Assessing the Utility of Procedural Modeling for the Urban Planning Discipline:

CityEngine and Missing Middle Housing

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Title: Assessing the Utility of Procedural Modeling for the Urban Planning Discipline: CityEngine and Missing Middle Housing

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Abstract

In recent years, procedural modeling techniques have been introduced to the urban planning discipline. By enabling the quick generation of design alternatives, these methods have the potential to expedite the public participation process. In this study, we explore ArcGIS CityEngine, an Esri procedural modeling software, and its application for depicting new missing middle housing developments in San Luis Obispo, California. Missing middle housing is an abstract planning concept and the public may benefit from 3D visualizations of the typology contextualized within their own neighborhood. To this end, we procedurally model two existing missing middle developments in San Luis Obispo and transfer them to three alternative contexts. Our team consists of two planning students with no programming background, granting us a relevant perspective on the experience for planning professionals. Through this exercise, we determined that procedural modeling can accelerate the design process when applied to a fitting scenario after the initial training period is complete.

Keywords: procedural modeling, CityEngine, Esri, ArcGIS, computer-generated architecture, parametric, urban planning, urban design, missing middle housing

Assessing the Utility of Procedural Modeling for the Urban Planning Discipline: CityEngine and Missing Middle Housing

Three-dimensional procedural modeling (PM) is a powerful tool for urban planners, allowing them to create detailed models of proposed developments quickly and accurately. California is in a housing crisis in which the available stock and affordability of housing is unsustainable. Furthermore, the state lacks diversity in the typologies of available housing, lacking adequate quantities of multifamily, duplexes, fourplexes, and townhomes. In recent years this type of multi-unit housing has been designated *missing middle housing:* housing that can supply density somewhere between single-family homes and apartment buildings. This project explores the viability of PM techniques for the development of these much-needed housing typologies. The applications of Esri's CityEngine (CE) software in the modeling of realistic proposed and existing developments, the ability to incorporate the software into the planning process, and the communication of plans to relevant stakeholders will all be explored.

Through the procedural modeling of *missing middle housing*, we will explore the suitability of this typology within a local context. To this end, we will select two extant missing middle projects within San Luis Obispo, attempt to recreate these developments with PM, and apply the models to vacant lots within the city. This methodology was selected because it provides a clear pathway for planning professionals to develop expressive models for the public without formulating an entirely new set of designs from scratch. Furthermore, the process of recreating an existing design through PM differs from replication using traditional methods. Exploring the practicality of this method will provide insight into the applications of CE for non-design professionals.

Through this experience, we will be able to better estimate the applicability of this software for local planning departments in their public participation efforts. Since we are neophytes to programming but have studied planning for several years, our user experience is representative of someone approaching the application for the first time from exclusively a planning background.

Literature Review

In this literature review, the current and potential role that procedural modeling (PM) and ESRI's CityEngine (CE) software play in urban planning is investigated. While urban planning entities and urban designers using rule-based PM are still in the minority, the existing body of literature suggests a promising path for this visualization method. Systematic analysis of literature clarifies the potentials, and the gaps in the current practice of PM. First, we present a definition for PM, followed by a brief history of CE; then we discuss the applications of PM in urban planning in four categories: a) Visualization, b) Urban Studies, c) Urban Design, d) Planning Support System (PSS).

Procedural Modeling

Procedural modeling (PM) is a modeling technique that generates content through a code segment or algorithm (Ebert et al., 2003). Introduced in the 1980s, PM has since been incorporated into several consumer software suites, including Blender, Houdini, and CityEngine (CE). Since PM relies upon code segments and parametric inputs, it can emulate complex generative processes more closely than manual methods, such as the production of terrain, plants, water, buildings, road networks, and urban areas (Smelik et al., 2014). At larger scales, PM can produce 3D models more efficiently than manual techniques by minimizing the marginal effort required to generate additional objects. Furthermore, PM enables rapid alterations to entire models, as different scenarios can be generated instantaneously by adjusting a chosen parameter (Badwi et. al., 2022). Finally, PM works within an analytical framework that extends functionality beyond manual modeling techniques to broader research applications.

Figure 1

Procedurally generated Pompeii model

Note: In this use case, a model of Pompeii was generated in CityEngine from historic building footprints. From Pascal Müller, Peter Wonka, Simon Haegler, Andreas Ulmer, and Luc Van Gool. (2006). Procedural modeling of buildings. ACM Trans. Graph. 25, 3 (July 2006), 614–623. Retrieved from https://doi-org.ezproxy.lib.calpoly.edu/10.1145/1141911.1141931

Many large-scale urban planning projects are the result of years or decades of work. There is a need for planning processes that utilize flexible frameworks to account for changes to conditions such as zoning code, or urban form, over time. Drafting or even editing large-scale urban environments is costly and time-consuming with conventional drafting and modeling programs. PM has proven itself to be useful to increase accuracy, decrease production time, and add an analytical dimension to 3D modeling. PM creates 3D geometries and textures using rules (procedures) instead of labor-intensive manual modeling. Procedural models can allow for database amplification, meaning large scenes can be created from a smaller set of rules in real-time (Luo, He, Liu 2016, Radies 2013). In addition, PM allows for universal design patterns, or best practices in design from a building to a neighborhood, to be formalized in codes. Because of this capability, the film and game industries have delved into PM techniques to create unique urban environments that are complex and imageable, while organized and cohesive. One of the leading programs in this field is ESRI's ArcGIS CityEngine.

