Dynamo, Grasshopper and their plugins: User opinion, usability and dissemination of knowledge

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Abstract. Parametric design applications have specific applications for different user profiles. Considering the two main tools available, this research seeks to identify the diffusion and usability of Dynamo (Autodesk) and Grasshopper (Robert McNeel) software. First, a systematic review of the bibliography in journals was carried out, where it was found that 85.25% of these users use Grasshopper, while 13.1% use Dynamo, and 1.6% use both tools. Next, qualitative research was carried out in the applications' discussion forums, where opinions and experiences of the community were obtained. Grasshopper proved capable of processing more complex geometries with a large number of modeling and design analysis plugins. Dynamo, on the other hand, proved to be better integrated with BIM systems, as well as being widely used in design process optimization and documentation generation.

Keywords: Design, Parametric, Architecture, Dynamo, Grasshopper.

1 Introduction

Parametric Design tools have evolved far beyond their origins in software development and product design companies, gradually gaining ground in construction project offices as well. These applications facilitate the optimization of repetitive and manual processes, including tasks such as modeling of complex structures and energy performance analysis, while also providing greater exclusivity in the design of architecture and facades. While these tools do offer adaptability to the individual methods of each designer, they come with a certain level of algorithmic complexity and a steep learning curve, thus requiring investment to learn new scripting languages. According to Oxman (2006), in the face of these technological knowledge barriers, the designer sometimes ends up limiting himself to CAD (Computer Aided Design) or BIM (Building Information Modeling) software, in which it is possible to work with a hybrid system between parameter modeling and

polygonal modeling, but still with algorithmic limitations. One of the difficulties of using CAD software, according to Hudson (2010), is that the designer is usually focused only on the final result of modeling, and not necessarily on how the model can be constructed and modified. While traditional CAD typically does not leave traces of the model development process, parametric design employing Visual Programming Language, on the other hand, features an open code with a logical structure that can be readily identified and modified in a collaborative form (Oxman & Gu, 2015, Mineiro & Magalhães, 2019).

For a good design of these characteristics, it's necessary a combination of data flow, clear identification of elements, partitioning of problems into subproblems; use of the same function to solve several problems, algorithmic thinking and associative geometries (Woodbury, 2010; Oxman, 2006). For Aish and Hanna (2017), parametric design application developers should also consider students as key users, so that they can develop parametric design skills while still in academia. Aish and Hanna (2017) also consider that the clarity of the main functions in the software interface encourages the user to discover their tools without needing much help, and this factor tends to encourage them to continue deepening their knowledge in the software, otherwise they will be subject to migrate to another system where they identify less complexity.

Within the CSA (Civil, Structural and Architectural) industry, two parametric design applications stand out. One of them is Grasshopper, which is a plugin developed in 2007 that uses the modeling application Rhinoceros as a graphic visualization platform, both developed by Robert McNeel & Associated (RMA, 2023). The next, Dynamo, is a plugin developed by Autodesk (2023) in 2011, and it is integrated within the BIM Revit platform. Both of these tools have previously been the focus of comparative studies conducted by at least three other authors. Zardo, Silva and Mussi (2017) carried out a qualitative study to obtain comparative data on the diffusion and usability of Grasshopper and Dynamo in CSA from 2011 to 2017, where they observe that Grasshopper was used in 87.5% of the works, and Dynamo in 12.5% of the works, when it comes to parametric building façade developments. In another comparative study, Brito, Silva and Checcucci (2020), developed the same exact model in both software programs, and noticed that Grasshopper was faster at processing data when modifying parameters in the model. Finally, Wortmann, Cichoka, and Waibel (2022) conducted international research by interviewing parametric designers in the field of CSA considering the use of simulation-based optimization tools for architecture and engineering. Among the existing available tools, Cichoka, and Waibel realized that Grasshopper emerged as the most widely utilized, with 90 participants, mainly for building energy and topology optimization, while Dynamo was used by 13, mainly for space planning and building optimization.

By identifying user needs, specific tool characteristics, and the current state of academic research, the aim of this study is to conduct a comparative analysis of the diffusion and usability of the two primary parametric design applications employed by CSA professionals.

2 Methodologies

The methodology consists of two stages. In the first stage, it was made a systematic review of the bibliography from academic and scientific articles to identify the usability of the applications "Dynamo" and "Grasshopper" by professionals of the CSA. In the second step, it was applied a methodology based on the research conducted by Zardo, Silva and Mussi (2017), which involves a qualitative analysis of user comments in the official community forums of the applications under study to identify descriptions and opinions from users of the same applications.

