RESQUAKE: SIMULATING POST-EARTHQUAKE DAMAGE IN PHILIPPINE HOMES USING PROCEDURAL MODELING

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by

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THESIS ABSTRACT

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7.1 **Rationale/Background of the study**

Traditional post-earthquake training often relied on predefined scenarios that lacked the randomness and variability necessary to adequately prepare trainees for the unpredictable and diverse situations encountered during actual earthquakes. These static training modules failed to simulate the dynamic and complex nature of real-world seismic events, limiting the effectiveness of disaster preparedness programs.

7.2 **Summary**

This research addressed this problem by introducing procedural modeling to create diverse models for simulations that reflected real-life post-earthquake situations.

1. To identify the characteristics of a Philippine urban residential structure.
2. To determine what procedural modeling techniques are applicable in generating diverse Philippine residential structures with post-earthquake-damage effect.
3. To integrate the procedural modeling techniques into a framework for a diverse model generation of a post-earthquake simulation environment.

7.3 **Findings**

Generating more than one training simulation environment rather than manually sculpting each led to a broader range of scenarios without a corresponding increase in time and resources needed to create them.

1. The characteristics of Philippine houses showcase a strong preference for concrete materials and tin roofs.
2. The detailed Voronoi fracture simulations enable complex crack patterns in concrete, while the RBD material fracture allows for precise control over the simulation parameters.
3. The study highlighted the Voronoi Fracture method's superior speed and effectiveness in simulating realistic earthquake damage, outperforming the Material Fracture technique in processing time and data storage efficiency

7.4 **Conclusions**

Preliminary results indicated that procedural modeling significantly enhanced the diversity of post-earthquake models offering a more dynamic environment.

1. Philippine houses predominantly use concrete materials and tin roofs, with distinct public and private spaces.
2. Voronoi fracture simulations and RBD material fractures in Houdini enable detailed and realistic post-earthquake damage modeling.
3. The Voronoi method excels in speed and efficiency, while RBD emphasizes detailed realism, making both valuable for disaster preparedness simulations.

7.5 **Recommendations**

To enhance the effectiveness and realism of disaster preparedness simulations, the following recommendations are proposed:

1. It's imperative to advance the stochastic rules for L-systems, broadening the range of simulated Philippine house models.
2. Expanding the use of Voronoi and RBD fracture techniques to include key structural elements like doors and windows can lead to more nuanced and comprehensive earthquake damage simulations.
3. Implementing the study's findings in VR-based training can revolutionize disaster preparedness.

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We would also like to dedicate this work to our esteemed panel member, Arnemie Gayyed, and our chairperson, Anna Rhodora Quitaleg, for their valuable insights and contributions to this study. Their guidance and expertise have enriched our research and contributed to its success.

T.P.C

T.D.S

C.S.C

DEDICATION

This research paper is wholeheartedly dedicated to our families and special someone, whose endless love, support, and encouragement have been our greatest strength. Their belief in our potential and sacrifices have fueled our resilience throughout this academic journey.

We also dedicate this work to the resilient communities in earthquake-prone regions, drawing inspiration from their strength and perseverance in the face of adversity.

Our commitment is fueled by a collective aspiration to contribute valuable insights that can aid in building safer, more informed societies. This paper symbolizes our shared journey, a testament to our collaboration, support, and shared vision in the pursuit of knowledge and impactful research. And in memory of Bambi, whose loyalty and love inspire us.

Tyra

Tyraxl

Charles

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Chapter 1

INTRODUCTION

Background of the Study

Earthquakes are considered the most destructive and terrifying of all-natural disasters (United Nations Office for Disaster Risk Reduction, 2022; Ipong, 2020) that pose an ever-present threat to the Philippines. Situated in a seismically active region known as the "Pacific Ring Of Fire," the country experiences a continuous risk of seismic activity (Ipong, 2020; Balahadia & Sayaman, 2023; Valenzuela et al., 2020; Rogayan & Dollete, 2020). Five major faults intersect the archipelago, generating an average of 20 earthquakes daily, with nearly 100-150 felt tremors annually [Ong et al., 2021; Dollete, 2020; Silent Gardens, 2019].

Throughout its history, the Philippines has endured significant earthquakes. The most devastating occurred in 1976 in Moro Gulf, with a 7.9 magnitude claiming up to 8,000 lives (PhilAtlas, 2023; Ong, 2023). The second deadliest, with a magnitude 7.8 killer earthquake, struck Northern and Central Luzon in 1990 (PhilAtlas, 2023). In 2017, the Surigao earthquake caused the third-highest damage cost of Php 720 million, striking northeastern

Mindanao with a magnitude of 6.7 (Ong, 2023).

Given its vulnerability to earthquakes, it is imperative that the Philippines invests in proactive disaster preparedness strategies. These strategies should encompass disaster risk reduction education and the development of robust post-disaster preparedness education. Undoubtedly, disaster risk preparedness and reduction are essential. However, a study by Cartusiano and Cruz (2023) underscores the equal significance of an efficient post-disaster response in safeguarding lives and mitigating the effects of inevitable natural catastrophes.

The initial post-earthquake period is often characterized by numerous casualties, aftershocks, mudslides, and other secondary disasters (Gong & Hu, 2023). A study on post-earthquake rescue by Hooshangi (2021) indicates that the first 48 hours after an earthquake have the greatest impact on rescuing people. Hence, the speed of rescue operations is extremely important. These events necessitate immediate and coordinated efforts in search, rescue, transfer, and treatment of victims, as well as supplying energy and other staples, and maintaining security and order (Sharif et al., 2023).

However, post-disaster response remains the least understood aspect of the disaster cycle due to its dynamic and complex nature, as noted by Valaei Sharif et al. (2023), Cook et al. (2018), and Zhang (2021). Additionally as quoted in a study by Rom & Kelman (2020), "Mitigation and preparedness involve both reducing the need for response and increasing the ability to respond," stressing the equal importance of disaster response alongside prevention and mitigation. This aligns perfectly with the main objective of the UN's Sendai Framework for Disaster Risk Reduction (DRR), which strives to prevent and reduce hazard exposure and vulnerability, enhance preparedness for response and recovery, and ultimately strengthen resilience. This, in turn, directly contributes to achieving Sustainable Development Goal (SDG) 11.b.1, highlighting the critical importance of DRR and resilience. While most research has focused on optimizing material facility deployment, the equally vital aspect of casualty rescue has been overlooked, potentially hampering effective emergency response efforts and leaving victims stranded (Gong & Hu, 2023).

In conclusion, these studies collectively emphasize the imperative need for the Philippines to invest in and refine its post-earthquake response strategies. The unpredictable nature of earthquakes, coupled with the potential for significant casualties and secondary disasters, necessitates a proactive, well-coordinated, and adaptable approach to disaster response. By addressing the challenges and gaps identified in these studies, the Philippines can significantly enhance its capacity to mitigate the impact of earthquakes and safeguard the well-being of its citizens.

Company Profile

At the core of the researchers' mission is a dedication to enhancing the safety of communities in post-earthquake events. Thus, the researchers' primary focus is on serving those at the forefront of disaster response: decision-makers and earthquake responders. This encompasses a broad spectrum of professionals, including emergency planners, rescue teams, urban planners, and governmental officials, who play essential roles in orchestrating and executing swift, life-saving responses in the aftermath of earthquakes. The researchers' solutions are crafted to enhance their decision-making capabilities, ensuring they have access to realistic training models when it matters the most.

The researchers aim to contribute to organizations at the helm of earthquake preparedness and response, such as the National Disaster Risk Reduction and Management Council (NDRRMC) and similar agencies dedicated to handling earthquake-related emergencies. The researchers' goal is to provide them with advanced tools and simulations that facilitate more effective training scenarios, risk assessment, and rapid response strategies.

The mission of this study is intrinsically aligned with the Sustainable Development Goals (SDGs), particularly focusing on SDG 11 (Sustainable Cities and Communities), which emphasizes the importance of making cities and human settlements inclusive, safe, resilient, and sustainable. By equipping this study's target audience with innovative simulation tools and procedural modeling techniques, we the researchers can contribute towards enhancing urban resilience, significantly reducing the loss of lives and economic losses in disasters, thereby supporting the broader agenda of sustainable development and disaster risk reduction.

Importance of the Study

This study is pivotal in advancing earthquake preparedness and response strategies, particularly through the innovative use of procedural modeling. By simulating post-earthquake scenarios, the research significantly contributes to the fields of disaster management and architectural resilience, particularly in earthquake-prone areas like the Philippines.

Efficient 3D Modeling. The importance of this study for efficient 3D modeling lies in its ability to automate the creation of varied and complex post-earthquake simulations. Traditional methods require extensive time and resources to manually craft each scenario, limiting the scope and diversity of training simulations. Procedural modeling, as demonstrated in this research, allows for the generation of numerous detailed and realistic models rapidly and efficiently. This innovation not only saves significant resources but also enhances the quality and effectiveness of the training materials, leading to better-prepared responders and more resilient infrastructures.

Post-earthquake Response. For post-earthquake response, the study's significance is profound. The enhanced training simulations, grounded in the realistic and varied scenarios generated by procedural modeling, equip responders with the experience to tackle unpredictable and complex real-world situations. This preparedness is crucial for effective emergency response, minimizing the time to act and potentially saving lives. Furthermore, the insights gained from these simulations can inform better disaster-preparedness policies, building codes, and urban planning, particularly in regions frequently affected by earthquakes.

Pioneering Research. This study is pioneering research in the field, offering new methods and exciting insights that challenge what is currently known and to future research. By providing a fresh foundation for understanding, this study opens up new directions for future research and advancements in the field of computer science.

Statement of the Problem

This research aims to explore various aspects of Philippine urban residential architecture and the application of procedural modeling in simulating post-earthquake damages. Specifically, the study seeks to address the following questions:

1. What are the characteristics of a Philippine urban residential structure?

2. What procedural modeling techniques are applicable in generating diverse Philippine residential structures

with post-earthquake damage effects?

3. How can procedural modeling techniques be integrated into a framework to generate houses with varying damage levels corresponding to the Richter scale, suitable for post-earthquake simulations?

Objectives of the Study

This study aimed to systematically analyze and model the architectural features and resilience of Philippine urban residential structures, especially in the context of earthquake impact. The specific objectives are:

1. To identify the characteristics of a Philippine urban residential structure.

2. To determine what procedural modeling techniques are applicable in generating diverse Philippine residential structures with post-earthquake-damage effects.

3. To integrate the procedural modeling techniques into a framework for a diverse model generation of a post-earthquake simulation environment.

Definition of Terms

In this section, the researchers provide clear, comprehensive, and concise definitions of key terms and concepts used throughout the study. Understanding these terms is essential for grasping the underlying principles, theoretical frameworks, and methodologies discussed in the research. The terms are arranged alphabetically for ease of reference, ensuring that readers can quickly locate and familiarize themselves with the necessary vocabulary.

Earthquake Preparedness and Risk Reduction is the concept related to the measures and actions taken before an earthquake to minimize the damage and enhance the ability to respond and recover.

L-system (Lindenmayer System) is a set of rules and symbols used to model complex patterns and structures, originally developed for simulating plant growth.

Magnitude is the measure of the energy released by an earthquake.

Procedural Modeling is a computer graphics method for automatically creating 3D models and textures using algorithms based on predefined rules, eliminating the need for manual modeling.

Rigid Body Dynamics (RBD) Material Fracture is a Houdini tool that simulates realistic fractures in materials like wood, concrete, and glass by pre-fracturing geometry.

Seismic Activity is the occurrence of earthquakes or earth vibrations.

<u>Seed</u> is a numeric value supplied to a randomizer. The seed dictates which values the randomizer will generate and in which order they will occur.

<u>Voronoi Fracture</u> is a technique that breaks objects into naturally irregular or cracked patterns.

Chapter 2

REVIEW OF RELATED LITERATURE

This chapter delves into the existing body of knowledge pertinent to the study, focusing on dissecting and understanding the characteristics of Philippine urban residential structures and the procedural modeling techniques employed in their representation and analysis. This aimed to contextualize the research within the broader academic and practical framework, drawing on a range of sources that established the solid foundation for the study's objectives. By reviewing the related literature, the study sought to identify gaps in the current understanding and how this research contributes to the existing body of knowledge. Furthermore, the chapter highlights the findings of previous studies, providing a comprehensive background that informs the research approach and validates its relevance.

Characteristics of a Philippine Urban Residential Structure

Philippine urban residential structures exhibit distinctive characteristics in their construction materials and architectural designs, reflecting the country's adaptation to its environment and available resources (Johnson et al., 2021; Adem, 2020; Rossini, 2021; Narvaez-

Pernes & Santos, 2020; Tiburcio-Garcia, 2020; Estacio et al., 2021; Lorenzo, 2021). A critical examination of the structural elements—beams, walls, and roofs—reveals a consistent preference for concrete and specific styles that cater to the local climate and urban landscape (Calliari, 2019; Jim & Hui, 2022; Abed et al., 2022; Papatzani et al., 2022).

Building upon this foundation, Philippine architecture demonstrates a dynamic evolution, particularly in the integration of traditional design features with modern architectural concepts (Mabborang et al., 2022; Almodovar-Melendo et al., 2022; Narvaez-Pernes & Santos, 2020; Widiastuti, (2022). The practical application of these integrative design principles, especially through the presentation of floor layouts, offers a tangible insight into the characteristics of the Philippine urban residential architecture.

The construction materials used in Philippine houses are a testament to the country's architectural ingenuity and its response to both environmental challenges and urban development needs (Martinez, 2017; Stubbs & Thompson, 2016; Malaque III et al., 2015; Kliment, 1977;). This section discussed the primary materials and methods employed in the construction of Philippine urban residential structures, focusing on the pivotal roles of beams, columns, walls, and roofs (Hadlos et al., 2023; Venable et al., 2021; Ray, 2019; Carrasco et al., 2016; Kliment, 1977;).

Beams and Columns: Reinforced concrete is the predominant material used in the construction of beams and columns within Philippine urban residential structures (Lejano, 2021; Roxas et al., 2023; Ashfaq, 2023; De Jesus, & Borais, 2019;). This preference underscores the reliance on concrete hollow blocks (CHB), not just for walls but as a fundamental element in the structural integrity of buildings (Bautista et al., 2023; Ayala Laverde, 2023; Osundina; 2021; Martínez-Rocamora et al., 2021; D'Ayala et al., 2020; Bornales et al., 2022; Maribbay, 2000;). The widespread use of concrete highlights its durability and availability (Jipa & Dillenburger, 2022; Orozco et al., 2023; Alfonso et al., 2023; Aprianti, 2017; Archila et al., 2001), making it a staple in the urban architectural fabric of the Philippines (Ray, 2019).

Walls: The construction of walls predominantly employs concrete hollow blocks (CHB) (Canlas et al., 2021; Imai et al., 2015; Ignacio et al., 2020; Bornales et al., 2022; Ongpeng & Umali, 2023), a method that has become increasingly common in residential structures over recent years (Mercado, 2004; Ongpeng, 2020; Imai et al., 2015; Canlas et al., 2021). This technique's popularity underscores CHB's adaptability to various design requirements and its effectiveness in meeting the structural and aesthetic needs of urban residences (Canlas et al., 2021; Imai et al., 2015; Ignacio et al., 2020; Bornales et al., 2022; Ongpeng & Umali, 2023; Martín-Morales et al., 2017; Elbashiry et al., 2023; Ismaeel & Mohamed, 2023; Nasreldin & Ibrahim, 2022).

Roofs: The roofing materials and designs further illustrate the adaptation to local conditions and preferences. A typical combination found in extended houses includes the use of tin for roofs and CHB for walls, indicating a practical approach to construction that balances cost and durability (Bredenoord, 2024; Ballesteros et al., 2023; Iyer et al., 2023; Zafra et al., 2021; Venable et al., 2021; Anderson, 2019; Asube et al., 2021; Soares et al., 2019; Seike, 2018). Additionally, the prevalence of gabled roofs, with a roof pitch of 16.7°, is indicative of a design that is both functional and common in the Philippine setting (Pantua, Calautit, & Wu, 2019). An analysis of buildings across 15 municipalities revealed a significant variety in roof shapes, with gable roofs, mono-slope roofs, and hip roofs being the most common, comprising 50.8%, 24.58%, and 12.89% of the structures, respectively (Tan et al., 2021; Venable et al., 2021; Enteria, 2016; Song et al., 2020; Mabborang et al., 2022; Garciano et al., 2013; Acosta et al., 2021; Eleftheriou 2022). These findings highlight the diversity and adaptability of roof designs in urban residential buildings, catering to different environmental, aesthetic, and functional requirements.