Background

CityEngine's public debut was at the 2001 SIGGRAPH conference, an annual conference on computer graphics (Parish & Mueller, 2001). Until 2007 the program was developed at ETH Zürich, the top-ranking technology university in Switzerland. In 2007 Dr. Pascal Mueller, the original author of the program, founded Procedural Inc. In 2011 ESRI (Environmental Systems Research Institute) acquired Procedural Inc to integrate the software into the ArcGIS suite. Today, the features of the program have expanded greatly and even include support for virtual reality viewing of generated urban environments.

Literature

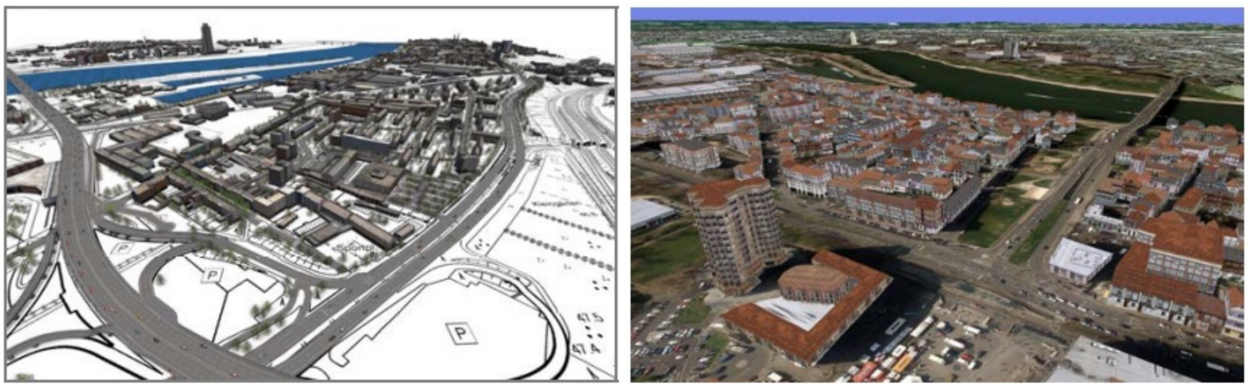
The applications of procedural modeling (PM) in urban planning, with a program such as CityEngine (CE), can be conceptualized in four categories:

Visualization of Existing Large-Scale Urban Environments. Simply the accurate visualization of existing conditions. CE can be used by municipalities and planning entities to quickly 3D model a city.

Visualization of urban spaces is one of the more intuitive aspects of the CE software. This is in part due to the accessible nature of the tools of the application and the ease in combining existing GIS (Geographic Information Systems) data. In a research project by Schaller, Ertac, Freller, Mattos, & Rajcevic (2015) CE is applied for the modeling of the Mülheim South district in Cologne, Germany. They attempted to use the technology to simulate future scenarios for this area of the city with various degrees of sustainable and innovative development. They created a *status quo* scenario and future scenarios that are based on development of GIS data including environmental, energy, and mobility data to promote sustainability. They found that using CE and available data they were able to model traffic, water supply and disposal, energy consumption, noise, and environmental quality. A by-product of this comparative study between the existing and potential scenario was an accurate and lively model of a neighborhood in Cologne, Germany seen in Figure 2.

Figure 2

CityEngine 3D visualization of Mülheim South



Note: This visualization accurately depicts the *status quo* scenario of Mülheim South with facades. From Schaller, J., Ertac, O., Freller, S., Mattos, C., & Rajcevic, Z. (2015). Geodesign apps and 3D modelling with CityEngine for the city of tomorrow. Digital Landscape Architecture, 59-70. Retrieved from https://gispoint.de/fileadmin/user_upload/paper_gis_open/DLA_2015/537555006.pdf

The team gave each building a custom rule to generate its façade to reflect its real-life counterpart most accurately. Due to the size of the district, they procedurally modeled every building in three different Level of Details (LOD). As this would have taken a lot of time to do individually, they used an automated method in areas where the building facades followed repeatable patterns. The result was a true to life visualization of Mülheim South that could be analyzed to best apply measures of sustainability to the city.

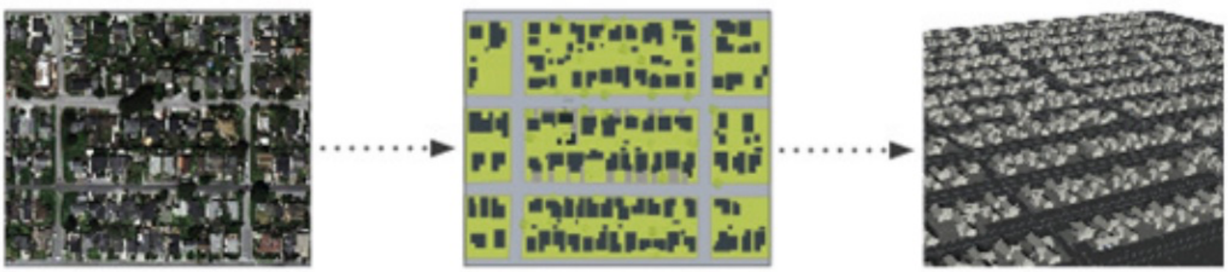
Urban Studies and Extraction of Pattern Languages. Patterns can be found in environments that can be synthesized into design principles and then into code. This code can then be applied to other areas in a process we refer to as reverse design.

