the relation of how genetic algorithm could link with the genetic algorithm and what will it can achieve.

6.6 RESEARCH EVALUATION

This research explores the potential of how database information could be further applied in a structural deformation. Although it does not succeed to achieve what has previously looking for, it still provides evidently information on how algorithm assisted structurally could be achieved to enhance the structural performance and generate under certain restrictions. It opens a gate of how information beside geological information could be stored for the further appliance in the architecture industry and to improve the performance in structural perspective

7. Discussion (evaluation and significance)

According to the result collected in this research, although it does not achieve what had purposed due to the database could not link with the Galapagos in Grasshopper. However, this research does show the potential of applying the genetic algorithm on generating truss system and also the possibility of applying the database information to run the generator. More importantly, it provides a version of how categorised information could be useful for further data utilisation.
The significance of this research is the exploration of how databased information could be applied in future architecture designing. This research may change the way that architects regard their design as privacy and turn the attitude into willing to share their design information for generating more reliable and reasonable designs according to others' experience. The limitation of this research is in this stage it still exploring how to link the database with the algorithm and how to minimise the effect of genetic algorithm and the different plugin will take longer to process and require the extra workforce to store this information and convert into database information.

8. Conclusion

According to the results found in this research, ideally, the SQL database should store all the information and further be generated in a genetic algorithm engine. However, Galapagos only allows input as variable sliders for the generation number and it does not provide full control to the user to create under certain circumstances. The result lost its accuracy and mislead the direction of processing. Also, this research only focusses on how it generates in the simple construction environment and has not considered the application under the reality environment. Galapagos does not have the function of outputting any result back to the user, therefore it is impossible to further generate and input to structural analysis software such as

Karamba. Then it lost the reliability for the user to understand whether the output result is the best solution. These results provide a piece of overall information and confidence in the finding could help in the architecture industry. Different from the previous purpose, the current only stays on the stage of input construction information, the database has not been online and has not shown the pretention of solving the problem in reality situation.

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