Energy simulation and analysis of accessory dwelling unit: an evolutionary approach

Journal Title
XX(X):3–8

DOI: 10.1177/ToBeAssigned
www.sagepub.com/
SAGE

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Abstract

****Needs refining and reducing, IJAC word count limit for abstract is 150, and much of my abstract was adapted into my intro- will update with final draft at end of quarter, working findings in****

The United States is experiencing an unprecedented housing crisis, resulting in a rising population of unhoused peoples and the inability to become a homeowner or to even afford monthly rent in many cities. Solutions to this dilemma are neither straightforward nor definite. Seattle, Washington; Portland, Oregon; and Vancouver, British Columbia are exploring the use of accessory dwelling units (ADUs) as one method to combat surging housing prices. Use of ADUs is an effective means of increasing housing density without replacing single family housing zones with new multi family residential construction. Additionally, ADUs are often designed to be rented, generating supplementary income for the homeowner. Ten detached ADU (or DADU) designs are pre-approved by the City of Seattle and are freely available online to entice homeowners. However, a 2019 city survey shows that there are calls for an increased focus on sustainability and cost. This research intends to explore whether the use of genetic algorithms to optimize DADU windows increases building performance and further encourages construction. The proposed methodology begins by reading example site data from the city of Seattle including building and vegetation context and rental/land prices from Seattle GIS and Zillow, respectively. Next, a genetic algorithm explores the design space for a viable floor plan solution based on a fitness function. This fitness function evaluates individual designs according to predefined traits. Traits to evaluate include window to wall ratio, insulation depth/type, ventilation strategy, and shading technique. Locating the correct combination of traits to minimize (or maximize) which results in a higher performance DADU is the desired outcome. Resulting designs will be analyzed and compared via energy performance simulation.

Keywords

Genetic algorithm, ADU, optimization, simulation, EUI, grasshopper, galapagos

Introduction

The United States is amidst an unprecedented housing crisis, stemming from parallel crises and outside issues, such as the neoliberal cuts to social benefits spending and increasing privatization of essentially every aspect of American life. The result is a rising population of unhoused peoples and the inability for many to become a homeowner or to even afford minimum monthly rent in many cities. Solutions to this dilemma are neither straightforward nor definite. However, as designers and architects, this problem can only be addressed at the symptom-level, while advocating at the root cause.

Seattle, Washington; Portland, Oregon; and Vancouver, British Columbia are exploring the use of accessory dwelling units (ADUs) as one method to combat surging housing prices. Use of ADUs is an effective means of increasing housing density without replacing single family housing zones with new multi family residential construction. Additionally, ADUs are often designed to be rented, generating supplementary income for the homeowner. Historically, homeowners associations and other local organizations have been resistant to any proposed density increases through zoning or other means. However, Seattle and the other previously mentioned cities in the Pacific Northwest have succeeded in allowing for the construction of ADUs in recent decades, with these groups beginning to see ADUs as a positive. ADUs

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offer many positives beyond an increased housing supply such as a path for homeowners to generate income and accommodating households with multigenerational or caretaking needs.

Beginning in 2014, the City of Seattle has moved to increase production of ADUs through various resolutions and legislation, removing barriers to entry and highlighting strategies for encouragement. In late 2019, a call for detached ADU (or DADU) designs was issued to designers. As a result, ten DADU designs were pre-approved by the City of Seattle and are available online to entice homeowners.The pre-approved designs are free, but still require standard permitting fees to be paid for approval and come with one significant downside of many other pre-designed structures- a lack of contextual design and individualization. This one-size-fits-all approach can have drastic effects upon energy consumption, reducing the appeal of such an investment. Further, these designs do not offer the scalability or energy efficiency that an ADU designed specifically per site offers.

Coincidentally, a November 2019 city survey shows that there are calls for an increased focus on sustainability and cost in the construction of ADUs[1]. This survey was positioned before the official call for submissions was broadcast. ’Low cost’ was the top ranked criteria with 48 percent of responses listing ’very important’, followed by ’green building’ being ranked similarly at 46 percent. Other suggestions sourced from surveyed respondents included low environmental costs, site specific considerations, and predictability.