Design codes represent a set of design and planning regulations including zoning rules, density, building and street typologies, building height and materials and rules (Schirmer, P., &

Kawagishi, N. 2011). Design codes construct a conceptual vision of urban settings and a set of instructions on how to get there. Urban studies that use design codes and then apply these rules to code is a process we refer to as reverse design. A case study in the San Francisco Bay Area by Kunze, Dyllong, Halatsch, Waddell, & Schmitt (2012) effectively demonstrates this process using CE. The process followed these steps: surveying quantitative design parameters, developing design rules and guidelines and then using that to generate building patterns, and synthesizing various building patterns in one parametric urban model. This design process is visualized in Figure 3.

Figure 3

Design process of converting housing building patterns into a procedural model



Note: The quantitative process of extracting a pattern language from a single-family neighborhood. 1, survey the quantitative design parameters. 2, develop design rules and guidelines to generate building patterns. 3, synthesize into a parametric urban model. From Kunze, A., Dyllong, J., Halatsch, J., Waddell, P., & Schmitt, G. (2012). Parametric Building Typologies for San Francisco Bay Area: A conceptual framework for the Implementation of design code building typologies towards a parametric procedural city model. Retrieved from https://www.researchgate.net/publication/242329728_Parametric_building_typologies_for_San_Francisco_Bay_Area_A_conceptual_framework_for_the_implementation_of_design_code_building_typologies_towards_a_parametric_procedural_city_model

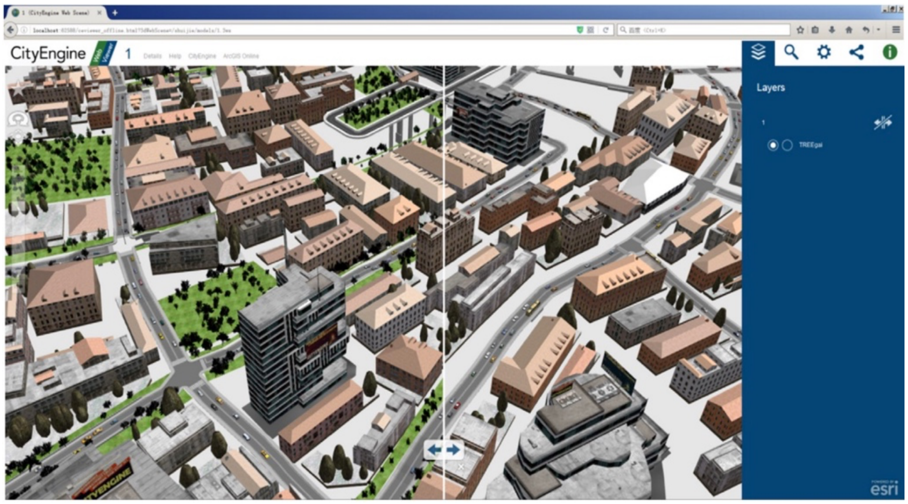
This workflow used zoning regulations as well as form-based codes to create a CGA building typology catalogue which was used to 3D model parts of the San Francisco Bay Area. The presented work was a conceptual framework and serves as an example for using digital design codes for procedural modeling of cities.

Urban Design. Due to the nature of PM, one can quickly change and compare different design scenarios.

The comparison of design scenarios in a side-by-side manner can quickly provide direction for a decision-making body. Alternative plan concepts can be found as a step in many forms of planning documents. A research paper by Luo, He & Liu (2016) highlights a case study in which CE was utilized to support protective planning of a historical district in Nanning, China. Water Street was the focus of the study, an old urban district that retained strong historical characteristics, e.g., arcade buildings, red-brick walls, sloped roofs. However, the area was threatened by encroaching high-rise development that could have obstructed essential views. CE was used to model development in surrounding neighborhoods with more appropriate heights and public greenspace. The process of the case study revealed strengths of CE and instances where additional outside modeling was necessary. The case study covered about one square mile and used a mix of CE modeling and other methods. Modeling done outside of CE was only for key landmark features such as a historic community center. The project team was able to compare a scenario that respected historical development patterns to one of more typical high-rise development. Figure 4 depicts the two scenarios side-by-side.

Figure 4

CityEngine 3D visualization of Water Street in Nanning, China



Note: The scene shown is two scenarios– existing and high density. They can be switched between using a sliding bar in the ArcGIS online web viewer. From Luo, Y., He, J., & Liu, Y. (2016). A rule-based city modeling method for supporting District Protective Planning. Sustainable Cities and Society, 28, 277–286. Retrieved from https://doi.org/10.1016/j.scs.2016.10.003

It became clear which scenario would alter the fabric of the neighborhood and which found a good middle ground. CE modeled both scenarios accurately and quickly and was an excellent tool for the planning team in the area's potential urban design.

Planning Support System (PSS). CE has the potential to help guide real-world planning and policy decisions. The software easily allows the public to visualize and interact with design scenarios.