This reveals that the Philippines' urban residential structures are characterized by a pronounced use of concrete hollow blocks for walls and reinforced concrete for beams and columns, alongside a preference for gabled and other sloped roofs. These characteristics not only reflect the architectural identity of urban Philippine homes but also showcase the practical considerations of durability, climate adaptability, and resource availability in the construction choices. Importantly, these foundational traits serve as the basis for the creation of diverse Philippine house models, illustrating the versatility and innovation inherent in Philippine urban residential architecture.

The study of floor layouts, particularly through the lens of Philippine house-selling websites, offers invaluable insights into the current trends and preferences in residential design within the country. These platforms, such as Pinoy Eplans and PhilConPrices, provide a rich repository of floor plans that reflect the practical application of architectural principles in urban Philippine homes. This section presents two examples of such floor plans, illustrating how modern Philippine urban houses navigate the balance between communal interaction and personal space. By analyzing these layouts, we can better understand the evolving dynamics of Filipino lifestyles and the architectural responses to these changes.

Figure 1

Sample 1 Storey Philippine House Floor Plan

Image source: https://www.pinoyeplans.com/listing/small-

house-designs-series-shd-2014008/

Figure 1 illustrates a simplified floor plan inspired by real designs sourced from Pinoy Eplans [12]. This layout is methodically organized into public and private zones. The public sector includes the living room, dining area, kitchen, and porch, with the entrance distinctly marked by the placement of the door. The private domain is composed of two bedrooms and a bathroom, delineating clear boundaries between communal and personal spaces. The design emphasizes functionality and comfort, catering to the needs of a modern urban family while maintaining a cohesive aesthetic.

Figure 2

<u>Sample 2 Floor Storey Philippine House Floor Plan</u>

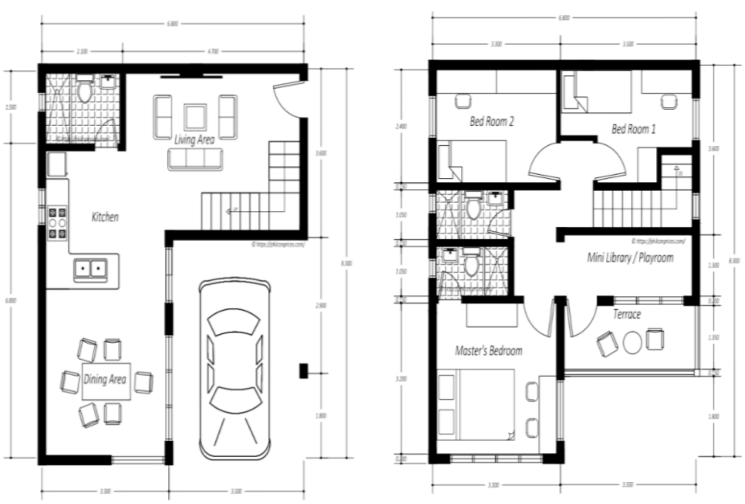


Image Source: https://philconprices.com/tag/average-cost-to-build-a-new-house/

Figure 2 showcases an elaborate two-story floor plan adapted from PhilConPrices (2023). It features a detailed space division into public and private areas within a Philippine residential setting. The ground floor is dedicated to public functions, featuring the kitchen, living, and dining spaces, facilitating social and familial interactions. In contrast, the second floor is reserved for private quarters, housing the bedrooms, thereby segregating personal living spaces from the communal areas.

The analysis of floor layouts from Philippine house-selling websites provides essential insights into residential design trends, emphasizing a treemap-like division of rooms that reflects a meticulous approach to space utilization in urban homes. This exploration, utilizing examples from Pinoy Eplans and PhilConPrices, reveals how modern Philippine houses strategically organize living areas. These observations had guided the development of diverse Philippine house models to meet realistic urban residents' settings.

Procedural Modeling Techniques

The term 'procedural modeling' encompasses a range of techniques used to generate complex structures and phenomena algorithmically (Kolkman, 2022; Jones et al., 2020; Talton et al., 2011; Deussen et al., 1998), a knowledge and technique that has been efficiently implemented in various domains such as video game development, architectural visualization, and urban planning simulations (Badwi et al., 2022; Ma, 2021; Bagnolo et al., 2021; Ghorbanian & Shariatpour, 2019; Adão et al., 2019; Smelik et al., 2014; Grêt-Regamey et al., 2013; Smelik et al., 2011; Kelly & McCabe, 2006). The concept was notably emphasized by Lopes (2010), who highlighted the method's capability to rapidly produce believable and architecturally sound floor plans. Procedural modeling's strength lies in its quick computation and the high degree of realism it can impart to simulated environments.

One procedural modeling technique as reviewed by Tong and Feng (2019) assessed methods for cellular automata models in land-use change and urban growth. Wu, Mao, and Li (2021) explored procedural game map generation using multi-leveled cellular automata and machine learning. Tong and Feng (2019) also developed a new PCGA-CA model integrating urban planning regulations. Additionally, Johnson, Yannakakis, and Togelius (2010) focused on real-time generation of infinite cave levels using cellular automata, while Bhardwaj and Upadhyay (2017) explained elementary cellular automata models. Kreitzer, Ashlock, and Pereira (2019) demonstrated the automatic generation of diverse cavern maps with morphing cellular automata.

Lindenmayer systems (L-systems), originating from

formal grammars and string rewriting systems, provide a powerful alternative or complementary approach to cellular automata in procedural modeling. They offer a unique perspective on modeling complex systems, capturing intricate patterns and enabling modular development (Liarokapis et al., 2020).

L-systems operate through production rules applied iteratively to strings, reflecting the modular growth observed in plants (Taylor, 1992). Their practical interpretation using the LOGO-style "turtle" language has been demonstrated, particularly relevant in computer graphics for creating graphical representations (Abelson & Disessa, 1982; Szilard & Quinton, 1979).

In gaming, L-systems play a significant role in procedural generation, such as in creating room shapes for 3D dungeons (Antoniuk, 2018), providing enhanced control over layouts. They are also utilized in urban planning simulations to generate symmetric urban layouts with user-controlled symmetry (Tong and Feng, 2019). Furthermore, L-systems are pivotal in the procedural generation of multilevel dungeons in gaming environments, leveraging schematic maps for efficient shape generation (Anonymous, 2021).

Architecturally, L-systems have been adapted from their original purpose of modeling plant growth to the generation of floor plans for Philippine houses (Claridades et al., 2022; Pexman et al., 2021; Quinay et al., 2020; Frankie et al., 2013; Kneidl et al., 2012). L-systems, initially developed to model the growth of plant life, have been adapted to create intricate, branching architectural structures (Nouri et al., 2023; Shu & Ludwig, 2023; Bielefeldt et al., 2019; Prusinkiewicz et al., 2018; Boudon et al., 2012, Allen et al., 2005), thus allowing for the procedural generation of complex and realistic building layouts (Nouri et al., 2023; Kutzias & von Mammen, 2023; Freiknecht & Effelsberg 2019; Magdics, 2009).

In the context of L-systems, a stochastic rule means that when the system applies a rule to a symbol, it has more than one possible outcome, and each outcome is associated with a certain probability. This adds variability to the generated patterns, making each iteration potentially unique even if it starts from the same axiom.

A key aspect of L-systems in procedural modeling is their use of stochastic rules, introducing randomness and variation into generated patterns (Antoniuk et al., 2018). These stochastic rules, like A=F+A:0.5 and A=F-A:0.5, are common techniques to create a variety of patterns from the same set of rules, making them particularly useful for generating complex, natural-looking forms or varied floor layouts.

Figure 3

Rules for L-system

```
axiom->function(_parameters): {set_of_resulting_symbols}
```

Figure Source: Adão, T. et.al (2019). Procedural modeling of buildings composed of arbitrarily-shaped floor-plans: Background, progress, contributions and challenges of a methodology oriented to cultural heritage. Computers, 8(2), 38.

The development of rules for L-systems, including axioms and functions, is facilitated through computer-based stochastic generation (Adão et al., 2019). This method ensures that room shapes remain interesting and non-repetitive, adding further depth to the procedural generation process.

Perlin noise is another procedural modeling technique spectral synthesis algorithm known for its ability to generate smoothing effects and coherence in randomness, making it a popular choice for procedural terrain generation (Emmanuel et al., 2019). While initially designed for mimicking textures like water and marble, its hierarchical properties have found application in landscape modeling, offering a wide range of spatial patterns akin to natural landscapes (Perlin, 1985; Musgrave et al., 1989). Despite its potential, Perlin noise remains underutilized in landscape ecology, where its hierarchical nature could align well with theories on landscape structure (Emmanuel et al., 2019). This algorithm, derived from fractal Brownian Motion (fBM), produces 2D maps with smooth undulating data, enhancing the realism of virtual terrains beyond what random number generation (RNG) can achieve (Emmanuel et al., 2019).

Another procedural modeling technique is called Voronoi fracture, it is used in computer graphics and computational geometry to fragment objects into pieces based on the Voronoi diagram (Low et al., 2021; DiFrancesco et al., 2021; Domaradzki & Martyn, 2016; Van Der Wielen & Rollinson, 2016; Schvartzman, 2013). In the context of fracturing, an object is broken up along surfaces that are equidistant to predetermined points within the object, creating a distinctive, naturally irregular pattern of cracked or shattered pieces (Domokos et al., 2020; Ali, 2023, Esatyana, 2022, Panera, 2019). Voronoi fracture is a technique that is used to create a realistic and more natural-looking earthquake damage effect (Liu et al., 2021; Ji et al, 2024; Zhang et al., 2023; Xu et al., 2020; Mohanty et al., 2022; Sanipour et al., 2022; Lin et al., 2024; Bahrani et al. 2023; Hamediazad & Bahrani, 2022; Sanipour , 2021).

According to Elkins (2020), utilizing the Voronoi Fracture by turning the model into a volume and scattering the points throughout, as seen in Figure 4, one can effectively create a rock-based fracture in a matter of minutes (Abdelaziz, 2023; Mejia et al., 2020). This method not only enhances visual realism but also improves computational efficiency by allowing for the quick generation of complex fracture patterns. Moreover, the adaptability of Voronoi fracture makes it suitable for various applications in both animation and simulation, offering a versatile tool for artists and engineers alike.

Figure 4

Voronoi Fracture Applied to a Sphere in Houdini

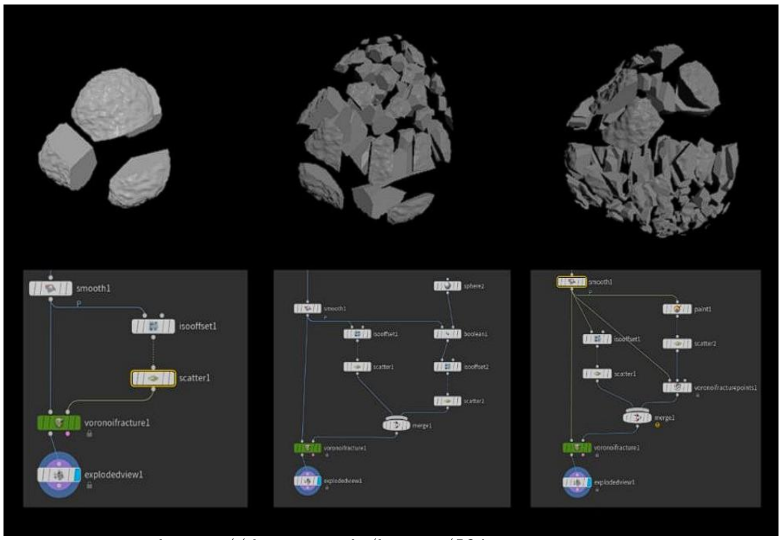


Image source: https://dc.etsu.edu/honors/524

This method is often used in visual effects (VFX) to simulate the breaking or shattering of objects realistically (Hwang & Lee, 2022; Elkins, 2020; Wolper et al., 2019; Monroe, 2014; Johansson-Evegård, 2012; Sreshta, 2019). By partitioning objects into Voronoi cells, it can create realistic break patterns that closely mimic the random yet patterned nature of real-world earthquake damage (Beyerer et al, 2024; Hexmoor, 2022; Montáns et al, 2023; Casali, 2020; Jiang & Shekhar, 2017). Voronoi diagrams are employed to simulate the fracture process in concrete (Zhang et al., 2023; Jung & Redenbach, 2023; Naderi & Zhang, 2022; Sun et al., 2019; Wei et al., 2020; Lv et al., 2017; Asahina et al., 2011). These simulations help in understanding the crack morphology and stress-strain responses in concrete, illustrating how the Voronoi-based models can influence crack initiation and growth (Naderi, Tu, & Zhang, 2021). The level of detail in Voronoi fracture simulations can be quite high, with the ability to model complex crack patterns and interactions within heterogeneous materials like concrete. These models account for the realistic representation of aggregates, enabling detailed analysis of fracture mechanisms under various loading conditions, including static and dynamic tensile loads (Naderi & Zhang, 2021). The Voronoi Fracture parameters can be adjusted to represent different intensities and types of seismic damage (Wang et al., 2021; Zhou et al., 2022; Liu et al., 2021; Wu et al., 2019; Satriano et al., 2011;), from fine cracks indicative of minor tremors to extensive fragmentation resulting from a major quake. Using points scattered in a density volume generated from the geometry using IsoOffset is a flexible way to generate cell points, as you can modulate the density in the volume before scattering to get more points within particular regions of the object (Dwivedi, 2011). Where there is higher point density, the Fracture SOP will generate more, smaller pieces.

Additionally, RBD (Rigid Body Dynamics) material fracture is another procedural modeling technique. RBD is the process of breaking or fracturing solid materials realistically within simulations (Mühling et al., 2021; Smelik et al., 2019; Veltin, 2021; Fan et al., 2022; Sreshta, 2019). This technique allows to subdivide a solid object into smaller fragments or pieces, mimicking the physical behavior of materials like glass, wood, or concrete when they break (Smelik et al., 2019; Cairns, 2012; Goffredo, 2010; Museth & Clive, 2008; Viswanathan, 2010).

Elkins(2020), built into the RBD Material Fracture node is a user interface that allows the artist to select the type of material they are wanting to fracture (concrete, wood, and glass) (DiNicolantonio, 2023). Based on the selection, the node will pre-fracture the geometry and set up parameters for customization (DiNicolantonio, 2023). Not only are the controls extensive within the node, but for the concrete and glass setting, further customization can come from outside of the node via points; this opens the door for using previously discussed methods such as the Voronoi Fracture Points clustering.

RBD material fractures have a distinct usability, this level of control ensures that the simulated damage closely matches real-world observations or theoretical predictions(Gabrovsek, 2017; SideFx, 2019). The Fracture Level will control how many cuts your object is going to have. Increasing this number will add more fractures to the existing fractured pieces, breaking each chunk into smaller pieces (SideFx, 2019).

Utilizing Rigid Body Dynamics (RBD) material fracture in Houdini for the procedural modeling of destruction and fracturing of 3D models is an innovative and highly effective technique, enabling detailed and realistic simulations (Okun et al., 2020; Smelik et al., 2019; Wisessing, 2014; Goffredo, 2010;). The procedural nature of Houdini allows for the creation of complex destruction effects through a node-based workflow (Lappi, 2023, Luque Bodet, 2022; Smith et al., 2020; Suarez et al., 2019; Rhodes-Robinson, 2018; Medina et al, 2020; Abgottspon; 2011), significantly enhancing the efficiency and art-directability of visual effects projects.

The RBD material fracture geometry node in Houdini is designed to handle the simulation of breaking and fracturing of materials in a highly customizable manner (Okun et al., 2020; Smelik et al., 2019; Rafferty, 2014).

Wayne Wu's project on material-based fracturing demonstrates the application of this technique to achieve visually realistic destructions by optimizing performance and introducing new tools like RBD Recursive Fracture and the Invoke SOP (Wu, 2023). Similarly, Gen Li's bridge destruction project showcases the integration of RBD simulation with vellum dynamics to simulate the destruction of a suspension bridge, highlighting the control and detail achievable with RBD material fracture (Li, 2020). Adrián Pueyo Bernardini's work further exemplifies the procedural modeling capabilities in creating high-quality building destruction simulations, organizing geometry into layers for detailed and layered destruction effects (Bernardini, 2024).