Methods

Design constraints and decisions

The ability to show users the estimated annual energy consumption of a new construction DADU would have a major impact on driving ADU construction demand based on survey responses noted. Using an optimization method such as a genetic algorithm can allow architects to arrive at the most effective design solution on a site specific basis while *predictably* minimizing both environmental and financial costs. This research explores the use of a genetic solver to find the optimal design solution of window-to-wall ratios (WWR) for a simple DADU form resulting in the lowest EUI value. Three sites in similar neighborhoods in the city of Seattle were selected based on a combination of proximity and slight density variance. The tool adheres to land use code to find estimated buildable area for a DADU on each site, creates a simple box-like form representing the DADU and then varies the WWR value for each of the four walls. A genetic solver plugin is then allowed to vary these ratios to find an optimal solution using a process largely mimicking natural genetic processes. Finally, an energy model is created from each individual iteration to find an estimate for overall EUI. From here, the process loops until an optimal solution (in this case, via minimizing EUI) is found.

Site locations were chosen through the use of the *ADUniverse* tool, developed by the University of Washington researchers at the eScience Institute[2]. ADUniverse allows for users to investigate the possibility of constructing an ADU through a map-based user interface. Site data was extracted from the city of Seattle's GIS website, converted into an AutoCAD .DWG file, and then imported into and extruded within Rhino. Trees are represented via spherical meshes created using a Grasshopper script and placed where necessary based on the .DWG file. These trees vary in opaque triangulated mesh coverage to simulate foliage cover and to more accurately cast shadows. Lot lines surrounding each house are fed into the Grasshopper definition, coupled with constraints in line with the current Seattle Land Use Code. Such constraints are as follows:

Assembly	Notes	R-Value	Path 1 (Insulation)	Path 2 (Framing)
Air Film	Interior	0.68	0.68	0.68
Gypsum Board	1/2”	0.45	0.45	0.45
Vapor Barrier		0	0	0
Fiberglass Insulation		3.5	28	-
2” x 8” Wood Stud	16” o.c.	14.68	-	14.68
Air Gap	1”	1	1	1
Wood Cladding	3/4”	0.93	0.93	0.93
Air Film	Exterior	0.17	0.17	0.17
		R-Total:	31.23	17.91
			x 85%	*x 15%*
			26.5455	2.6865
		Wall R-Value:	29.232	
		Wall U-Value:	0.0342	

Table 1. Wall Assembly R- and U-Values

Energy simulation and analysis

Honeybee, part of the open-source Ladybug Tools plugin suite for Grasshopper and Rhino, has become an industry standard for daylighting simulation and energy modeling within architecture and engineering.

Genetic algorithm

Results

Conclusion

Looking forward, moving on from the Grasshopper platform gives the benefit of non-reliance on developers to maintain the software in which the tool depends. Creation of such a tool in a singular programming language (in this case Python) further offers the ability to quickly and easily run the tool on a high variance of devices. In turn, this theoretically increases the rate of adoption by lowering the requirement to use the design tool. Additionally, Python is used within Rhino/Grasshopper (or a flavor thereof), provides many useful math and geometry libraries, and has options for injection into a web app (Flask and Django). Utilizing Galapagos and Grasshopper offers a sandbox environment to begin to understand genetic algorithms and to arrive at tangible design solutions faster than using a home-brewed algorithm. Galapagos offers many fewer input parameters and a much narrower scope in which to define the fitness function. In its out-of-the-box form, Galapagos only accepts number sliders as input and can only optimize integers and floats- in reality, there is not means in which to define a true fitness function, only numerical values to target.

User ability to override window sizing and placement- feedback loop?

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Acknowledgements

This class file was developed by Sunrise Setting Ltd, Brixham, Devon, UK.

Website: http://www.sunrise-setting.co.uk

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Declaration of conflicting interests

The author declares that there is no conflict of interest.

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