In many cases, the use of 3D modeling is crucial to help planners investigate the world in true perspective and make informed decisions. One such case from Guo, Sun, Qin, WaiWong, SingWong, WaiYeung, & QipengShen (2017) emphasized the importance of 3D modeling in a feasibility report on increasing maximum floor area ratio (FAR) and building heights for 21 sites in Hong Kong. Hong Kong faces many challenges in terms of land supply and therefore the Civil Engineering Development Department (CEDD) is very particular in all decisions related to land use. The CEDD had already explored feasibility by assessing environmental impacts, infrastructure capacity, and public consultation using 2D GIS. They found that although they could quantify the impact of different development scenarios, an informed decision anywhere proved to be difficult without 3D modeling and spatial analysis. They were particularly concerned with how increasing the maximum FAR (Floor Area Ratio) and building heights would impact the skyline, sightlines, and shadows of the sites. The project team and the CEDD were then able to let the decision-making body and public assess the factors of increased FARs and building heights. They used CE as a planning support system to make effective decisions for each of the 21 sites' appropriate densities.

Conclusion

Using rule-based procedural modeling (PM) in the field of planning has increased accuracy, speed, efficiency, and flexibility in design (Guo, et al. 2017; Kunze, et al. 2012; Luo, He, Liu 2016; Schaller, et al. 2015). Each case study highlights various aspects of the potential for CE in visualization, urban study, urban design, and as a planning support system for decision making. The workflow of the PM process using Esri's ArcGIS CityEngine is intuitive, comes at a relatively low cost, and promotes public participation through compatibility with other Esri applications. CE has its place in many scales and functions of planning and appears to be a future direction for the integration of planning and practice.

Methodology

This study commenced with a literature review on the application of procedural modeling (PM) for city planning projects. In it we explored the history of PM and of the Esri software CityEngine (CE). We used four categories to evaluate PM applications in city planning: Visualization, Urban Studies, Urban Design, and as a Planning Support System. Through analyzing several use cases, we refined our concept of procedurally modeling existing buildings to evaluate their suitability in new contexts. The literature review worked as proof of concept allowing us to use existing demonstrations to guide our inquiry.

After reviewing the literature, our team spent several months learning to work with the CGA (computer-generated architecture) programing language. CE ships with official Esri tutorials, with accompanying instructions online and video resources. We completed these training courses to gain an overall understanding of the program. As the project developed, we consulted the CGA documentation and posts on the official CE forum for answers to specific questions.

The existing sites were selected as examples of *missing middle housing* projects approved by the city of San Luis Obispo and inhabited by residents. The sites are compliant with local design ordinances and thus fit into the existing context. Neither site was selected to optimize compatibility with the alternative sites nor for any standout aesthetic/functional value. The Iron and Oak and Righetti site was selected partly because it was recently approved and is still being built as of 2022. This site, if anything, reflects how the city of San Luis Obispo would want its new missing middle housing to look.

Alternative sites for the models were selected from our dataset of vacant lots throughout the City of San Luis Obispo. Sites were chosen to explore a variety of settings found in mid-sized cities. For example, the Foothill Boulevard and Fuller Road sites represent typical suburban infill sites in single-family neighborhoods, whereas the site at Broad Street and Tank Farm Road could accommodate a large planned-unit development. Furthermore, the Broad and Tank Farm site is surrounded by big-box commercial buildings and open space.

To model the existing sites, our team visited them both in-person to document their overall design and scale. Floor plans were also consulted from the developers' websites to find their real-life dimensions. Photo documentation was collected during multiple site visits, which guided the modeling process. With this information two distinct CGA rule files were composed corresponding to the two existing housing developments.

Existing Project Models

Iron and Oak at Righetti. Iron and Oak is a master planned community on Hatchery Lane. It is located to the south of downtown off Broad Street, near the Marigold Shopping Center and the San Luis Obispo County Regional Airport. The condominium complex is comprised of a mix of new duplexes and triplexes with a distinctive farmhouse Americana architectural design. It is developed with interior automobile circulation in mind and access to off street garage parking for all units. As of 2022, all homes in the development have been sold while construction is still underway. The development can be seen in Figures 5 and 6.

Figure 5

Rendering of the Iron and Oak Master Planned Community

Note: Rendering reflects current conditions. From, Righetti by Ambient Communities. NewHomeSource. (2023). Retrieved from https://www.newhomesource.com/community/ca/san-luis-obispo/r-righetti-by-ambient-communities/156492

Figure 6

Street View of the Iron and Oak Master Planned Community

Note: Development shown under construction. From, Google. (n.d.-a). [Tiburon Way]. Retrieved January 4, 2023, from https://goo.gl/maps/Ej5jZZJHYRfiRYP86

Windermere Condominiums. The Windermere Condominiums are located at the corner of Los Osos Valley Road and Oceanaire Drive in southwest San Luis Obispo. It is near Laguna Lake Park, the Irish Hills Natural Reserve, and the Laguna Village Shopping Center. The complex is comprised of a mix of two-bedroom and three-bedroom condominiums built between

1980 and 1982. Each unit shares a wall with at least one other unit forming a central courtyard with two open grassy knolls split by the main entrance road and shared parking. The rear of the units also has automobile access and an alley that connects to garages. The architecture is unique for the central coast and creates a European feel. The development can be seen in Figures 7 and 8.