2.1 Systematic Review of the Bibliography

In the first step, a systematic literature review was conducted to identify the predominant use of parametric design applications by authors of articles who are professionals and researchers in the field of CSA. For this, we first sought to identify journals and databases that contain articles related to parametric design in CSA. For the knowledge of these research tools, the Portal of Periodicals of the “Coordenação de Aperfeiçoamento de Pessoal de Nível Superior” (CAPES) was used, in which a search was made from the strings "parametric AND architecture", where 67 results were obtained. From these, 10 journals and databases were identified to be used in the search for articles in which parametric design applications are used in CSA, these being: DOAJ; ScienceDirect Journals; SAGE Premier; MDPI; DergiPark; Springer Online Journals; IOPscience; DataCite; CumInCAD; SciELO.

For the search of articles, keywords were used from the search strings: Grasshopper; Dynamo; parametric; architecture and; design, together with Boolean operators according to the search tools of each journal. To obtain more updated data, a time frame from 2019 to 2022 was used, with languages in English, Portuguese and Spanish, generating a sum of 469 search results. All results were first analyzed by title, and those related to the theme were also analyzed prior to the abstract, to confirm their relationship to the following criteria: architectural modeling, such as geometries, layouts, facades, structures, roofs and area and feasibility studies; related to architectural analysis, such as material performance, thermal performance, acoustic performance, flow analysis and analysis of historic buildings; the generation of BIM documentation, project information and process optimization. The pre-selected articles were then analyzed in the body of the

text, with the same criteria, in their methodologies with a search for the keywords "Grasshopper" and "Dynamo", to identify the specific application of the tools.

2.2 Review in the Official App's Forums

The second step of the methodology consists of a survey with an exploratory qualitative approach, carried out on the official forums of the developers of the applications. The aim of this method is to collect opinions and experiences of CSA professionals about the two main parametric design plugins. To do so, comments on McNeel (Grasshopper) forums were analyzed using the search term "Dynamo" and then searched for the term "Grasshopper" on the DynamoBIM (2023) forum. This inversion in search terms allowed finding comments with common relationships between both applications, bringing comparative information about the usability and performance of each.

For the selection of comments, the same themes addressed in the literature review method were considered. Comments from novice users who were still unfamiliar with the software were not included, except in relation to perceptions about the interface of the applications. The search was carried out backwards in time, starting from the most recent comments to previous comments. When reaching comments prior to 2019, it was observed that many issues and problems described had already been corrected in subsequent software updates, which could result in situations that had already been resolved. Consequently, the searches were halted at that juncture, and the time frame from 2022 to 2019 was delimited. Under these conditions, 19 comments were selected in the Dynamo forum and 19 in the Grasshopper forum, which show the preferences of using parametric designers' applications, bringing comparisons, potentialities and weaknesses in the applications of certain tasks. The comments were classified according to groups of subjects identified between authors Woodbury (2010), Oxman (2006) and Aish and Hanna (2017), such as process and flow performance, intuitive interface, associative geometries, data processing, intuitive interface. More classification categories were created according to subjects collected for further analysis of pros and cons of each application, from the user's point of view.

3 Results

The data obtained from the methodologies described in this paper were also analyzed in two stages. The first stage involved the information obtained from the systematic literature review, while the second stage involved the analysis of descriptions gathered from the official forums of the applications.

3.1 Results and Discussions of the Systematic Review of the Bibliography

The search in the journals and databases resulted in 122 papers that met all the criteria described in the methodology, and in each one the application used by the author was identified.

Table 1. Journals and databases

JOURNAL / DATABASE	RESULTS OBTAINED	USED ARTICLES
DOAJ	19	4
ScienceDirect Journals	30	18
SAGE Premier	66	9
MDPI	27	18
DergiPark	49	2
Springer Online Journals	66	8
IOPscience	55	22
DataCite	9	3
CumInCAD	110	34
SciELO	38	4
Total	469	122

Source**:** Authors, 2023.

Among the papers analyzed, Grasshopper and Dynamo were used as tools for complex modeling of architectural structures made of wood and steel for architectural designs of buildings and pavilions. For such, many of the authors used plugins to facilitate specific design processes, such as "Kangaroo" for Grasshopper and "Dynashape" for Dynamo mainly to help modeling roof truss structures. Another significant topic concerns the optimization of the design process, which involves the integration of parametric applications with BIM modelling software such as Revit and Archicad, using plugins such as "Rhino Inside Revit", "Rhynamo" and "Archicad Live Connection" for Rhino/Grasshopper data insertion. This enables the establishment of scripting routines tailored for repetitive tasks, like organizing or randomizing construction details, which can be subsequently applied in future projects. Furthermore, Dynamo permits the formulation of scripting routines for construction documentation, facilitating the evolution of parametric modeling while seamlessly integrating Revit's inherent material

textures, descriptions, and quantitative aspects.