The detailed guide on RBD Material Fracture provided by SideFX outlines the operational specifics of the node, including parameters for randomness, corner ratio, edge, and interior noise, allowing for a customizable fracture simulation that adds to the realism of the destruction effects (SideFX, 2019). An artist's practical example of creating a cracking concrete effect emphasizes the procedural nature and flexibility of Houdini's setup, showcasing the iterative process of simulation and the capability to adjust and refine at any stage (Villà & McKenzie, 2023). These collectively demonstrate that RBD material fracture in Houdini is not only a procedural modeling technique but also a robust tool suitable for applying detailed and realistic destruction to 3D models, enhancing both the visual quality and the workflow efficiency in visual effects production (Okun et al., 2020; Smelik et al., 2019; Rafferty, 2014; Kumar, 2021).

Particle systems are a versatile tool in computer graphics for simulating complex phenomena. Jeschke et al. (2020) introduce an extension to procedural water wave animation, maintaining realistic wave behavior. Jain et al. (2021) present an approach to automated 3D tree generation using grammar-based modeling and particle systems, addressing limitations of existing tree libraries.

The integration of particle systems with procedural modeling techniques enhances the versatility of digital content creation, facilitating the simulation of natural and artificial phenomena with greater fidelity and efficiency, supporting a wide range of applications in animation, simulation, and interactive environments.

Chapter 3

METHODOLOGY

This chapter detailed the conceptual framework for the procedural generation of Philippine houses and analyzes the effects of earthquake damage on these models. This explains the procedural generation methodology, emphasizing the principles and algorithms used to create a diverse and efficient house model, and highlights the architectural styles and construction techniques.

The chapter then explores the simulated impacts of seismic activity, examining how different magnitudes on the Richter scale affect structural damage. A simulation process illustrates various earthquake scenarios and their effects on the generated houses. The experimental analysis assesses the damage at different Richter scale magnitudes, evaluating the resilience of these structures, identifying weaknesses, and suggesting areas for reinforcement.

The chapter concludes with insights and recommendations to enhance the earthquake resilience of the housing models, contributing valuable knowledge to architectural design and disaster preparedness.

Figure 5

Conceptual Framework

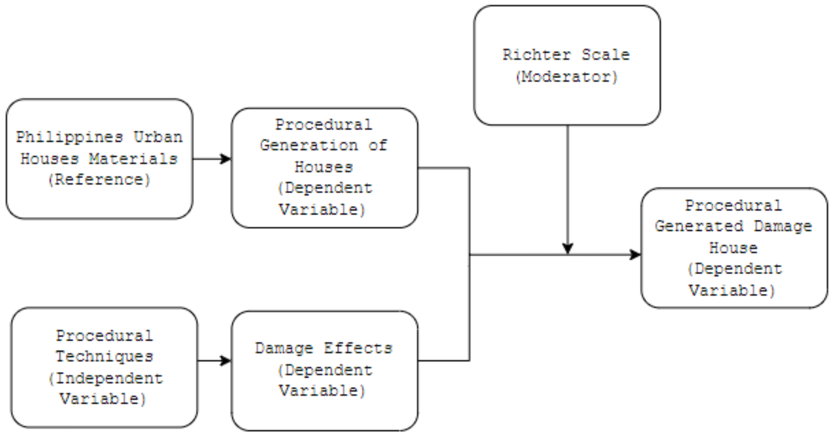


Figure 5 shows the conceptual framework that is used by the researchers to answer the SOP of the study. This shows the framework of the creation of the model until the Richter Scale is used to analyze the damage effect that was applied to the models.

Philippines Urban Houses Materials(Independent Variable): This step is a stand-alone variable that involves reviewing the characteristics and structures of urban houses in the Philippines. This likely includes studying architectural styles, building materials, and common structural features.

Procedural Generation of Houses (Dependent Variable): Procedural Generation of Houses Depends on the review of

Philippines Urban houses. A procedural generation is used to create digital models of these houses based on the reviewed houses. Procedural generation involves using algorithms to automatically create detailed and varied house models, ensuring a diverse range of architectural styles and features.

<u>Procedural Technique (Independent Variable):</u> There are two main options which are Voronoi Fracture, and RBD Material Fracture, each offering unique advantages for creating destruction patterns. This procedural technique is an important variable that will be based for the damage effect.

<u>Damage Effects (Dependent Variable):</u> If the Voronoi Fracture technique is selected, the model undergoes damage simulation using Voronoi fracturing, a method that breaks the structure into smaller, irregular pieces, resembling natural fracture patterns.

If the Material Fracture technique is chosen, the model is damaged using material fracture methods, which simulate how different materials in the house would realistically crack and break under stress.

<u>Procedural Generated Damage House (Dependent Variable):</u> This Variable will depend on both Procedural

Generation of Houses and Damage Effects. This will reveal the combined result of both variables resulting in the Procedural Generated Damage House.

Richter Scale (Moderator): The Richter Scale will be a moderator which means that the outcome of the Procedural Generated Damage house can be affected by the Richter Scale. The researchers perform a Richter Scale analysis on the damaged models. This analysis assesses the severity of the simulated earthquake effects, possibly correlating the damage to different magnitudes on the Richter scale.

Research Design

This research has utilized experimental research design by numerous testing of procedural modeling techniques which are Voronoi Fracture and RBD (Rigid Body Dynamics) Material Fracture. These procedural modeling techniques are compared to each other based on their performance in generating diverse Philippine residential structures with post-earthquake damage effects.

Software Development Methodology

According to Terry (2020) & Atlassian (2023) lean methodology, rooted in the Toyota Production System, focuses on continuous improvement and respect for people to eliminate waste and enhance efficiency. It is built on five core principles: identifying value by understanding customer needs, mapping the value stream to visualize and streamline processes, creating a smooth workflow to ensure continuous flow, establishing a pull system based on actual customer demand, and seeking perfection through ongoing refinement.

While originally developed for manufacturing, Lean principles are now effectively applied to knowledge work, promoting cross-functional collaboration and fostering a culture of innovation and productivity by eliminating non-value-added activities. This approach aims to create value and reduce waste, driving organizations towards sustainable excellence, ultimately leading to improvedcustomer satisfaction and increased market competitiveness.

Figure 6

Five Principles of Lean Methodology

Image Source: https://theleanway.net/The-Five-Principles-of-Lean

The researchers utilized lean methodology due to the project's nature, involving experimental modeling, modifications, and evaluations to achieve an outcome that addresses the study's objectives

Define Value. Defining the value of the study is base on the objective and methods that was utilized through the whole research.

The researchers utilized this phase to set the foundation for generating diverse urban Philippine houses using procedural modeling and integrating earthquake damage effects into these models.

Map the Value Stream. Mapping the value stream involves selecting the software and techniques to model

Philippine residential structures.

The researchers searched for relevant data that was found through methods such as literature review and empirical research, focusing on procedural modeling techniques, earthquake damage simulations, and the characteristics of urban Philippine houses. By thoroughly planning and mapping out these steps, the researchers ensured that all necessary processes were covered and avoided unnecessary steps, thus reducing waste.

Create a Flow. Creating a flow ensures that the best method flows into the next phase. This keeps the project moving smoothly by selecting the most effective technique for simulating earthquake damage.

The researchers adjusted the simulation parameters by comparing two techniques (Voronoi and RBD), this ensured that the Richter scale is accurately modeled, reflects real-world scenarios, maintaining a smooth flow of accurate data and results through the research process.

Establish Pull. Establishing a pull by focusing on real-world applicability of the fracture techniques and adjusting the models based on actual damage simulations.

The researchers ensured that the work was driven by actual data and needs, rather than hypothetical scenarios, calibrated earthquake impact simulations by basing the simulations on the Richter scale, and aligned the research output with real-world needs and demands, ensuring that the findings are relevant and useful.

Pursuit Perfection. Seeking perfection throughout all phases is important in creating a more accurate model and better outcome of data.

The researchers were constantly refining and calibrating the models based on new data and comparisons. This continuous improvement approach ensured that the research outcomes are as accurate and reliable as possible.

Scope and Delimitation of the Study

The scope of this research is specifically focused on the Philippines, aiming to simulate post-earthquake damage in Philippine urban traditional homes using procedural modeling.

The delimitation of the study extends to several key constraints, notably that the Resquake: Simulating Post-earthquake Damage in Philippine Homes Using Procedural Modeling is not a stand-alone software. It depends on the exclusive use of a free and non-licensed version of Houdini software. However, the final output of this study includes a user interface that is available for download as part of the Resquake software package.

The limited time frame allotted for the research completion confined the researchers, which inevitably restricts the study, limiting the thoroughness of simulations, effects, and the extent of data analysis. This time constraint may also impact the iterative process of model refinement and the ability to conduct extensive validation of the simulated results.

Moreover, utilizing a non-licensed version of Houdini might limit access to advanced features, possibly affecting the sophistication and detail of the earthquake damage simulations. These factors collectively define the boundaries of the research, framing its capacity to explore and interpret the post-earthquake scenarios within these specified limitations.

Furthermore, the post-earthquake simulations, which were derived from existing images manually collected by the researchers, have inherent limitations. Specifically, these simulations focus solely on the damage to walls and beams while the roofs of the houses remain intact. Due to the lack of comprehensive data on Philippine homes, the simulations do not include damage to roofs and doors, which only determine the private and public zones and were not considered for the strength of the house.

Additionally, the study focuses solely on general urban Philippine house designs and does not apply to modern house designs. The simulations are also limited to exterior walls and beams, with no consideration of interior walls and beams. Moreover, the researchers aimed to recreate the aftermath impacts of tectonic earthquakes within their simulations.

Data Gathering Techniques

The data-gathering techniques of this research employed a combination of techniques tailored to harness a comprehensive understanding of post-earthquake damage simulation in Philippine homes using procedural modeling. These techniques are pivotal in collecting relevant data and insights that inform the research analysis and outcomes that answered the statement of the problem of this study.

Document Analysis. The first technique involves an extensive review of related literature and existing studies. This encompasses a thorough examination of scholarly articles, journals, conference papers, and existing research related to procedural modeling, earthquake simulations, and the structural characteristics of Philippine homes. This review aims to gather existing knowledge and findings that provide a theoretical foundation and contextual background for the study. It helps in understanding the current landscape of earthquake damage simulation technologies and identifying gaps to which this research can contribute. The insights derived from these studies are instrumental in shaping the research framework, defining its objectives, and refining its methodology.

Web Scraping. The second technique is manual web scraping, which involves systematically collecting data from various online sources. This process is crucial for acquiring specific data sets, such as Philippine house floor layouts and images depicting the aftermath of earthquakes, including examples of damage scales corresponding to different magnitudes on the Richter scale. This manual scraping targeted the architectural websites, disaster management databases, and digital libraries to gather visual references and structural designs pertinent to Philippine residential architecture. The collected data is instrumental in creating realistic procedural models and simulating accurate earthquake damage effects. By analyzing these layouts and images, the study aims to enhance the authenticity and relevancy of the simulated models, ensuring they reflect actual Philippine housing characteristics and the tangible impacts of seismic activities.

Sources of Data

The research relies on meticulously chosen sources of data to ensure a comprehensive and authoritative foundation for the study. These sources are instrumental in providing both theoretical background and empirical data necessary for the research's successful execution.

Academic Repositories. The primary source of data comes from an extensive array of online research libraries and digital repositories. Esteemed platforms such as ACM Digital Library, ResearchGate, arXiv, Elsevier, Wiley, MDPI, Clemson, IOP, and Google Scholar are considered pivotal resources. These libraries offer a wealth of peer-reviewed articles, conference papers, journals, and academic publications, providing a rich reservoir of existing knowledge, previous studies, and scholarly discussions pertinent to procedural modeling, earthquake simulations, and architectural studies focused on the Philippines. Utilizing these platforms allows the research to be grounded on validated scientific findings and global expertise, ensuring that the study's framework, methodology, and subsequent analyses are informed by credible and high-quality scholarly work.

Google Images. For visual data and comparative analysis, Google Images served as a crucial source. This platform is used to manually collect a diverse range of images, including Philippine house floor layouts, earthquake-damaged houses, post-earthquake damage illustrations, and Richter scale representations. These images are essential for the study as they provide real-world examples that support the simulation models, enhance the visual accuracy of the damage predictions, and offer a basis for validating the procedural modeling outcomes. The visual data gathered from Google Images had been instrumental in refining the simulation parameters, ensuring the modeled scenarios closely mirror actual earthquake effects, and providing a tangible comparison between the simulated results and real-world earthquake impacts.

Philippine House-Selling Websites. Images sourced from websites such as PhilConPrices and Pinoy Eplans were crucial for this study. These websites provide valuable information on house designs, construction materials, and floor layouts prevalent in Philippine urban residential structures. By analyzing images from these platforms, researchers gained insights into current construction and design innovations in Philippine housing, complementing the academic and visual data with practical examples. This enriched understanding facilitated a more comprehensive examination of the relationship between architectural trends and seismic vulnerability, contributing to more informed assessments of earthquake-resilient design strategies within the Philippine context.

SideFX Houdini Apprentice. This software was used by the researchers as their main software to use in performing the simulations of the whole study. Houdini Apprentice provide the procedural modelling techniques that can be used and modified by the users in simulation, and modelling of various materials. The features that the software provide is enough for the researchers to use and develop the ideas of this study.

Chapter 4

DISCUSSION OF FINDINGS

This section discusses the findings derived from the methodology, which involved procedural modeling to achieve the intended results. These findings are crucial for addressing the stated problems, which are outlined in the statement of problem. The discussion is structured into three sections, each addressing different aspects of the problems identified. This approach ensures a thorough exploration of how the methodology's results contribute to understanding and potentially solving the issues at hand.

Characteristics of a Philippine Urban Residential Structure

This section presents the findings of the experimental research conducted through review and analysis of related literature by the researchers to discover the characteristics of a Philippine urban residential structure.

Philippine urban residential structures primarily utilize concrete hollow blocks (CHB) for walls and reinforced concrete for beams and columns, showcasing durability, climate adaptability, and resource availability in construction choices, reflecting a practical approach to urban construction.

The reliance on reinforced concrete underscores its importance not only as a structural element but also as a fundamental component in the architectural fabric of the Philippines. Moreover, the prevalence of gabled roofs, alongside other roof designs, reflects a practical approach to construction, balancing cost and durability while adapting to local conditions.

The integration of traditional design elements with modern architectural concepts further emphasizes a dynamic evolution in Philippine architecture, responding to functional requirements and aesthetic preferences. Notably, features like elevated floors and open ventilation systems highlight a sophisticated response to the local climate, blending tradition with modernity to enhance living conditions. These characteristics serve as the foundation for diverse Philippine house models, illustrating the versatility and innovation inherent in Philippine urban residential architecture, shaping the understanding of its distinct characteristics which answers the SOP 1.

Table 1

Characteristics of Philippine Homes

Characteristics of Philippine	Takeaways	Reference

Homes		
Concrete Hollow Blocks (CHB)	CHB is a staple in Philippine urban residential structures due to its adaptability and effectiveness in both structural and aesthetic roles.	Canlas et al., 2021; Imai et al., 2015; Ignacio et al., 2020; Bornales et al., 2022; Ongpeng & Umali, 2023; Martín-Morales et al., 2017; Elbashiry et al., 2023; Ismaeel & Mohamed, 2023; Nasreldin & Ibrahim, 2022
Concrete Wall	Philippine urban residential structures predominantly use concrete hollow blocks (CHB) for walls. This choice highlights CHB's adaptability to various design requirements and its effectiveness in meeting structural and aesthetic needs. The construction materials reflect a combination of traditional and modern elements. Concrete is widely used due to its durability and availability. The use of concrete reflects practical responses to environmental challenges and urban development needs, highlighting durability	Martinez, 2017; Stubbs & Thompson, 2016; Malaque III et al., 2015; Kliment, 1977; Hadlos et al., 2023; Venable et al., 2021; Ray, 2019; Carrasco et al., 2016; Kliment, 1977

	and availability as key factors.	
Concrete Beams and Columns	Reinforced concrete is the predominant material used for beams and columns, ensuring the structural integrity of buildings. This approach is essential for urban architecture.	Lejano, 2021; Roxas et al., 2023; Ashfaq, 2023; De Jesus, & Borais, 2019; Bautista et al., 2023; Ayala Laverde, 2023; Osundina, 2021; Martínez-Rocamora et al., 2021; D'Ayala et al., 2020; Bornales et al., 2022; Maribbay, 2000
Roof Material	Tin is commonly used for roofs in extended houses, balancing cost and durability. The use of tin for roofs in combination with CHB walls shows a pragmatic approach to balancing cost and durability in urban residential construction.	Bredenoord, 2024; Ballesteros et al., 2023; Iyer et al., 2023; Zafra et al., 2021; Venable et al., 2021; Anderson, 2019; Asube et al., 2021; Soares et al., 2019; Seike, 2018
Roof Design	Gabled roofs are prevalent, with a pitch of 16.7°. Roof design variations include gable roofs, mono-slope roofs, and hip roofs, catering to different environmental, aesthetic, and functional requirements.	Pantua, Calautit, & Wu, 2019; Tan et al., 2021; Venable et al., 2021; Enteria, 2016; Song et al., 2020; Mabborang et al., 2022; Garciano et al., 2013; Acosta et al., 2021; Eleftheriou, 2022

Table 1 offers a comprehensive analysis of the distinctive features found in Philippine urban residential structures. It outlines key aspects such as construction materials, architectural designs, and their practical implications, providing valuable insights into local housing trends and practices.