Figure 7

View from the Windemere Condominiums Inner Courtyard

Note: Interior circulation and greenspace is shown. From, Zillow Properties.1106 Oceanaire Drive, San Luis obispo, CA 93405. Zillow Inc. (2021). Retrieved from https://www.zillow.com/homedetails/1106-Oceanaire-Dr-San-Luis-Obispo-CA-93405/2079352900_zpid/

Figure 8

Entrance to the Windemere Condominiums

Note: Also shown is rear garage access. From, Google. (n.d.-a). [Windemere Condominiums]. Retrieved January 4, 2023, from https://goo.gl/maps/b9iexgZQiSquRgC69

Alternative Settings

Broad Street & Tank Farm Road. APN: 053-421-003. The first alternative setting is located at the corner of Broad Street and Tank Farm Road in south San Luis Obispo. It is near the Damon-Garcia Sports Complex, the Marigold Shopping Center, and the San Luis Obispo County Regional Airport. The site is 8.96 acres of undeveloped land. Most of the level and developable part of the land is situated near the intersection of Broad Street and Tank Farm Road. The site is less than a mile from the existing Iron Oak at Righetti project. The site was chosen as an alternative setting due to its undeveloped status, its proximity to already successful housing developments, and ease of access. The larger site gives freedom in the design of how the project models can be oriented without the impediments of existing development. South San Luis Obispo has seen many new developments in the past decade giving context for further development on the site. A bird's eye view of the site can be seen in Figure 9.

Figure 9

Broad Street & Tank Farm Road

Note: Birdseye view of the first alternative setting. From, Google Earth, earth.google.com/web/.

Fuller Road. APN: 053-411-014. The site on Fuller Road is located half a block off Broad Street in south San Luis Obispo. It is adjacent to the EA French Park, the Marigold Shopping Center, and the San Luis Obispo County Regional Airport. The site is around 2.55 acres of flat and mostly undeveloped land surrounded by single-family homes. The site's existing structures are used for light storage by the current owner. The site is less than a mile from the existing Iron and Oak at Righetti project. The site on Fuller Road was chosen as an alternative setting due to its mostly undeveloped status, its proximity to already successful housing developments, and its potential to be classified as an infill development or up-zoning project. The acreage is most like the two existing projects while providing an opportunity to show what is possible on smaller lots. In addition, denser communities within existing single-family neighborhoods fulfill one of the key goals of the *missing middle housing* concept. A bird's eye view of the site can be seen in Figure 10.

Figure 10

Fuller Road

Note: Birdseye view of the second alternative setting. From, Google Earth, earth.google.com/web/.

Foothill Boulevard & Rosita Street. APN: 052-011-052. The site on Foothill Boulevard and Rosita Street is located is west San Luis Obispo. It is near the Bishop Peak Foothill Trailhead, Throop Park, and bus transit that connects to the California Polytechnic University. The site is around 1.8 acres of existing single-family homes forming the entire block contained by Foothill Blvd, Rosita St, Patricia Dr, and Cerro Romualdo. The site is surrounded by the Foothill neighborhood of primarily single-family homes. The site is split into 12 parcels, two of which have particularly low lot coverage creating large backyards for two residences. The site on Foothill Boulevard and Rosita Street was chosen as an alternative site due to its low existing lot coverage, its proximity to a successful housing development, its potential to be classified as an infill development or up-zoning project, and its proximity to existing public transportation. With the smallest acreage of the three-alternative settings, this site will create challenges regarding the layout and design while showing what is possible on smaller lots. In addition, the redevelopment of existing single-family homes with connectivity to an important transit corridor fulfills multiple goals of the *missing middle housing* concept. A bird's eye view of the site can be seen in Figure 11.

Figure 11

Foothill Boulevard & Rosita Street

Note: Birdseye view of the third alternative setting. From, Google Earth, earth.google.com/web/.

Design

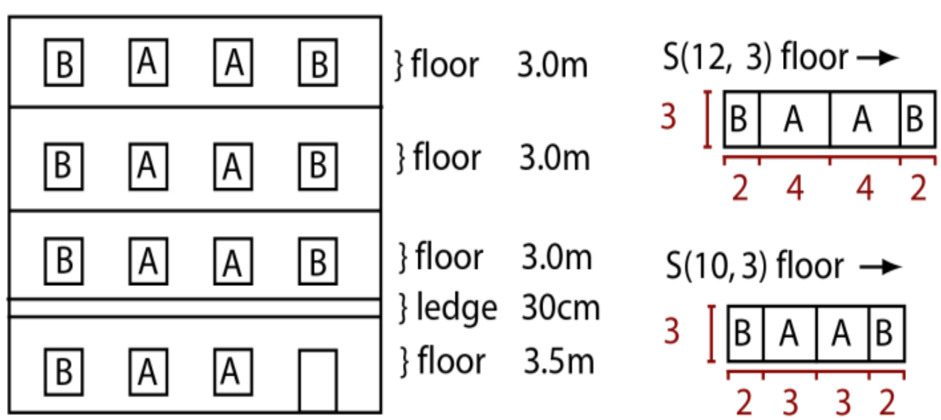
Design Process

The process of converting real buildings into procedural elements required in-depth research and experimentation with the CityEngine (CE) software. The process can be divided into three distinct steps: a) documentation, b) writing the CGA rule(s), and c) applying the code to alternative settings.

Documentation. The first element of design was defining the CE coding standards that our team should follow. Standard methods for writing CGA rule files were drawn from official Esri documentation. These methods allowed our team to follow a well-known path to generating existing buildings in this procedural setting. Figure 12 from official ESRI documentation illustrates a basic façade design from which our methodology was based.