Another plugin that has been gaining ground is VisualARQ for Rhinoceros, which can also operate associated with Grasshopper providing tools for preliminary algorithmic studies, and also allows modeling and documentation for construction within Rhinoceros itself.

In particular, when it comes to analyzing solar energy performance in buildings, 95% of authors gave preference to Grasshopper over Dynamo (Table 1). This is largely due to the impressive performance of its "Honey Bee" and “Ladybug” plugins, which are able to process large amounts of data with accuracy and stability. In addition to solar energy analysis, Grasshopper is a very useful tool for thermal studies, including the analysis of façade materials and geometries, as well as testing different window sizes and their position in a building for optimal energy performance. Among the 122 papers analyzed (Figure 1), Grasshopper was used in 85.25% of the papers analyzed, while Dynamo was applied in 13.1% of the papers, and in 1.6% of the papers, authors used both applications.

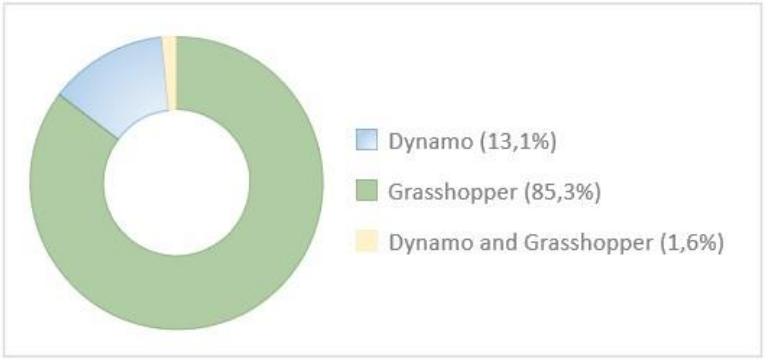

Figure 1. Usability of Dynamo and Grasshopper. Source: Authors, 2023

As an example of the combined use of both tools within the same project, it was utilized Dynamo for the numerical sequencing of the building structure, while Grasshopper was employed for the organic modeling of architectural elements. Dynamo proved to be proficient in BIM integrated parametric modeling, space planning and in producing construction documentation. On the other hand, Grasshopper is more widely distributed among the community and is known for its strength in specific performance analysis, as it has more plugins and native tools options. The collected data were classified into 3 categories according to the main topics identified in the bibliographic review, namely parametric analysis of constructions, parametric modeling of architecture and construction documentation.

Grasshopper has the most usage records for solar energy performance analysis and optimization for the building design process. These involve high-performance and sustainable buildings, user thermal comfort, smart

algorithm-based solutions for design-build, such as wall modulation or roof structures for agile and cheaper construction. Another relevant application is for contemporary architectural façade design, with constant use for kinetic aluminum façades and biomimetic façades. Visual comfort analysis involves luminosity and field of view of windows and doors (Table 1).

Table 1. Categories of use of Dynamo and Grasshopper

	Predominance of use by categories	Dynamo	Grasshopper	Both	Total
Parametric building analysis	Analysis of acoustic performance		1		1
	Analysis of circulation flow	1	1		2
	Analysis of constructive material		2		2
	Analysis of energy efficiency	3	4		7
	Analysis of environmental performance		2		2
	Analysis of seismic energy		1		1
	Analysis of solar energy performance	1	19		20
	Analysis of visual comfort		4		4
	Analysis of wind performance		6		6
	Subtotal				36,9%
Parametric architecture modeling	Modeling and performance of Façade		10		10
	Modeling for architectural heritage conservation	5	5		10
	Modeling of architectural building	1	2		3
	Modeling of architectural structure	1	9		10
	Modeling of massing studies		3		3
	Design process of complex geometries	1	8		9
	Educational process		2	1	3
	Optimization for building design process		19	1	20
	Subtotal				55,7%
Construction documentation	Digital fabrication	1	2		3
	BIM integrated project	2	4		6
	Subtotal				7,4%
	Total	16	104	2	122

Source**:** Authors, 2023.

There is a demand among **CSA** parametric designers to model complex geometries and surfaces with large amounts of data for surface modeling and optimization, which are mostly not feasible in CAD or BIM software (Figure 1).