Philippine urban homes are characterized by their pragmatic use of durable and readily available materials, such as CHB and reinforced concrete, to address structural integrity and aesthetic versatility, often reflecting a balance between functionality and affordability. Roof designs typically prioritize functionality and cost-effectiveness, with gabled roofs being the most prevalent. This blend of traditional and modern elements reflects a practical approach to meeting environmental challenges and urban development requirements.

Procedural Modeling Techniques in Generating Diverse Procedural Philippine Houses With Earthquake Effects

This section delves into the discussion of procedural techniques used to generate Philippine houses, as previously discussed in the section on earthquake damage effects. Table 2 summarizes the key points from the review of related literature on procedural modeling techniques.

Table 2

Procedural Modeling Techniques and Their Applications

Procedural Modeling Technique	Description	Applications
L-system	Formal grammars for modeling complex systems, especially plant growth patterns.	1. Urban planning (layout symmetry, varied building layouts), 2. Gaming (room shapes, multilevel dungeons), 3. Random architectural floor plan generation.
Voronoi fracture	Fragmentation method based on Voronoi diagrams, creating realistic fracture patterns.	1. Visual effects (object shattering), seismic damage simulation in concrete, geological modeling
RBD material fracture	Realistic fracturing of solid materials within simulations, allowing for customizable fracture patterns.	1. Visual effects (destruction simulations, fracturing models) 2. Material behavior simulations (e.g., glass, concrete)
Particle systems	Versatile tool for simulating complex phenomena like water waves and dynamic foliage growth.	1. Procedural water wave animation, automated 3D tree generation 2. Dynamic environmental

		effects in virtual environments (e.g., wind, fire)
Cellular Automata	Grid-based models using simple rules to simulate complex behaviors and patterns.	1. Urban growth modeling 2. Land-use change simulations 3. Generation of cave levels in games
Perlin Noise	Spectral synthesis algorithm for generating smoothing effects and coherent randomness.	1. Procedural terrain generation 2. Texture generation (e.g., water, marble) 3. Landscape modeling

Table 2 presents various procedural modeling techniques, including L-systems, Voronoi, RBD material fracture, particle systems, cellular automata, and Perlin noise. The detailed descriptions of these techniques and their applications provided crucial insights, enabling the researchers to determine the most suitable procedural modeling technique for the study's objectives.

This table illustrates that the procedural modeling technique L-systems is the most suitable for this study due to its alignment with the aim of generating diverse urban Philippine houses. L-systems offer the capability to model complex and branching architectural structures, making them ideal for creating varied house layouts of urban homes.

Additionally, table 2 highlights that Voronoi fracture and RBD material fracture techniques are the closest in replicating earthquake damage effects. These techniques excel in simulating realistic fracture patterns and material behavior, making them valuable tools for modeling earthquake-related scenarios in the context of urban environments.

On the other hand, cellular automata and Perlin noise, while versatile in other applications, may not be as directly applicable to the specific goals of generating diverse urban houses and replicating earthquake damage as L-systems, Voronoi fracture, and RBD material fracture techniques are, which offer a more precise and controlled approach to modeling complex structures and their destruction.

To foster diverse urban Philippine housing designs, the methodology hinges on procedural generation. The process commences with the deployment of the "Floor Layout Randomizer" network, powered by the “lsystem1” node in figure 7. This node harnesses L-system algorithms to intricately map out line paths, serving as the blueprint for Philippine house models. Through iterative transformations, refinements, and duplications, these paths evolve into a myriad of randomized floor layouts. This approach forms the cornerstone for developing distinctive and progressive housing designs that cater specifically to the urban environments prevalent throughout the Philippines.

By leveraging these techniques, the researchers aim to innovate within urban planning by offering novel solutions that blend functionality with cultural and architectural diversity, enriching the fabric of urban landscapes across the Philippines.

Figure 7

Floor Layout Randomizer Nodes

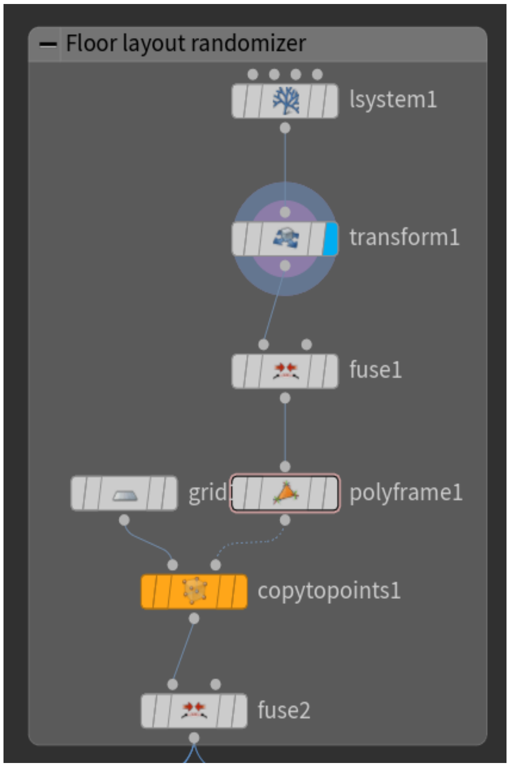
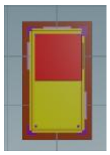
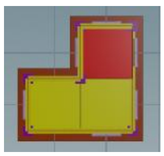
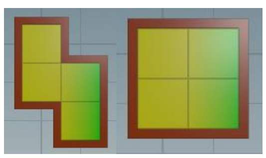
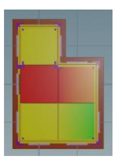
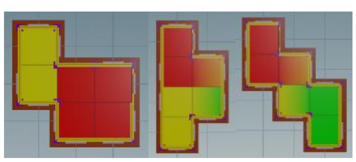
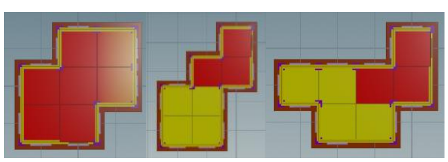
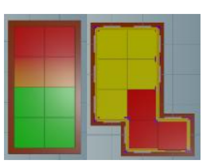


Figure 7 shows the node connections, starting with an L-system to generate basic patterns. This serves as the main node for randomizing the floor layouts of the model generator, which is then subsequently processed through several nodes to achieve an architectural floor layout, as shown in Table 3.

Table 3

Generated Floor layout Grids Legend

Grid Number	Generated Floor Layout Image
Two grids	
Three grids	
Four grids	
Five grids	
Six grids	
Seven grids	
Eight grids	

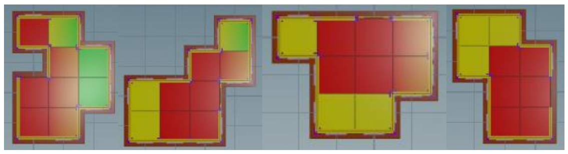
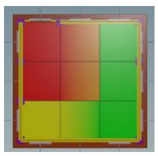
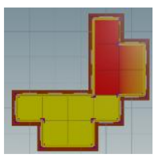
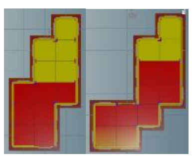
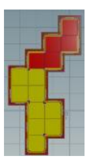
Nine grids	
Ten grids	
Eleven grids	
Twelve grids	
Fourteen grids	

Table 3 illustrates various floor layouts generated using different stochastic rules. It's noteworthy that despite the variations in rules, certain floor layouts appear identical, differing only in their orientation (rotated by 90, 180, 240, or 360 degrees). To facilitate analysis, floor layouts were categorized based on their underlying structural patterns, irrespective of their rotational orientation. This summarization accounts for the similarities observed in the layouts. Such findings highlight the robustness of the design algorithms, ensuring consistent layout patterns.

As discussed by Adão et al., 2019 of the l-system rules, table 4 provides the count for the models corresponding to different stochastic rules tested by the researchers.

This l-system rule used by the researchers starts with a symbol 'A' and changes 'A' using simple rules. The rules say that 'A' can become 'F+A:0.1' or 'F-A:0.1'. Each time a rule is used, the pattern grows. For example, starting with 'A' and using the first rule, 'A' turns into 'F+A:0.1'. If the rule is used again, the pattern becomes 'F+F+A:0.1:0.1'. Each step makes the pattern longer and more detailed.

The rules change by increments of 0.1, where 'F' indicates a forward movement and 'A' represents an angle adjustment. The +0.1 means a 10 degrees of turning right. The -0.1 means a 10% degrees of turning left. The test results are shown in table 4.

Legend for Table 4:

Axiom: A which is the starting variable

F: indicates forward movement.

-/+: represents the turning to (-)left or (+) right.

A:#.#: is the decimal equivalent of the angle

Table 4

L-system Rules and Findings

L-system Rules	Frame Number of the Corresponding Grid Count	Total number of models
Rule 1: A=F+A:0.1 Rule 2: A=F-A:0.1	2 grid - 2, 4, 5, 18, 31, 34, 37, 39 3 grid - 8, 27 4 grid - 30	11 over 51
Rule 1: A=F+A:0.2 Rule 2: A=F-A:0.2	2 grid - 3, 4, 5, 6, 11, 18, 23, 31, 34, 37, 39, 42, 50 3 grid - 8, 25, 27, 45 4 grid - 2, 30, 32	18 over 51
Rule 1: A=F+A:0.3 Rule 2: A=F-A:0.3	2 grid - 3, 4, 6, 11, 14, 19, 21, 28, 34, 37, 39, 42, 50 3 grid - 5, 7, 8, 25, 27, 31, 33, 36, 38, 45 4 grid - 2, 18, 30, 32 6 grid - 17 7 grid - 23	29 over 51
Rule 1: A=F+A:0.4 Rule 2: A=F-A:0.4	2 grid - 4, 14, 29, 35, 37, 40, 42, 50 3 grid - 5, 21, 31, 33, 34, 38, 39, 47 4 grid - 0, 22, 28, 30, 32, 41, 43, 45 5 grid - 2, 8, 27 6 grid - 3, 6, 11, 17, 18, 19, 36 7 grid - 7, 13, 44, 46, 49 8 grid - 10, 25 11 grid - 9, 23	43 over 51

Rule 1: A=F+A:0.5 Rule 2: A=F-A:0.5	2 grid - 29, 40 3 grid - 31, 33, 47, 4 grid - 24, 30, 45 5 grid - 4, 18, 34, 39, 42 6 grid - 19, 36, 43, 44, 46, 49, 50 7 grid - 0, 7, 10, 13, 23, 41 8 grid - 1, 3, 6, 9, 11, 21 9 grid - 5, 9, 12, 15, 20, 26, 27, 32, 37, 48 10 grid - 28, 35, 38 11 grid - 14, 22 12 grid - 2, 17, 25 14 grid - 16	51 over 51
Rule 1: A=F+A:1 Rule 2: A=F-A:1	2 grid - 29, 40 3 grid - 31, 33, 47 4 grid - [all the remaining 46 models]	51 over 51

Table 4 displays the model numbers corresponding to different grid counts for each stochastic rule. For instance, using the 0.1 rule, grids of sizes 2, 3, and 4 were generated, resulting in 11 different versions out of the expected 51 models. The 0.2 rule produced grids of sizes 2, 3, and 4 with 18 different variations out of the 51 expected models. Similarly, the 0.3 rule resulted in 5 different grid counts: 2, 3, 4, 6, and 7, generating 29 models out of the expected 51. Rule 0.4 generated grids of sizes 2, 3, 4, 5, 6, 7, 8, and 11, with 43 different versions out of the expected 51 models. Notably, rule 0.5 produced the most number of models with 12 grid counts: 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 14, meeting all 51 expected models. Lastly, rule 1.0 generated 3 grids, meeting the expected 51 models.

This analysis underscores that rule 0.5 generated the highest number of grids and successfully met the expected 51 models, indicating its effectiveness in producing diverse floor layouts. The diversity and complexity of the layouts produced, as presented, underscore the rapidity and efficiency inherent in procedural generation techniques. Not only does this method allow for a wide variety of designs to be created quickly, but it also demonstrates that procedural generation can significantly expedite the design process when compared to traditional methods.

Figure 8

L-system Modified Rules

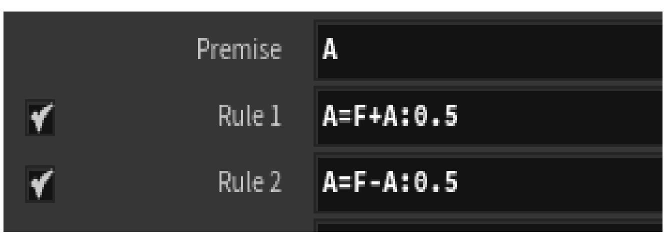


Figure 8 illustrates the derived rules of an L-system from Table 4 to be used in the final model. In both Rule 1 and Rule 2, the starting point is established with a single variable 'A'.

Rule 1 is defined as A=F+A with a probability of 0.5. This means that each instance of 'A' in the string has a 50% chance of being replaced with 'F+A'. Here, 'F' indicates a forward movement, and '+' represents a right turn. So, whenever 'A' is encountered, there is a 50% chance that it will be replaced by a sequence that moves forward and then turns right.

Similarly, Rule 2 specifies A=F-A, also with a probability of 0.5. This means that each instance of 'A' has a 50% chance of being replaced with 'F-A'. In this rule, 'F' again indicates a forward movement, but '-' represents a left turn. Therefore, each 'A' in the string might be replaced by a sequence that moves forward and then turns left.

Figure 9

L-system Geometry Parameters

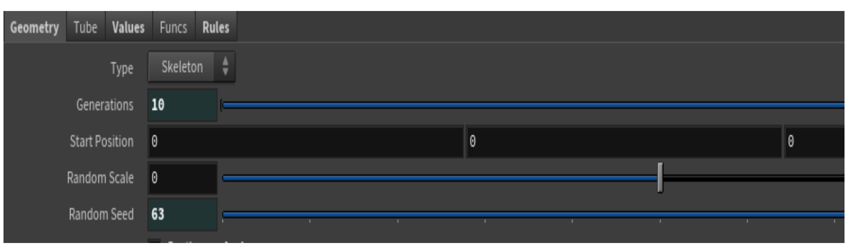


Figure 9 illustrates the Geometry Node, which governs two main parameters: the Generation parameter and the

Random Seed parameter. The Generations parameter specifies the number of paths to be generated, serving as a control for the extent of the output. Meanwhile, the Random Seed Parameter functions as the randomizer, introducing variability and uniqueness into the process by altering the seed value used in the generation algorithm.

The Transform Node, in figure 7, adjusts the "Lsystem" generated paths by rotating them to align with the x-axis, ensuring that the pattern growth is oriented along this axis. Then Fuse Node takes the individual generated paths and connects them, creating a continuous line. Following this, the Copypoints node duplicates the grid onto the fused lines, which have been structured by the Polyframe. The Polyframe node is responsible for calculating the coordinated frames necessary for this process. Lastly, the Fuse Node reappears, this time to connect the grids that have been generated, solidifying the complex network of paths into a unified structure.