Figure 12

Façade Design Using CGA Splits



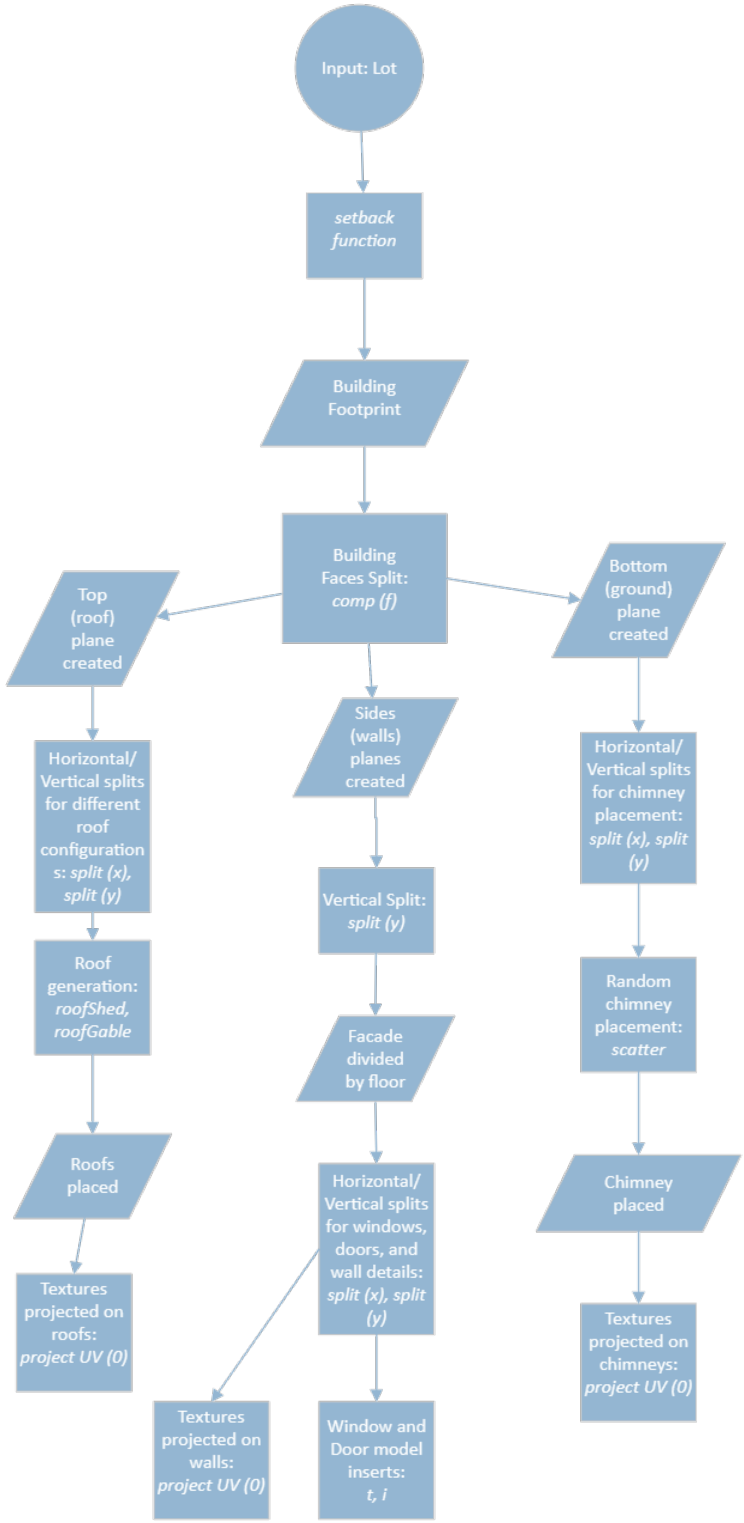
Note: This diagram is derived from the paper that established the methodology of tiling building facades with splits in CGA rules. We applied this method to our models in the form of tiles for windows, doors, walls, and other design elements. From, Müller, P., Wonka, P., Haegler, S., Ulmer. A., Van Gool, Luc. (2006, July). Procedural modeling of buildings. ACM Transactions on Graphics, 25(3), 614-623.

It was ascertained that a fundamental characteristic of CE is its capacity for parametric design. Using parametric design in modelling allows the model's geometry to change according to set variables. In practice, not every model has the exact same dimensions or textures, creating a truer to life representation. In both models, parametric design methods were implemented.

CGA Rules. Creating the code(s) that can procedurally generate our existing developments requires us to conceptually combine the dimensions of the built structures with the CE standards of parametric modeling. The product of the written code will then be able to depict our housing developments in virtually any setting. CGA modeling works by taking a starting geometry (in this case, two-dimensional polygons representing lots) and applying transformations to it in steps. Thus, it is essential to conceptualize how the rulefile will translate the physical building into a virtual model before starting. The code flowchart, seen in Figure 13, reflects our method for modeling these specific buildings. We segmented the buildings into unique design elements (e.g., walls, windows, chimneys, roofs, etc.) and then considered the logical order to progress from the initial lot geometry to final details. We created the building envelope using setback and extrusion functions. Attaining the building geometry was primarily achieved through included functions, namely vertical and horizontal splits, compositional façade splits, and extrusions. Roof forms are created from the functions included in the program such as shed and gable roofs. After tiling the facades through vertical and horizontal splits, window and door objects were inserted into the models. Finally, texture files were projected on surfaces. Chimney, porch, and garage forms were all modelled fully within CE's CGA framework using splits and extrusions.

Figure 13

Code Flowchart



Note: This flowchart demonstrates the overall hierarchy of the code for our models. The names of CGA functions are italicized.