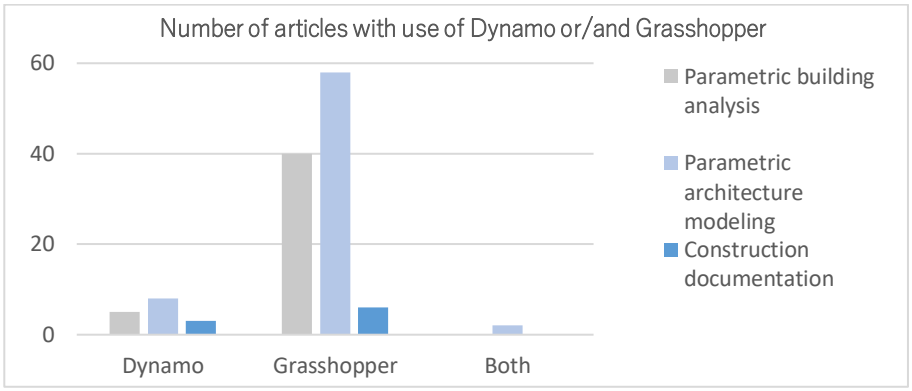

Figure 1. Predominance of use of Dynamo and Grasshopper**.** Source**:** Authors, 2023

The locations of the institutes that published the articles were recorded, so that it was possible to find the global trend towards parametric design for **CSA**. Some articles were written by more than one institution in different countries and therefore more than one country may be involved in the same study. The countries were categorized by the following regions: South America (Brazil, Chile); North America (Canada, USA); North Africa (Egypt); Western Europe (Austria, Denmark, Germany, Finland, Greece, Italy, Netherlands, Norway, Portugal, Scotland, Spain, Sweden, Switzerland, UK); Eastern Europe (Hungary, Poland, Russia, Serbia, Slovakia, Turkey); Western Asia (India, Iran, Qatar, Saudi Arabia, UAE); Eastern Asia (China, Indonesia, Singapore, South Korea, Taiwan); Oceania (Australia) (Figure 2).

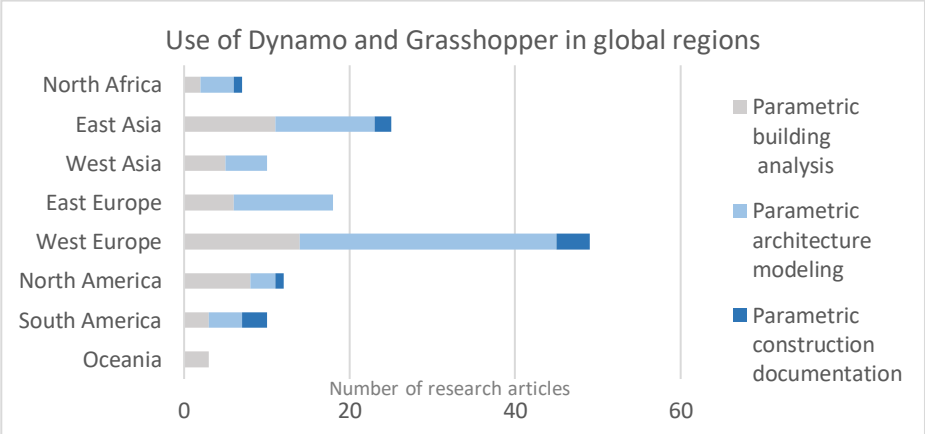

Figure 2. Diffusion of Dynamo and Grasshopper worldwide**.** Source**:** Authors, 2023

Western Europe shows a predominance in the use of parametric models for AEC, with the main focus on architectural modeling of buildings, pavilions, facades and structural projects with complex and organic geometries. It is

notable that Grasshopper has gained a prominent position for parametric design around the world, especially in countries such as China, which is investing heavily in high-performance buildings, and Italy, which focuses on preserving historical building data. Other countries that have shown greater adoption of parametric design are Brazil, Turkey, the USA, Egypt, Spain and the UK.

3.2 Results and Discussions of the Analysis in the Official Forums of the Applications

In the search for comments in the official Dynamo and Grasshopper forums, the experiences and opinions of 28 users were extracted, which generated some comparative results, where parametric designers show in their points of view the best uses for each application. To mention the user's opinions, they were numerically named from 1 to 28. As an example of geometry modeling, User #27 suggests that Grasshopper may be the most suitable application to make a Voronoi diagram, a geometric system that can be applied for example in modeling facades and roofs, as well as in urban analysis. Regarding the process and workflow, User #2 suggests that Grasshopper's geometry processing has better performance compared to Dynamo, which is in agreement with Users #8 and #16, who mention the ability to process large amounts of data without losing workability and with less processing time.