With the generated empty houses, based on the size ratio of the room and the total area of the building, the researchers can estimate the desired area of the room. After generating the Floor layouts, starting from the front door, public rooms are added (Lopes, 2010) and the left space as Private Zones depending on the number of floors.

Figure 10

Algorithm for 1-Storey House Division

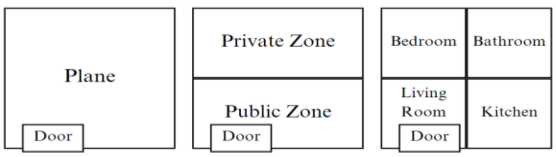


Figure 10 illustrates a floor layout division algorithm, categorizing spaces into Public and Private zones. The Public zone, defined by door position, includes a Living Room and Kitchen, while the Private zone contains a Bedroom and Bathroom.

Figure 11

Algorithm for 2 or more Storey House Division

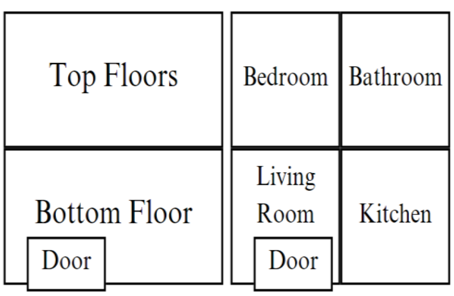


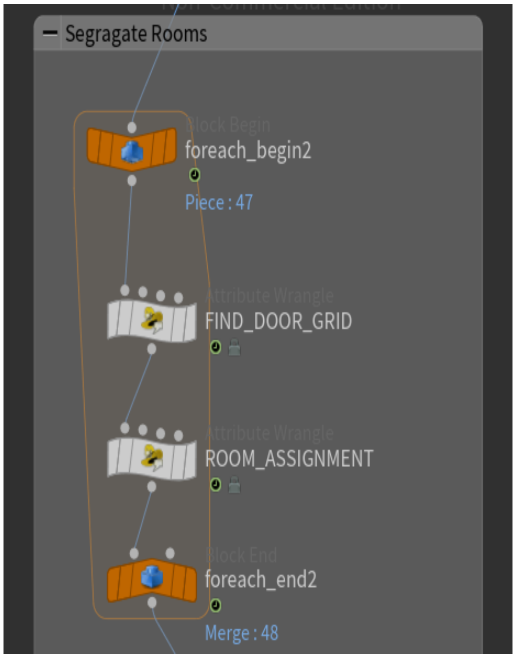
Figure 11 detailed a corresponding Floor Layout Division algorithm for multi-story houses, applicable when the number of floors exceeded one. It categorized the first floor entirely as a Public space, which included a Living Room and Kitchen, typically near the entrance. The algorithm then designated the remaining floors exclusively as Private spaces, composed of Bedrooms and Bathrooms.

Figures 10 and 11 illustrate a rule-based algorithm used in a procedural modeling system to create architectural floor plans. This method employs a treemap subdivision approach, where a rectangular polygon is divided into smaller sections using intersection and dimensioning operations. These steps ensure that the resulting floor plans have an efficient and well-organized house layout, facilitating easy navigation and optimal space utilization.

The research undergoes rigorous validation through the outlined procedures in figure 12, centering on room processing and assignment. It employs a two-step process for each room, as explained in the same figure. This structured approach ensures the accuracy and efficiency of room allocation, thereby improving the reliability and effectiveness of the entire methodology. The results of this validation demonstrate that the algorithm consistently produces functional and aesthetically pleasing floor plans. Future enhancements will aim to incorporate additional design constraints and preferences to further refine the generated layouts, potentially exploring user-defined room shapes, sizes, and spatial relationships to enhance customization.

Figure 12

Room segregation Nodes



In the "foreach" step, the "find_door_grid wrangle node" plays a crucial role by precisely determining the grid coordinates of a door within a room. This initial step is critical as it provides the system with vital insights into the room's layout, particularly regarding access points. Pinpointing the grid location of the door is essential for subsequent procedural generation tasks, ensuring they accurately consider its placement. This information directly influences the flow and functionality of the space, contributing significantly to its overall design and usability, and coherence.

After identifying the door grid using the 'find_door_grid wrangle node,' the 'room_assignment wrangle node' is used. This node assigns each room a specific function or type based on a set of criteria or algorithms. This classification is crucial as it organizes the spaces according to their intended uses, ensuring they are effectively utilized in the later stages of procedural generation.

By implementing the room division method detailed in Figure 12, the sample models generated by the algorithm exhibited enhanced efficiency and accuracy in spatial allocation. These findings validate the efficacy of the proposed methodology for optimizing interior layouts in architectural design, as documented in Table 5. The systematic approach ensures that spatial organization meets functional requirements in various architectural contexts , thereby enhancing the overall quality and usability of the generated spaces.

Table 5

Sample models applying the room division algorithm

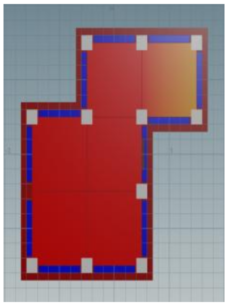
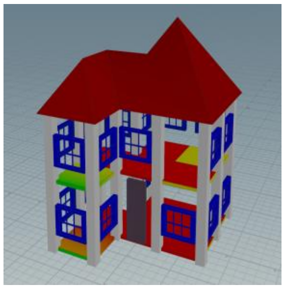
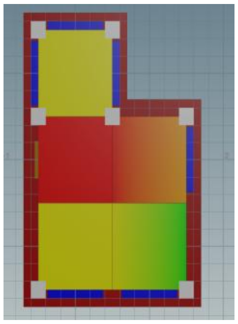
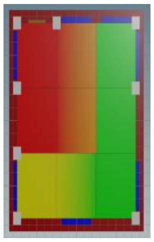
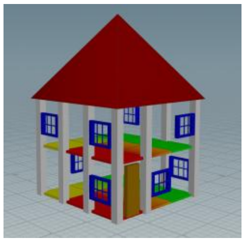
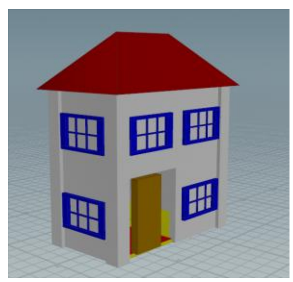
Floor Layout applying the Floor Division	Procedural Generated Houses
	
	
	

Table 5 compares the generated floor layout (left) with the extruded house model (right). The left side shows the procedurally generated floor plan, while the right side displays the corresponding 3D model, illustrating the framework's ability to translate 2D designs into 3D forms. This comparison illustrates the framework's ability to procedurally generate both detailed floor plans and corresponding 3D house models, demonstrating its effectiveness in turning design concepts into visual forms.

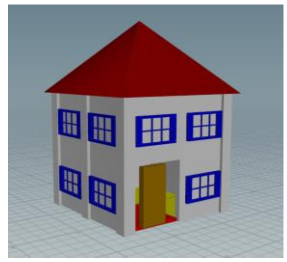
Table 6

Philippine Houses and Procedural House Generated Models

Philippine Houses	Philippine Houses Images	Procedural Generated Houses
2-storey single detached house no balcony for sale in Gapan Nueva Ecija	 Image Source: https://onepropertee.com/gapan-nueva-ecija-house-and-lot-for-sale	
2-storey(basement, 1st and 2nd floor) no balcony for sale house in Bakakeng Central, Baguio City	 Image Source: https://www.carousell.ph/p/baguio-1209013296/	
1-storey Bungalow Row House for sale in Economic Zone, Baguio City	 Image Source: https://onepropertee.com/rush-house-lot-property	

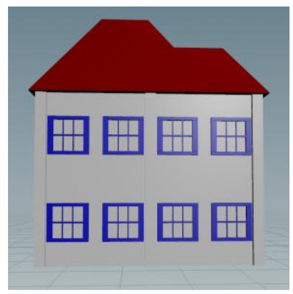
2-storey no balcony concrete house

Image Source: https://www.lamudi.com.ph/buy/pampanga/porac/house/swimming-pool/



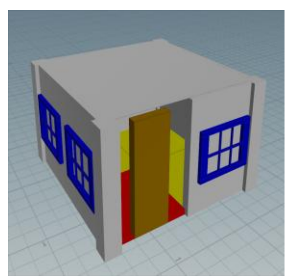
2-storey row attached house with balcony concrete house

Image Source: https://www.tripadvisor.com.ph/Hotel_Review-g294249-d941225-Reviews-Greenview_Lodge-Banaue_Ifugao_Province_Cordillera_Region_Luzon.html



Construction of a concrete house in a former rice paddy in Puerto Galera

Image Source: https://www.alamy.com/puerto-galera-philippines-dec-4-2018-construction-of-a-concrete-house-in-a-former-rice-paddy-due-to-population-growth-and-urban-expansion-image407722851.html

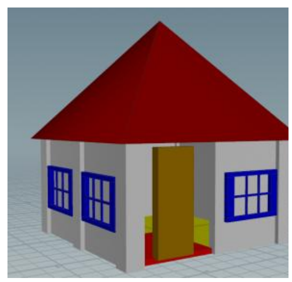


1-storey row bungalow house

Image Source: https://www.redcross.org/about-us/news-and-events/news/2018/typhoon-haiyan-5-years-on-in-the-philippines.html

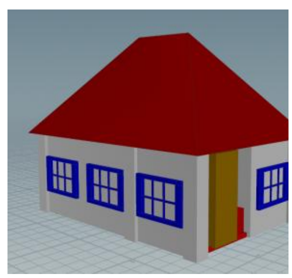
A bamboo construction eco-system for social housing in Negros Occidental, Philippines

Image Source: https://www.hiltifoundation.org/projects/sustainable-social-housing-in-the-philippines



1-storey concrete unfinished bungalow house

Image Source: https://topcebucontractors.info/basic-house-construction-guideline-handbook-in-the-philippines/nggallery/page/2/slideshow



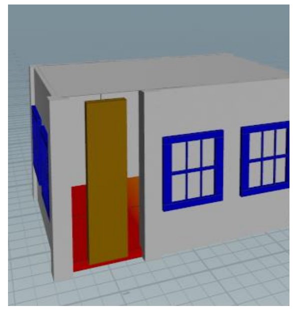
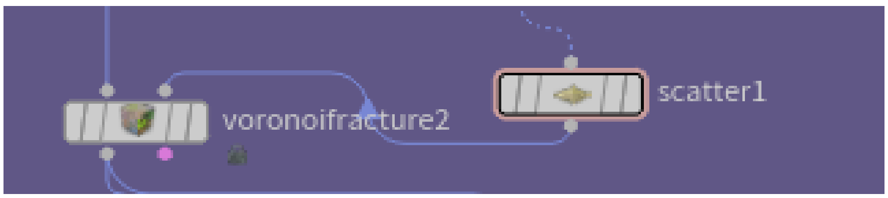
1-story No Gabled roof unpainted concrete house	 Image Source: https://www.iccsafe.org/building-safety-journal/bsj-technical/how-much-does-resilient-housing-cost/	
2-storey Single Attached No balcony for sale in New City Cavite	 Image Source: https://pinoydeal.ph/real-estate/lancaster-new-city-cavite-colleen-ready-home_i25109#google_vignette	

Table 6 compares manually scraped images from Google with Philippine houses modeled using the techniques discussed in the methodology. This comparison highlights the significant capability of the study's proposed framework to convert real-life Philippine houses into detailed 3D models.

The Voronoi Fracture and RBD Material Fracture was used for creating the earthquake damage effect. By creating procedural models and applying the earthquakes procedural modeling damage effect on the houses, researchers aimed to answer the SOP2.

Figure 13

Scatter node connected to the Voronoi node



In Voronoi fracture nodes and the scatter node is the key node that can be modified and enhanced. This is connected to the Voronoi fracture node.

Scatter node parameters can be adjusted to increase the damage cracks and breaks depending on the magnitude that is simulated.

Figure 14

Scatter node parameter

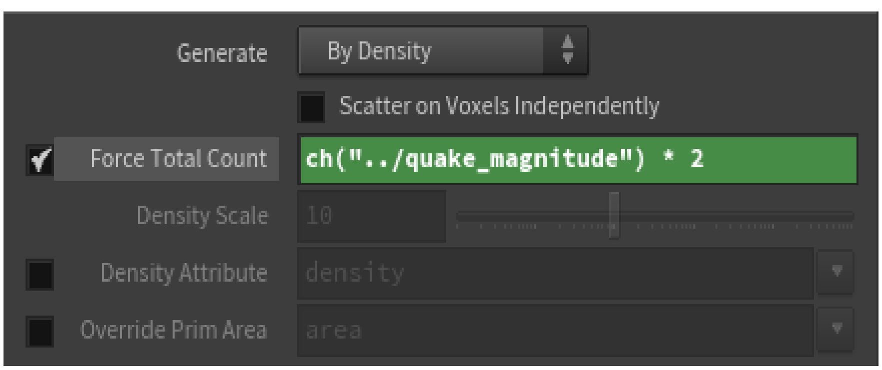


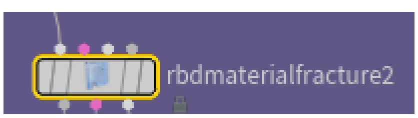
Figure 14 shows the parameter that is modified in the scatter node. Inside the 'Force Total Count' is a value that increases the cracks and damage effect of the simulated model. The ch("../quake_magnitude") is referencing from the magnitude level ranging from 1 to 10. This value then is multiplied by 2 which results in increased cracks and damage on the model.

In analyzing the RBD Material Fracture as discussed in the RRLs reveals that the effects are highly realistic in terms of physical behavior, as the pieces interact with each other the quality often depends on the parameters set in the simulation, such as material strength, collision force, and constraints.

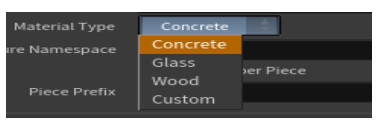
Figure 15

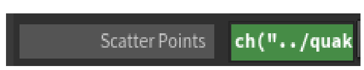
RBD Material Fracture Node and Parameter

RBD Material Fracture Node



RBD Material Fracture Parameter





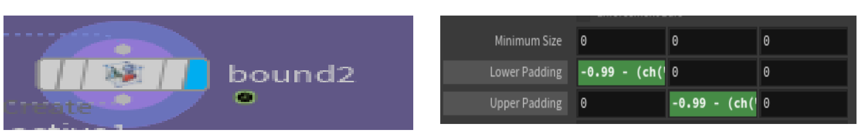
The Figure 15 shows the RBD Material Fracture Node and its parameters. Under the RBD Material Fracture parameters the 'Material Type' is a parameter where you can choose what type of material should be applied. This specific parameter is what differentiates it from Voronoi Fracture where it applies the earthquake effects considering the material type.

The 'Scatter Points' showed in Figure 15 is similar to the 'Force Total Count' showed in Figure 14 of a scatter node where it is a value that increases the cracks and damage effect of the simulated model. The same formula is applied which is the the (ch("../quake_magnitude") * 2) which results in increased cracks and damage to the model.

Another node that is applied to both procedural modeling techniques is the bound node. This node generated a bounding box that encloses the input geometry. This bounding box is represented as a simple geometric shape, usually a box, that outlines the extent of the geometry.

Figure 16

Bound Node and Parameter

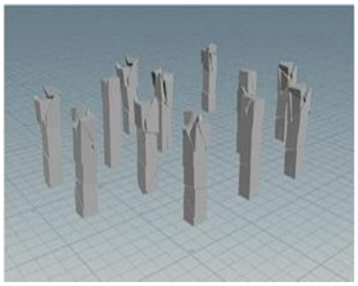
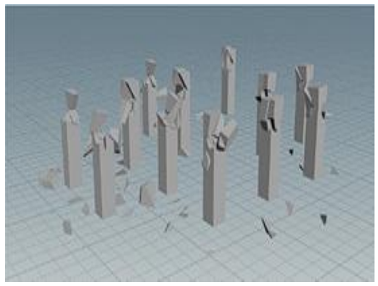


The bound node contains parameters that can be modified depending on the magnitude of the earthquake's effects. This parameter determines how large the area of the material should be affected by the damage effects to the model. The 'Lower Padding' left side has the same formula as the 'Upper Padding' center shown in Figure 16. The formula that was used was (-0.99 - (ch("../quake_magnitude")*-0.1)). The area of the damage effect on material can be increased depending on the magnitude level of the damage effect.