Applying to Alternative Settings. With working codes, the next element of the design process is applying them to the vacant lots. This first required deriving a base map from the Open Street Maps database, a built-in feature of CityEngine (CE). The "Get Map" command then pulls info for a selected area such as streets, building footprints, bus stops, terrain, etc. and creates layers for them. There is also a rule file that then generates buildings from their footprints which completes the surroundings and site of our alternative settings.

The application of our codes onto the alternative settings utilized the more manual elements of CE's toolset. First, using the rectangular shape drawing tool, the lot was drawn according to the dimensions of the existing developments. The codes were then applied to these lots which generated the corresponding models. Additional refinement was achieved by using the "align terrain to shapes" function which leveled the sites and removed any unrealistic grade. Figures 14 through 31 illustrate the corresponding renderings and finished product of the code visualized through CE.

Figure 14

Iron and Oak, Broad Street and Tank Farm Road, 1

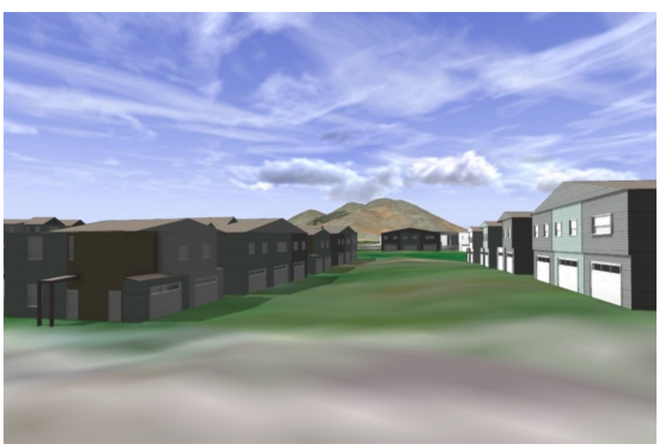


Figure 15

Iron and Oak, Broad Street and Tank Farm Road, 2

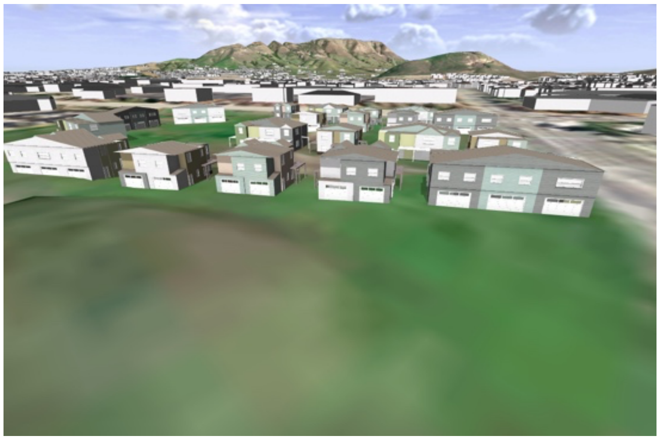


Figure 16

Iron and Oak, Broad Street and Tank Farm Road, 3

Figure 17

Windemere Condominiums, Broad Street and Tank Farm Road, 1

Figure 18

Windemere Condominiums, Broad Street and Tank Farm Road, 2

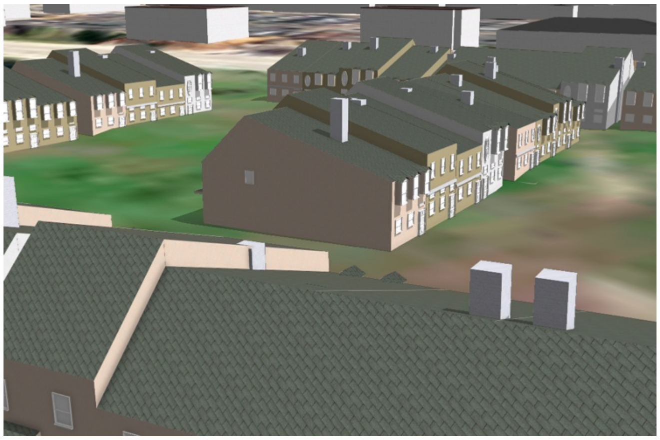


Figure 19

Windemere Condominiums, Broad Street and Tank Farm Road, 3

Figure 20

Iron and Oak, Fuller Road, 1

Figure 21

Iron and Oak, Fuller Road, 2

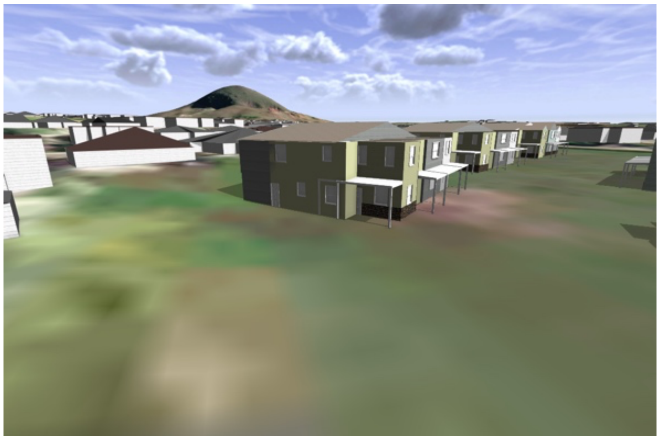


Figure 22

Iron and Oak, Fuller Road, 3

Figure 23

Windemere Condominiums, Fuller Road, 1

Figure 24

Windemere Condominiums, Fuller Road, 2

Figure 25

Windemere Condominiums, Fuller Road, 3

Figure 26

Iron and Oak, Foothill Boulevard and Rosita Street, 1

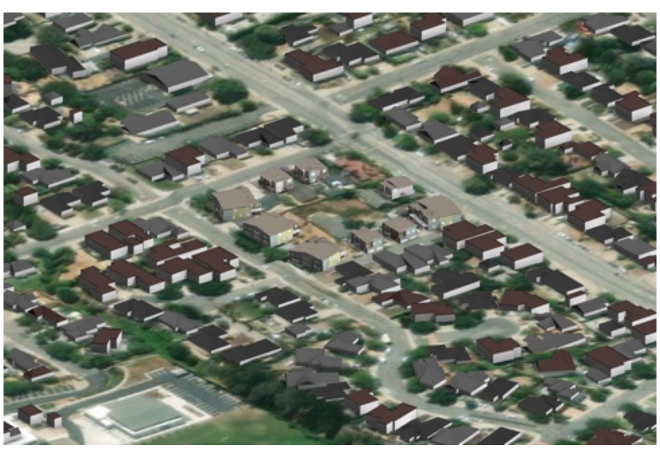


Figure 27

Iron and Oak, Foothill Boulevard and Rosita Street, 2

Figure 28

Iron and Oak, Foothill Boulevard and Rosita Street, 3

Figure 29

Windemere Condominiums, Foothill Boulevard and Rosita Street, 1

Figure 30

Windemere Condominiums, Foothill Boulevard and Rosita Street, 2

Figure 31

Windemere Condominiums, Foothill Boulevard and Rosita Street, 3

Conclusion

This research was completed to combine two emerging trends in urban planning. One is the idea of *missing middle housing*, that a range of multi-unit housing types is needed to meet the growing demand for walkable urban living and increase the stock of affordable housing. The other is procedural modeling (PM), which can allow planners to quickly model large three-dimensional urban environments to aid in the planning process. These two ideas come together as our research paper shows procedural models of typical missing middle housing in a mid-sized California city that suffers from a lack of affordable housing. San Luis Obispo was chosen for its proximity to the researchers as well as its local housing deficiencies and planning context. One of the obstacles this project faced was the relative newness of procedural modeling techniques in planning contexts. Therefore, PM founded the basis for our literature review and our experimentation while *missing middle housing* was used as a supplemental idea to guide our design.