In terms of application usage profiles, User #12 perceives Dynamo as being primarily oriented towards construction, while Grasshopper is utilized by product designers and programmers too, making it more versatile and widely used. User #5 suggests that detailed documentation processes for construction are still lacking in Grasshopper. This aspect is in line with the point of view of Autodesk programmer Zach Kron, who suggests that Dynamo was developed to operate with greater involvement with construction and its processes, allowing it to manipulate components and construction systems in a more comprehensive way in BIM, unlike Grasshopper, which is based solely on CAD (Dynamobim, 2014). User #3 opines that Grasshopper has a higher learning curve, which makes it more difficult to implement in project offices.

Another factor that can impact the choice of parametric design software is cost. Rhinoceros/Grasshopper offers users a 90-day free trial period, after which a license must be purchased. It is possible to purchase a lifetime business account or a student/teacher account at a discount of 80% off the full license price. Meanwhile, Revit/Dynamo offers a 30-day free trial period, after which you must purchase a monthly, annual or three-year license. One of Autodesk's advantages is that it offers students the possibility to purchase a free Revit/Dynamo student license, which is valid for one year and can be renewed. A summary of the comments is available in Table 2 and is divided into categories.

Table 2. Predominance of the use of Dynamo and Grasshopper

	User analytics and experiences	Dynamo	Grasshopper
Processes and flows	Better processing and calculation of geometries		✓
	Improved performance in distribution of parking spaces		✓
	Better workflow for heavy and complex geometries		✓
	Better flexibility and stability		✓
	More efficient to automate the process to the fullest	✓	
	The best at processing exercises of lighter geometries	✓	
	Allows the creation of custom workflows for processes	✓	
Plugins	Has more plugins		✓
	Stability in the processing of plugins		✓
	Ability to handle different types of geometric constraints		✓
BIM and data	Processes Revit data well by Rhino-inside-Revit		✓
	Allows connection to Archicad Live Connection		✓
	Allows identification of elements in Revit	✓	
	Best documentation data manipulation capabilities	✓	
	Preparation of schedules, revisions, spreadsheets and annotations	✓	
	More efficient in managing High Dimension Data	✓	
Users	More job opportunities in construction	✓	
	Larger community		✓
Interface	Most beautiful and friendly interface		✓
	Shows the runtime of each node		✓
	Easier to find tools	✓	
	Allows to "expand" lists and content trees without extra panels	✓	
	Has transparent Viewport option for model viewing	✓	
	Allows textual programming next to elements from Codeblocks	✓	
Geometry	More flexible for work with geometry intersection		✓
	More efficient to make a Voronoi diagram		✓
	Curvature and parameterization of lines on a curved surface		✓
Analysis	Better operability to create isovista functions		✓
	Accuracy in sun exposure time at one point		✓

Source: Authors, 2023

The cost of Revit's annual license for professionals is significantly higher than that of Rhinoceros, which may partly explain the higher number of Grasshopper adopters. Even so, it was noticed in this search that in recent years more people have started using Revit, and with that, there has also been an increase in the number of proficient Grasshopper users seeking to learn Dynamo in order to integrate their models into the BIM system more effectively. However, in 2021, the release of the "Rhino Inside Revit" plugin changed this scenario, as it allows these users to bring Rhinoceros models directly into Revit, along with their parameters, without relying on Dynamo. This resulted in many users turning their attention back to Grasshopper.

4 Discussion

It is evident that the predominant advantages identified in Dynamo are the direct interaction with BIM and the ability to document parametric elements for project execution. With this, CSA offices that require less geometry complexity and have a need for greater agility in construction documentation can benefit from exploiting Dynamo's facilities. Meanwhile, the potential of Grasshopper to optimize construction projects can be exploited through integration with BIM software, with plugins such as "Rhino Inside Revit". It is noticeable that there is a larger community of users making use of Grasshopper, mainly for the development of geometries that need to process elements with a large amount of information without losing performance and with greater availability of auxiliary plugins, which may be one of the justifications for having greater diffusion among parametric designers. The existence of a more extensive user community and the availability of a greater variety of plugins in Grasshopper can be also attributed to the fact that this software has been on the market since 2007. On the other hand, Dynamo is relatively more recent, with its initial experimental applications dating back to 2011 but experiencing significant expansion only since 2013 (Dynamobim, 2014).

Despite the existence of a wide variety of plugins, both Dynamo and Grasshopper allow most 3D modeling solutions to be developed without the need for external plugins, as they have very complete toolkits. There is a growing trend among design offices in search of quick solutions, as well as an increase in the demand for professionals with parametric design skills, which brings a debate about the new roles that architects, engineers and even urban planners are about to assume in the near future. It is understood that these professionals still need to face a cultural barrier about learning new languages to design, and this can be mitigated with a contact with these tools still during the academic period.

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