The result of the applied procedural modeling techniques to create a scenario was measured by their efficiency in terms of performance in generating diverse Philippines residential structures with a post-earthquake damage effect. The post-earthquake effect was applied to the beams and walls of the generated residential structure. Voronoi Fracture and RBD Material Fracture were tested separately and the outcome of both techniques is compared to one another.

Figure 17

Earthquake effects applied to beams

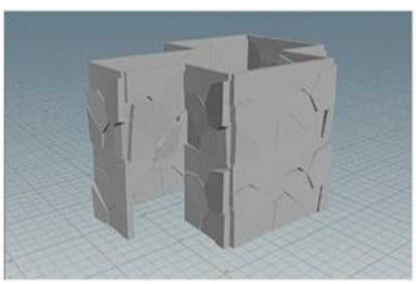
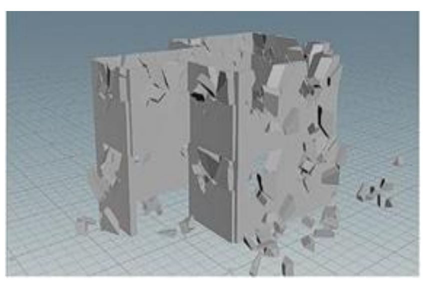



Voronoi Fracture RBD Material Fracture

Figure 17 illustrates a comparison between the Voronoi Fracture and RBD Material Fracture damage effects applied to the beams. These effects are evaluated for their application in the modeled Philippine houses, providing insight into how each fracture method impacts the structural integrity of the beams under simulated conditions.

Figure 18

Earthquake Effects Applied to Walls

Voronoi Fracture RBD Material Fracture

Figure 18 reveals the comparison between the Voronoi Fracture and RBD Material Fracture damage effect applied to the walls of the modeled Philippine house. In comparing test results of speed caching time, this can significantly impact performance and system efficiency.

Table 7

Test Results of Speed Caching Time

Procedural Modeling	Beam (Seconds)	Wall (Seconds)	Whole House (Seconds)
Voronoi Fracture	4.18s	4.34s	8.73s
RBD Material Fracture	4.41s	11.9s	23.14s

Table 7 showed the speed of caching time in seconds and comparing the results of the two procedural modeling techniques that are used based on the simulated material that it is being applied to.

The Voronoi Fracture's superior efficiency revealed that it is better suited for time-sensitive projects. On the other hand, Material Fracture's attention to material properties gives it longer processing times for simulations requiring detailed realism. Therefore, the choice of technique should consider both computational efficiency and the desired visual quality, depending on the project's specific needs.

Voronoi Fracture and RBD Material Fracture were implemented independently in distinct scenarios to facilitate a comparative analysis of their computational efficiency. By isolating each technique, the researchers were able to precisely measure and contrast their caching time performance over a standardized 100-frame benchmark, providing valuable insights into the real-time capabilities and resource utilization of both procedural modeling approaches.

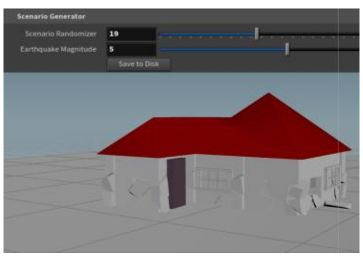
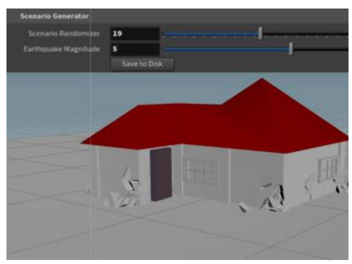
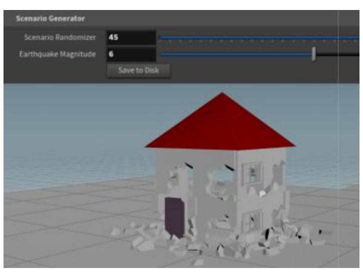
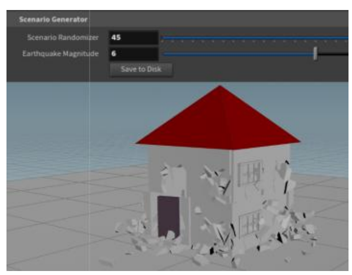
Procedural Post-earthquake Models Framework

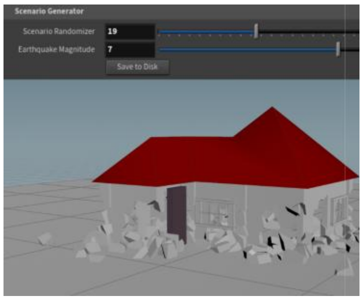
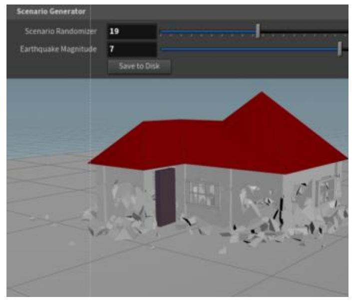
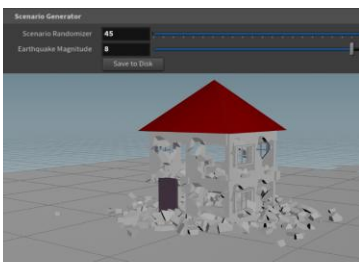
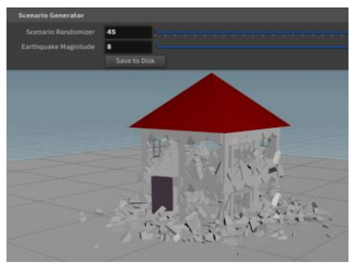
This section of the study aims to satisfy the Statement of the Problem three of the research by quantifying earthquake magnitudes using the Richter scale and correlating them with the corresponding severity of damage effects observed on generated Philippine house models. By simulating earthquakes of varying intensities and visually analyzing their impact on the procedural house models, the researchers sought to establish a correlation between the Richter scale magnitude and the level of structural damage, providing insights into the Philippine housing structures to seismic events.

Table 7 illustrates a Philippine residential structure with simulated post-earthquake damage effects. Magnitude levels from the Richter scale range from 5 to 8, detailed in Columns A and B. With increasing magnitude, damage severity proportionally intensifies. This systematic display effectively portrays the diverse impacts of seismic events on urban housing in the Philippines, providing valuable insights for disaster preparedness and mitigation strategies.

Table 8

Procedural Post-earthquake Models Using RBD Material Fracture & Voronoi Fracture

Magnitude Number	**Voronoi Fracture**	**RBD Material Fracture**
5		
6		

7		
8		

In Table 8, Voronoi and RBD material fracture techniques are used to demonstrate the impact of earthquake magnitudes on procedurally generated philippine house models. This table reveals a minor difference between the two techniques in terms of appearance. Applying the same earthquake magnitude to the same house model results in almost identical damage, yet there is a small but significant difference in the realism of the earthquake cracks.

When assessing the effectiveness of these simulations, the RBD Material Fracture method appears visually superior to the Voronoi fracture, as shown in Table 8. However, as indicated in Table 7, the Voronoi fracture exhibits significantly faster processing speeds compared to the material fracture technique. This trade-off between realism and processing efficiency suggests that each method offers distinct advantages depending on project requirements. Nevertheless, both methods provide viable options, offering a balance between efficient processing times and satisfactory levels of visual realism necessary for accurate earthquake damage simulation in urban housing contexts.

Figure 19

Final User Interface of the Model and Parameters

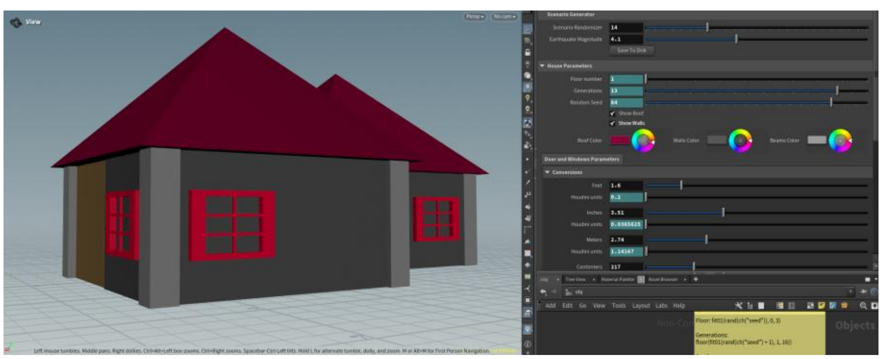


Figure 19 shows the final interface that the user will see after downloading Resquake. This interface is designed to be user-friendly and intuitive, allowing users to easily navigate through the various features and functionalities of the software. Each segment of the interface is carefully organized ensuring that users can efficiently access the tools and resources they need.

Figure 20 shows the Model Viewport can be rotated 360 degrees, allowing users to view the model from all angles. This functionality provides a comprehensive and detailed examination of the model, enabling users to closely inspect and analyze every aspect. Whether for design, review, or presentation purposes, the ability to rotate the viewport ensures that no detail is missed and that the model can be thoroughly evaluated from every possible perspective.

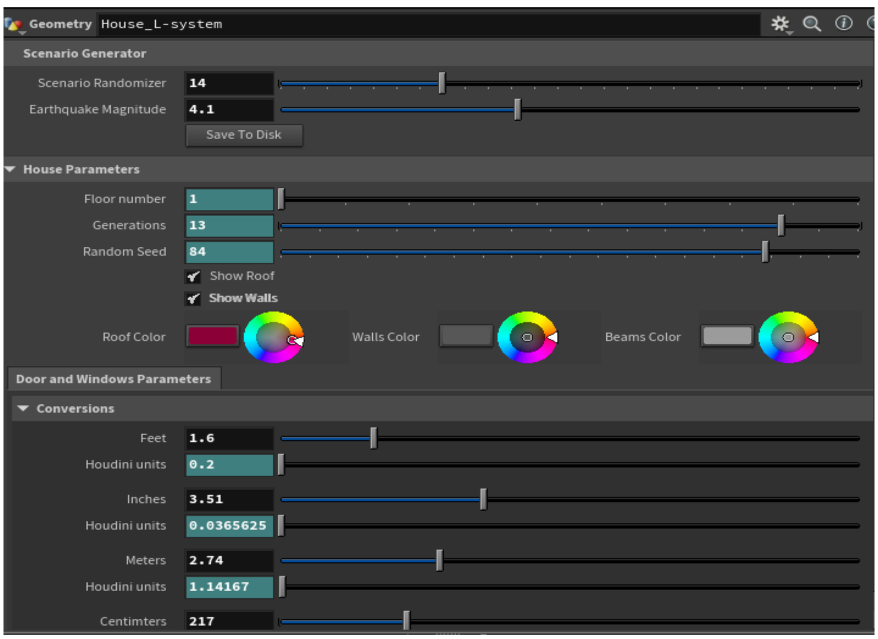
Figure 20

Model Viewport

The final user interface in the side panel of the system is shown in figure 21. This includes several key parameters, such as the Scenario Randomizer, Earthquake Magnitude, and House Parameters folder.

Figure 21

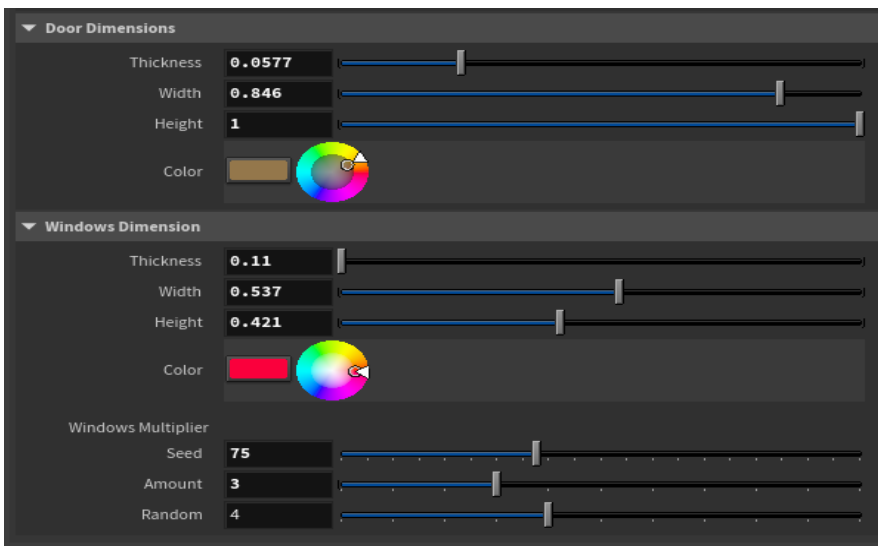
Parameters Side Panel



The House Parameters folder contains options for adjusting the Floor Number, Generations, and Random Seed using sliders, as well as checkboxes for Show Roof and Show Walls. Additionally, it includes color wheels for Roof Color, Walls Color, and Beams Color. Below this section is the Door and Windows Parameters folder, which contains the Conversions folder and settings for Door Dimensions and Window Dimensions. The Conversions folder provides options to convert units, including Feet to Houdini units, Inches to Houdini units, Meters to Houdini units, and Centimeters to Houdini units.

Figure 22

Parameters Side Panel continuation



The Door Dimensions folder contains sliders for adjusting Thickness, Width, and Height, as well as a color wheel adjuster for setting the color. Similarly, the Windows Dimensions folder includes sliders for Thickness, Width, and Height, a color wheel adjuster, and additional sliders for Seed, Amount, and Random.

Figure 23

Scenario Randomizer Parameters

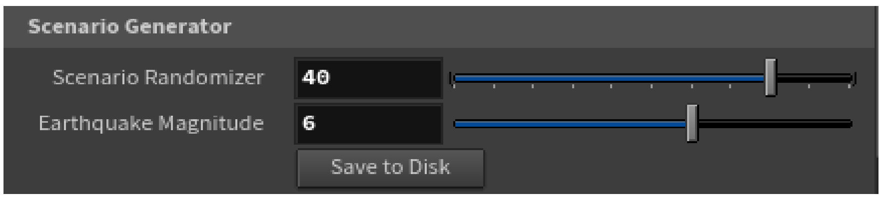


Figure 23 shows the final procedural parameters for the targeted model parameters in Resquake. The Scenario Randomizer slider allows the user to select different random houses displayed in the viewport. The Earthquake Magnitude slider enables the user to set the desired magnitude to be applied to the selected random house.

Figure 24

House Parameters

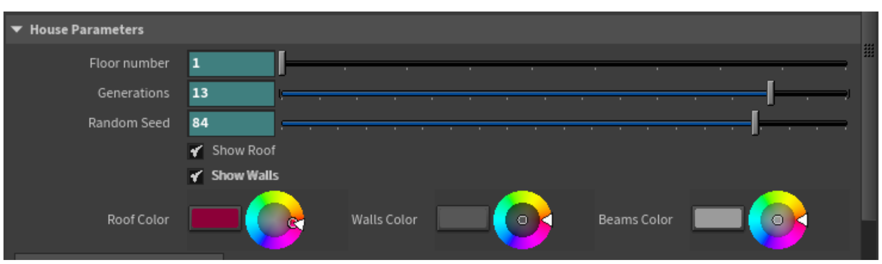


Figure 24 shows the house parameters that can modify the model. The Floor Number specifies the number of floors in the model, while Generations determine the quantity of grids generated. The Random Seed introduces variability in grid growth. The Show Roof Checkbox removes the roof when unchecked, and the Show Walls Checkbox hides the walls accordingly. Additionally, the Roof Color, Walls Color, and Beams Color options allow for customization of the roof, walls, and wall beams, respectively, based on the provided RGB values.

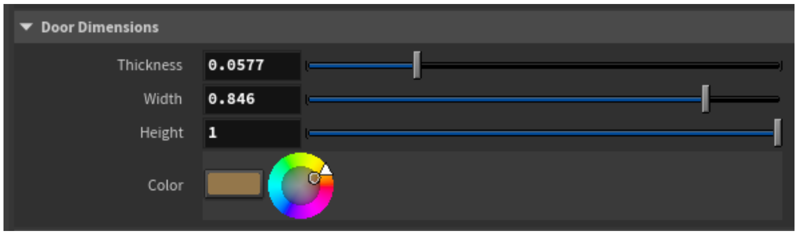
Figure 25

Conversion Parameters

Figure 25 displays the conversion parameters from feet to inches, meters to inches, and centimeters to inches that the user can use as a reference. These conversions are essential for ensuring accurate measurements in 3D modeling simulations, providing a convenient tool for users.