Our team experienced CityEngine (CE) from a valuable perspective and finished this project with a better understanding of the program's potentials and limitations when used in the planning context, specifically in the modeling of particular buildings. As planning students familiar with planning concepts but without in-depth programming knowledge, our journey of learning the CGA rule file language and CE system would closely mimic the journey of planning staff attempting to garner knowledge of the program for the first time. Our team was self-taught utilizing the available collection of official Esri tutorials and video resources. This was a time-consuming process that also required consulting the Esri community CE forum for specific issues. This illustrates our first limitation of the program in a planning context, which is the time to train staff for them to be able to effectively utilize CE for a planning proposal. It is possible as the product of this research paper shows, however it may be more realistic to account for the cost of expert consulting. Furthermore, the small user base and niche qualities of the software (the unique CGA coding language) may lead to difficulties sourcing a consultant.

The original goal of this project also revealed that CE is limited in its ability to accurately model a specific real-life building with procedural elements. Our team began the project assuming that through following the CE standard that a detailed and true to life model of our chosen housing developments was easily attainable. What was learned is that in order to achieve the level of detail imagined, an excessive number of splits to the mass model was required. This drove our code into sometimes messy and sometimes completely impractical territories in terms of its complexity. The limits of the program to model in high detail were quickly found and the resulting models balance these challenges in their design which was envisioned to be much more life-like.

Through the completion of this project, we identified several potential benefits of PM over traditional methods. PM requires less marginal effort to create new objects/scenarios at larger scales and levels of complexity. While developing a CGA rulefile often takes more effort than modeling a building through traditional means, parametrization in procedural methods enables users to immediately generate a variety of alternative designs from a single rule. CE is thus highly suited for populating entire neighborhoods or cities with unique buildings. Furthermore, the software's API lends itself to usage by non-design professionals and the public by allowing programmers to create a menu of parameters that can be adjusted with simple input boxes and drop-down menus (the inspector window). After these parameters are identified in the rulefile, users can adjust variables without further programming. This functionality is ideal for situations where planning professionals, inexperienced employees, and the public interact. With a well-developed set of rulefiles, a staff of planners could potentially generate many site alternatives without intervening in the code. Furthermore, CE is excellent for quickly applying design concepts to different locations. The “Get Map” function enables users to immediately pull terrain, street network, and building footprint data (among many other optional layers) from Open Street Maps. Models can then be easily implemented within the actual project context. The cumulative effect of all these features is an expedited design process after the initial rulefiles are developed.

This exploration into CE’s capabilities in working with the process of urban planning has revealed great potential. One aspect that should be further explored is the software's potential applications for public outreach and communication with relevant stakeholders. CE can act as a guiding bridge between complex policy and visualization that non-planners can understand and interact with. Furthermore, CE’s compatibility with the existing library of Esri products and other modeling software may allow for a more polished and presentable 3D visualization. If this research was to be expanded on, the potential for the software to assist public outreach and the ability for its final product to be improved through additional software should be the next field of study.

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