Figure 26

Door Dimensions Parameters



The parameters for door dimensions encompass a range of values: the thickness, the width, and the height. Additionally, the Color allows for more customization of the color of the door based on the user and the provided RGB values or adjustment in the color wheel.

Figure 27

Window Dimensions Parameters

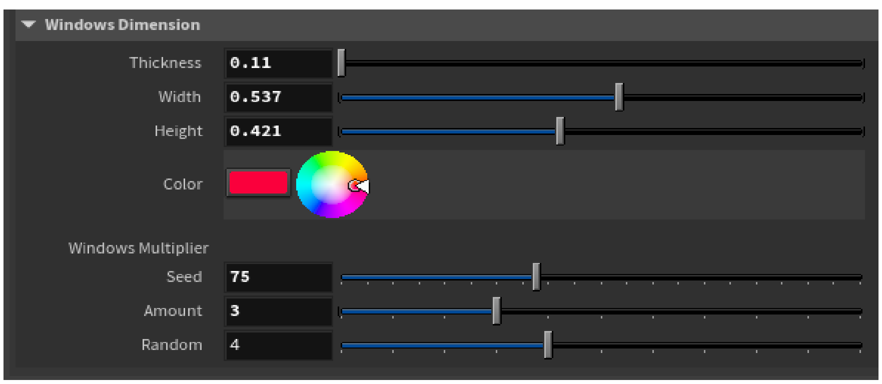
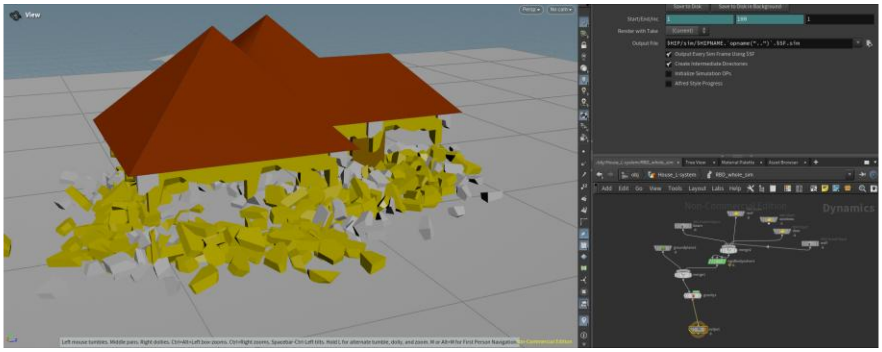


Figure 27 shows the window dimension parameters, which are adjustable based on the type of house being replicated. The first tab contains the window dimensions with sizing in inches. The Color allows for customization of the color of the window based on the provided RGB values or adjustment in the color wheel. The windows multiplier functions as a random controller, while the seed parameter governs randomness, including the starting spawn point. The amount parameter specifies the quantity of windows, and the random parameter determines the degree of randomness in window placement.

Figure 28

<u>After Applying Earthquake effects interface</u>

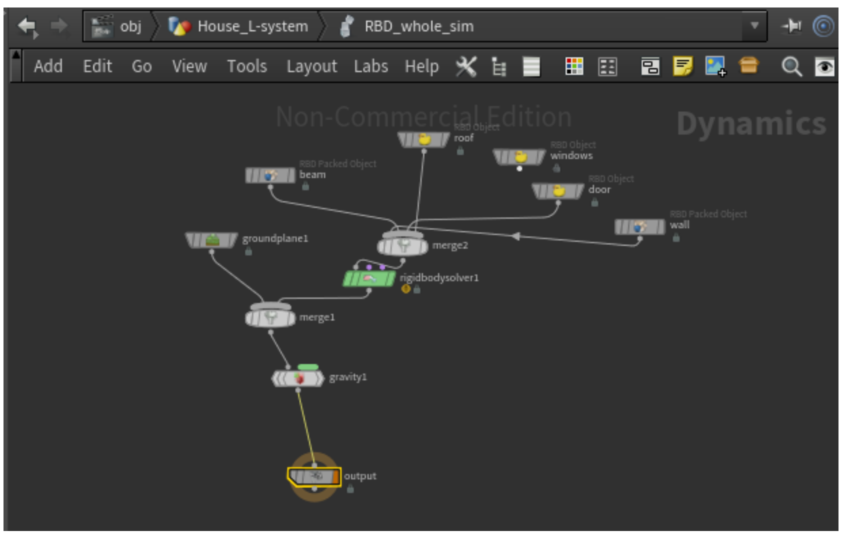


The above image illustrates the interface after applying the earthquake effect. This process involves selecting the desired magnitude using the slider, saving the configuration by clicking "Save Disk," and then initiating the simulation by pressing the play button. These steps ensure that the chosen parameters are accurately reflected in the simulated earthquake effect, providing a comprehensive visualization of the impact on the model.

Figure 29 Shows the inner nodes of the chosen earthquake effect technique to be able to play the simulation.

Figure 29

Earthquake damage effect node to play the simulation



By utilizing both RBD Material Fracture and Voronoi Fracture techniques, the researchers conducted a comprehensive comparison of real-life post-earthquake damage across various houses commonly found in the Philippines. These fracture methods effectively simulate and analyze how structural integrity is impacted under seismic stress, offering crucial insights into the vulnerabilities of different building types.

Figure 30

Sample comparison for Magnitude 6

Real World Sample RBD Material Fracture

The researchers manually scraped through the internet to find real life scenarios of post-earthquake damages in Philippine houses. The Magnitude 6 shown in figure 30 happened in southern part of the Philippines and this particular post-earthquake is caused by magnitude 6.

Figure 31

Sample comparison for Magnitude 7

Real World Sample Voronoi Fracture

The magnitude 7 in figure 31 shows the post-earthquake damage on the house also happened in the northern part of the Philippines and the damages are simulated to closely resemble the damage house cost by the magnitude 7 earthquake.

In conclusion, the comparison between the RBD Material Fracture and Voronoi Fracture techniques reveals that, while both methods effectively simulate earthquake damage on various house models, the differences in the resulting damage patterns are subtle. Voronoi Fracture, which generates cracks based on random cells from the Voronoi diagram, demonstrates faster performance due to its procedural efficiency. However, RBD Material Fracture offers more realistic and detailed simulations, particularly in replicating the way concrete cracks under stress, thanks to the advanced capabilities of Houdini software. Ultimately, the choice between these techniques may depend on whether the priority is speed and simplicity (Voronoi) or realism and accuracy (RBD Material Fracture).

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

This research held the potential to significantly improve post-earthquake preparedness and response efforts in the Philippines and other earthquake-prone regions.

Conclusions

1. The characteristics of a Philippine urban residential structure that the research have found through the systematic review of studies, showcases a strong preference for concrete materials and tin roofs. Floor layouts emphasize a clear division between public and private spaces with distinct areas dedicated to communal living and personal quarters.

Commented [1]: Relate these findings to simulation

2. The procedural modeling techniques applicable in generating diverse Philippine residential structures with post-earthquake damage effects include Voronoi fracture simulations and RBD material fracture methods. Voronoi fracture simulations enable the analysis of complex crack patterns in concrete, while the RBD material fracture method in Houdini allows for precise control over simulation parameters, ensuring the depicted damage closely aligns with potential real-world earthquake scenarios. The study validated the effectiveness of these techniques in

creating house models for earthquake simulation. The Voronoi Fracture method was identified as the optimal approach for modeling realistic earthquake-induced damages due to its superior speed and data efficiency, while the RBD method excelled in achieving detailed realism.

3. This study developed a conceptual framework for generating diverse post-earthquake simulation environments using procedural modeling techniques. The framework integrated Voronoi and RBD (Rigid Body Dynamics) Material Fracture parameters to model varying damage levels in Philippine urban house structures. By reviewing the characteristics and structures of these houses, the procedural generation of digital models was informed, ensuring accurate and varied architectural representations.

The framework utilized Voronoi fracture simulations to depict damage intensities ranging from minor cracks to extensive fragmentation, tailored to different earthquake magnitudes. This method provided a naturalistic representation of crack patterns. Meanwhile, the RBD Material Fracture technique simulated realistic physical behavior by considering factors such as material strength and collision force, ensuring material-specific damage effects. Both methods employed bound nodes to control the damage-affected area based on seismic intensity.

The Richter scale was incorporated as a moderating variable, allowing the framework to assess the severity of damage in relation to earthquake magnitudes. This step ensured that the procedural-generated damage models accurately reflected potential real-world scenarios.

Overall, this comprehensive framework demonstrated the effectiveness of integrating procedural modeling techniques with the Richter scale to generate house models with varying levels of earthquake-induced damage. The resulting models are highly suitable for post-earthquake simulations, offering valuable tools for disaster preparedness, response planning, and enhancing community safety in the face of seismic events.

Recommendations

The recommendations section is pivotal for translating research findings into actionable strategies. Focused on the study "RESQUAKE: SIMULATING POST-EARTHQUAKE DAMAGE IN PHILIPPINE HOMES USING PROCEDURAL MODELING," these recommendations aim to refine the procedural modeling techniques and apply them innovatively for enhancing earthquake preparedness and risk reduction.

1. It's imperative to advance the stochastic rules for

L-systems, broadening the range of simulated Philippine house models. This will make the simulation more representative of real-world scenarios.

2. Expanding the use of Voronoi and RBD fracture techniques to include key structural elements like doors and windows can lead to more nuanced and comprehensive earthquake damage simulations, aiding in the creation of more resilient building designs. If possible, the incorporation of material properties (such as elasticity, density, and strength) into the simulation can help in recreating accurate material behavior during seismic events is crucial for realistic results.

3. Implementing the study's findings in VR-based training can revolutionize disaster preparedness, offering realistic, immersive training environments that enhance the skillsets of emergency responders and reduce the risks associated with earthquake disasters.

REFERENCES

A. Published Materials

Archila, H., Kaminski, S., Trujillo, D., Zea Escamilla, E.,& Harries, K. A. (2018). Bamboo reinforced concrete: a critical review. Materials and Structures, 51, 1-18. (2023). doi.org/10.1617/s11527-018-1228-6

Abdelaziz, A. (2023). Stress, strain, and failure in heterogeneous and anisotropic rock (Doctoral dissertation, *University of Toronto (Canada)*). Retrieved from: hdl.handle.net/1807/127926

Abed, J., Rayburg, S., Rodwell, J., & Neave, M. (2022). A Review of the Performance and Benefits of Mass Timber as an Alternative to Concrete and Steel for Improving the Sustainability of Structures. Sustainability, 14(9), 5570. doi.org/10.3390/su14095570

Abgottspon, A. (2011). Procedural modelling in Houdini based on Function Representation (Doctoral dissertation, Master's thesis, National Centre for Computer Animation, *Bournemouth Univ*). Retrieved from: https://nccastaff.bournemouth.ac.uk/jmacey/MastersProject/MSc11/Andy/HoudiniFrepThesis.pdf

Adão, T., Pádua, L., Marques, P., Sousa, J. J., Peres, E., & Magalhães, L. (2019). Procedural modeling of buildings composed of arbitrarily-shaped floor-plans: Background, progress, contributions and challenges of a methodology oriented to cultural heritage. Computers, 8(2), 38.

Adem, Y. U. L. U. (2021). Slums of Southeast Asia: The Case of Manila, Philippines. Türk Coğrafya Dergisi, (77), 171-182. doi.org/10.3390/computers8020038

Alfonso, K. K. B., Atud, M. K. M., Fulguirinas, S. I. T., & Castro, C. J. A. (2023). ECOnstruction: Analysis of Market-Available Green Cement in Building Sustainable Structures and Reducing Carbon Pollution.IRE Journals, Volume 6 Issue 12, 2456-8880. Retrieved from: https://www.irejournals.com/formatedpaper/1704820.pdf

Allen, M. T., Prusinkiewicz, P., & DeJong, T. M. (2005). Using L-systems for modeling source–sink interactions, architecture and physiology of growing trees: the L-PEACH model. New phytologist, 166(3), 869-880. DOI: 10.1111/j.1469-8137.2005.01348.x

Almodovar-Melendo, J. M., Rodríguez-Cunill, I., & Cabeza-Lainez, J. (2022). The Search for Solar Architecture in Asia in the Works of the Architect Antonin Raymond: A Protracted Balance between Culture and Nature. Buildings, 12(10), 1514. doi.org/10.3390/

buildings12101514

Anderson, M. B. (2019). Local Resource Management Project Santo Domingo, Albay, Bicol Region, Philippines: Project Implementing Agency: International Institute of Rural Reconstruction. In Rising From The Ashes (pp. 241-257). *Routledge*. ISBN: 9780429304859.

Antoniuk, I., Hoser, P., Strzęciwilk, D. (2019). L-system Application to Procedural Generation of Room Shapes for 3D Dungeon Creation in Computer Games. In: Pejaś, J., El Fray, I., Hyla, T., Kacprzyk, J. (eds) Advances in Soft and Hard Computing. ACS 2018. Advances in Intelligent Systems and Computing, vol 889. Springer, Cham. https://doi.org/10.1007/978-3-030-03314-9_32

Antoniuk, I., Rokita, P. (2019). Procedural Generation of Multilevel Dungeons for Application in Computer Games using Schematic Maps and L-system. In: Bembenik, R., Skonieczny, Ł., Protaziuk, G., Kryszkiewicz, M., Rybinski, H. (eds) Intelligent Methods and Big Data in Industrial Applications. Studies in Big Data, vol 40. Springer, Cham. https://doi.org/10.1007/978-3-319-77604-0_19

Aprianti, E. (2017). A huge number of artificial waste material can be supplementary cementitious material

(SCM) for concrete production–a review part II. Journal of cleaner production, 142, 4178-4194. doi. org/10.1016/j.jclepro.2015.12.115

Asahina, D., Landis, E. N., & Bolander, J. E. (2011). Modeling of phase interfaces during pre-critical crack growth in concrete. Cement and Concrete Composites, 33(9), 966-977. doi.org/10.1016/j.cemconcomp.2011. 01.007

Ashfaq, A. (2023). Exploring the potential of design for manufacture and assembly (DFMA) in post-disaster housing solutions (Doctoral dissertation, *Politecnico di Torino*). Retrived from: http://webthesis.biblio. polito.it/id/eprint/30104

Badwi, I. M., Ellaithy, H. M., & Youssef, H. E. (2022). 3D-GIS parametric modelling for virtual urban simulation using CityEngine. Annals of GIS, 28(3), 325-341. doi.org/10.1080/19475683.2022.2037019

Bagnolo, V., Argiolas, R., Cuccu, S., & Paba, N. (2021). Beyond HBIM: serious games and procedural modelling for heritage dissemination. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 46(4), 55-60. doi.org/10.5194/ isprs-archives-XLVI-4-W4-2021-55-2021

Ballesteros, L., Ourang, S., Pazdon, J., & Kuffel, K. (2023). Increasing safety in residential construction through a simplified earthquake-and typhoon-resistant guidelines. Journal of Future Sustainability, 3(3), 119-124. DOI: 10.5267/j.jfs.2023.1.001

Bautista, F. M. A., Manansala, R. a. V., Provido, G. a. C., & Tan, J. N. M. (n.d.). Comparative Analysis of the Compressive Strength of Concrete Hollow Blocks Containing Different Treatments of Rice (Oryza sativa) Husk. Animo Repository. Retrieved from: https://animorepository.dlsu.edu.ph/conf_shsrescon/2023/paper_men/1/

Beyerer, J., Hagmanns, R., & Stadler, D. (2024). Pattern recognition: introduction, features, classifiers and principles. *Walter de Gruyter GmbH & Co KG*. doi.org/10.1515/9783111339207

Bhuyan, S. (2020, April 11). Seismic Waves: Definition, Types, Examples, and diagram. *Science Facts*. Retrieved from: https://www.sciencefacts.net/seismic-waves.html

Bhardwaj, R., & Upadhyay, A. (2017). Cellular Automata: Elementary Cellular Automata. J. Organ. End User Comput., 29, 42-50. DOI: 10.4018/JOEUC.2017010103

Bielefeldt, B. R., Reich, G. W., Beran, P. S., & Hartl, D.

J. (2019). Development and validation of a genetic L-System programming framework for topology optimization of multifunctional structures. Computers & Structures, 218, 152-169. doi.org/10.1016/j.compstruc.2019.02.005

Bornales, A. P. P., Velasco, M. A. P., Layderos, J. A., & Dela Cruz, O. G. (2022, December). Comparison of Autoclaved Aerated Concrete (AAC) Blocks and CHB Using Life-Cycle Cost Analysis. In International Conference on Civil Engineering and Architecture (pp. 157-167). Singapore: Springer Nature Singapore. DOI: 10.1007/978-981-99-4049-3_14

Boudon, F., Pradal, C., Cokelaer, T., Prusinkiewicz, P., & Godin, C. (2012). L-Py: an L-system simulation framework for modeling plant architecture development based on a dynamic language. Frontiers in plant science, 3, 21069. doi.org/10.3389/fpls.2012.00076

Bredenoord, J. (2024). Bamboo as a Sustainable Building Material for Innovative, Low-Cost Housing Construction. Sustainability, 16(6), 2347. https://doi.org/10.3390/su16062347

Calliari, E., Staccione, A., & Mysiak, J. (2019). An assessment framework for climate-proof nature-based solutions. Science of the Total Environment, 656, 691-700. doi.org/10.1016/j.scitotenv.2018.11.341

Carrasco, S., Ochiai, C., & Okazaki, K. (2016). Impacts of resident-initiated housing modifications in resettlement sites in Cagayan de Oro, Philippines. International Journal of Disaster Risk Reduction, 17, 100-113. doi.org/10.1016/j.ijdrr.2016.05.001

Claridades, A. R. C., Choi, H. S., & Lee, J. (2022). An indoor space subspacing framework for implementing a 3d hierarchical network-based topological data model. ISPRS International Journal of Geo-Information, 11(2), 76. doi.org/10.3390/ijgi11020076

D'Ayala, D., Galasso, C., Nassirpour, A., Adhikari, R. K., Yamin, L., Fernandez, R., ... & Oreta, A. (2020). Resilient communities through safer schools. International journal of disaster risk reduction, 45, 101446. DOI: 10.1016/j.ijdrr.2019.101446

De Jesus, R., & Borais, J. (2019). Assessment Of Out-of-plane Failure Of Non-engineered Masonry Wall Due To Storm Surges. Geomate Journal, 17(59), 1-7. DOI: 10.21660/2019.59.4552

DiFrancesco, P. M., Bonneau, D. A., & Hutchinson, D.

J. (2021). Computational geometry-based surface reconstruction for volume estimation: A case study on magnitude-frequency relations for a LiDAR-derived rockfall inventory. ISPRS International Journal of Geo-Information, 10(3), 157. DOI: 10.3390/ijgi10030157

Emmanuel, K. S., Mathuram, C., Priyadarshi, A. R., George, R. A., & Anitha, J. (2019). A Beginners Guide to Procedural Terrain Modelling Techniques. 2019 2nd International Conference on Signal Processing and Communication (ICSPC). DOI: 10.1109/ICSPC46172.20 19.8976682

Esatyana, E. (2022). Anisotropic Fracture Toughness Characterization of Shale Formation from Drill Cuttings (Doctoral dissertation). https://doi.org/ 10.2118/205488-PA

Elbashiry, E. M., Hao, N., Chen, J., & Song, Y. (2023). A novel bionic straw-filled concrete block: compression and heat-transfer performance. Emerging Materials Research, 12(3), 276-284. DOI: 10.1680/ jemmr.22.00226

Eleftheriou, E., Lopez Muñoz, L. F., Habert, G., & Zea Escamilla, E. (2022). Parametric approach to simplified life cycle assessment of social housing projects. Sustainability, 14(12), 7409. DOI: 10.33 90/su14127409

Enteria, N. A. (2016). CFD evaluation of Philippine detached structure with different roofing designs. Infrastructures, 1(1), 3. DOI: 10.3390/infrastructures 1010003

Estacio, A. D. L., Sarmiento, A. A. D., Arizabal, A. M. D. S., & Viloria-Libiran, C. (2021). Resurfacing the Spirit of the Place; An Urban Design Study of Historic Santa Ana Streetscapes. International Journal of Scientific Research and Engineering Development. (Cited January 2022), 4(4). ISBN: 2456-1363

Fan, L., Chitalu, F. M., & Komura, T. (2022). Simulating brittle fracture with material points. ACM Transactions on Graphics (TOG), 41(5), 1-20. DOI: 10. 1145/3522573

Frankie, T. M., Gencturk, B., & Elnashai, A. S. (2013). Simulation-based fragility relationships for unreinforced masonry buildings. Journal of Structural Engineering, 139(3), 400-410. DOI: 10.1061/(ASCE)ST. 1943-541X.0000648

Freiknecht, J., & Effelsberg, W. (2019). Procedural generation of multistory buildings with interior. IEEE Transactions on Games, 12(3), 323-336. DOI: 10.1109/TG .2019.2957733

Galuszka, J. (2020). Adapting to informality: multistorey housing driven by a co-productive process and the People's Plans in Metro Manila, Philippines. Co-production-between service delivery strategy and urban governance transformation approach, 83. DOI: 10.3828/idpr.2020.8

Galuszka, J., & Wilk-Pham, A. (2022). Incremental housing extensions and formal-informal hybridity in London, United Kingdom. Questioning the formal housing imaginaries in the 'North'. Habitat International, 130, 102692. DOI: 10.1016/j.habitatint.2022.102692

Girard, J. C. (2021). Leandro Valencia Locsin: Filipino Architect. *Birkhäuser*. DOI: 10.1515/978303562 0931

Grêt-Regamey, A., Celio, E., Klein, T. M., & Hayek, U. W. (2013). Understanding ecosystem services trade-offs with interactive procedural modeling for sustainable urban planning. Landscape and urban planning, 109(1), 107-116. DOI: 10.1016/j.landurbplan.2012.10.011

Hadlos, A., Opdyke, A., & Hadigheh, S. A. (2023).

Deriving expert-driven seismic and wind fragility functions for non-engineered residential typologies in Batanes, Philippines. Scientific Reports, 13(1), 22008. DOI: 10.1038/s41598-023-49398-2

Hamediazad, F., & Bahrani, N. (2022). Simulation of hard rock pillar failure using 2D continuum-based Voronoi tessellated models: The case of Quirke Mine, Canada. Computers and Geotechnics, 148, 104808. DOI: 10.1016/j.compgeo.2022.104808

Hameedaldeen, K. A., Altassan, A. A., & Kotbi, A. G. (2023). Determining Artificial Lighting Criteria for Traditional Mud Buildings and Their Impact on Aesthetic Values and Functional Aspects (A Case Study: Historical At-Turaif District). Buildings, 13(10), 2546. DOI: 10.3390/buildings13102546

Hexmoor, H. (2022). Essential principles for autonomous robotics. *Springer Nature*. DOI: 10.2200/ S00506ED1V01Y201305AIM021

Hwang, M. S., & Lee, H. (2022). Pipeline Design for Efficient Visual Effects Production. Journal of Multimedia Information System, 9(3), 219-226. DOI: 10.33851/JMIS.2022.9.3.219

Ignacio, P. L. C., Acierto, D. I. A., Camba, C. P. P., Gomez, R. V. L., & Ozaeta, M. I. M. (2020, April). A Comparative Study of Concrete Hollow Blocks with and without Rice Husk Powder as Partial Replacement to Cement. In Journal of Physics: Conference Series (Vol. 1529, No. 3, p. 032045). *IOP Publishing*. DOI: 10.1088/1742-6596/1529/3/032045

Ismaeel, W. S., & Mohamed, A. G. (2023). A structural equation modelling paradigm for eco-rehabilitation and adaptive reuse of cultural heritage buildings. Building and Environment, 242, 110604. DOI: 10.1016/j.buildenv.2023.110604

Iyer, A. V., Rao, N. D., & Hertwich, E. G. (2023). Review of Urban Building Types and Their Energy Use and Carbon Emissions in Life-Cycle Analyses from Low- and Middle-Income Countries. Environmental Science & Technology, 57(26), 9445-9458. DOI: 10.1021/acs.est.2c06418

Ji, D., Cheng, H., & Zhao, H. (2024). A Voronoi tessellated model considering damage evolution for modeling meso-mechanical mechanism of the sandstone. Engineering Analysis with Boundary Elements, 158, 446-467. DOI: 10.1016/j.enganabound.2023.11.013

Jiang, Z., & Shekhar, S. (2017). Spatial big data science. *Schweiz: Springer International Publishing AG*.DOI: 10.1007/978-3-319-60195-3

Jim, C. Y., & Hui, L. C. (2022). Offering green roofs in a compact city: Benefits and landscape preferences of socio-demographic cohorts. Applied Geography, 145, 102733. DOI: 10.1016/j.apgeog.2022.102733

Jipa, A., & Dillenburger, B. (2022). 3D printed formwork for concrete: State-of-the-art, opportunities, challenges, and applications. 3D Printing and Additive Manufacturing, 9(2), 84-107. DOI: 10.1089/3dp.2021.0024

Johnson, B. A., Estoque, R. C., Li, X., Kumar, P., Dasgupta, R., Avtar, R., & Magcale-Macandog, D. B. (2021). High-resolution urban change modeling and flood exposure estimation at a national scale using open geospatial data: A case study of the Philippines. Computers, Environment and Urban Systems, 90, 101704. DOI: 10.1016/j.compenvurbsys.2021.101704

Johnson, Lawrence & Yannakakis, Georgios & Togelius, Julian. (2010). Cellular automata for real-time generation of infinite cave levels. DOI: 10.1145/1814256.1814266

Johnson, L., Yannakakis, G., & Togelius, J. (2010).

Cellular automata for real-time generation of infinite cave levels. https://doi.org/10.1145/1814256.1814266

Jones, R. K., Barton, T., Xu, X., Wang, K., Jiang, E., Guerrero, P., ... & Ritchie, D. (2020). Shapeassembly: Learning to generate programs for 3d shape structure synthesis. ACM Transactions on Graphics (TOG), 39(6), 1-20. DOI: 10.1145/3414685.3417812

Jung, C., & Redenbach, C. (2023). Crack modeling via minimum-weight surfaces in 3d Voronoi diagrams. Journal of Mathematics in Industry, 13(1), 10. DOI: 10.1186/s13362-023-00138-1

Kelly, G., & McCabe, H. (2006). A survey of procedural techniques for city generation. The ITB Journal, 7(2), 5. DOI: 10.21427/D76M9P

Kneidl, A., Borrmann, A., & Hartmann, D. (2012). Generation and use of sparse navigation graphs for microscopic pedestrian simulation models. Advanced Engineering Informatics, 26(4), 669-680. https://doi.org/10.10 16/j.aei.2012.03.006

Kolkman, D. (2022). The (in) credibility of algorithmic models to non-experts. Information, Communication & Society, 25(1), 93-109. DOI: 10.1080/1369118X.2020. 1761860

Kutzias, D., & von Mammen, S. (2023). Recent Advances in Procedural Generation of Buildings: From Diversity to Integration. *IEEE Transactions on Games*. DOI: 10.1109/ TG.2023.3262507

Lin, Y., Lai, Z., Ma, J., & Huang, L. (2024). A combined weighted Voronoi tessellation and random field approach for modeling heterogeneous rocks with correlated grain structure. Construction and Building Materials, 416, 135228. DOI: 10.1016/j.conbuildmat. 2024.135228

Liu, G., Chen, Y., Du, X., Xiao, P., Liao, S., & Azzam, R. (2021). Investigation of microcrack propagation and energy evolution in brittle rocks based on the voronoi model. Materials, 14(9), 2108. DOI: 10.3390/ma14092108

Low, P. E., Wong, L. K., See, J., & Ng, R. (2021). Pic2PolyArt: Transforming a photograph into polygon-based geometric art. Signal Processing: Image Communication, 91, 116090. DOI: 10.1016/j.image.2020. 116090

Lv, Y., Li, H., Zhu, X., & Liu, W. (2017). Discrete element method simulation of random Voronoi grain-based models. Cluster Computing, 20, 335-345. DOI:

10.1007/ s10586-016-0705-3

Ma, Y. P. (2021). Extending 3D-GIS district models and BIM-based building models into computer gaming environment for better workflow of cultural heritage conservation. Applied Sciences, 11(5), 2101. DOI: 10. 3390/app11052101

Mabborang, M. H., Nozaleda, B. M., Maguddayao, R. N., Udaundo, L., Laggui, N., Martin, E., & Sibal, C. (2022). Vernacular House Architecture and Climate Change Adaptation: Lessons from the Indigenous Peoples of Cagayan, Philippines. Journal of Climate Change, 8(4), 25-33. DOI: 10.3233/JCC220027

Martinez, D. J. S. (2017). Concrete Colonialism: Architecture, Infrastructure, Urbanism and the American Colonization of the Philippines (Doctoral dissertation, *Columbia University*). https://doi.org/ 10.7916/D88P6BXX

Martínez-Rocamora, A., Rivera-Gómez, C., Galán-Marín, C., & Marrero, M. (2021). Environmental benchmarking of building typologies through BIM-based combinatorial case studies. Automation in Construction, 132, 103980. DOI: 10.1016/j.autcon.2021.10398

Martín-Morales, M., Cuenca-Moyano, G. M.,Valverde-

Espinosa, I., & Valverde-Palacios, I. (2017). Effect of recycled aggregate on physical-mechanical properties and durability of vibro-compacted dry-mixed concrete hollow blocks. Construction and Building Materials, 145, 303-310. DOI: 10.1016/j.conbuildmat.2017.04.013

Mata, J. L., Orejudos, J. N., Opon, J. G., & Guirnaldo, S. A. (2022). Optimizing Building Orientation and Roof Angle of a Typhoon-Resilient Single-Family House Using Genetic Algorithm and Computational Fluid Dynamics. Buildings, 13(1), 107. DOI: 10.3390/buildings13010107

Medina, J. J., Maley, J. M., Sannapareddy, S., Medina, N. N., Gilman, C. M., & McCormack, J. E. (2020). A rapid and cost-effective pipeline for digitization of museum specimens with 3D photogrammetry. PLoS One, 15(8), e0236417. DOI: 10.1371/journal.pone.0236417

Mejia, L., Zhu, P., Hyman, J. D., Mohanty, K. K., & Balhoff, M. T. (2020). Coreflood on a chip: Core-scale micromodels for subsurface applications. Fuel, 281, 118716. DOI: 10.1016/j.fuel.2020.118716

Mohanty, M., Sarkar, R., & Das, S. K. (2022, November). Earthquake-Induced Damage Assessment of

Coal Mine Overburden Dump Slope Using Extended Finite Element Method Coupled with Voronoi Tessellation Scheme. In Symposium in Earthquake Engineering (pp. 39-49). Singapore: Springer Nature Singapore. DOI: 10.1007/ 978-981-99-1579-8_4

Montáns, F. J., Cueto, E., & Bathe, K. J. (2023). Machine Learning in Computer Aided Engineering. In Machine Learning in Modeling and Simulation: Methods and Applications (pp. 1-83). Cham: *Springer International Publishing*. DOI: 10.1007/978-3-031-36644-4_1

Mühling, M., Winkler, M., & Augat, P. (2021). Prediction of interfragmentary movement in fracture fixation constructs using a combination of finite element modeling and rigid body assumptions. Computer Methods in Biomechanics and Biomedical Engineering, 24(15), 1752-1760. DOI: 10.1080/10255842.2021.1919883

Museth, K., & Clive, M. (2008). CrackTastic: fast 3D fragmentation in" The Mummy: Tomb of the Dragon Emperor". In ACM SIGGRAPH 2008 talks (pp. 1-1). DOI: 10.1145/1401032.1401110

Naderi, S., & Zhang, M. (2022). 3D meso-scale modelling of tensile and compressive fracture behaviour of steel fibre reinforced concrete. Composite Structures, 291, 115690. DOI: 10.1016/j.compstruct.2022.115690

Nasreldin, R., & Ibrahim, A. (2022, April). How the Covid-19 Pandemic Affects Housing Design to Adapt With Households' New Needs in Egypt?. In The International Research & Innovation Forum (pp. 791-807). Cham: Springer International Publishing. DOI: 10.1007/978-3-031-19560-0_68

Ongpeng, J. M., & Umali, M. V. (2023). Life-cycle assessment of concrete hollow blocks and autoclaved aerated concrete blocks. In Life-Cycle of Structures and Infrastructure Systems (pp. 3166-3173). CRC Press. DOI: 10.1201/9781003323020-386

Orozco, C., Tangtermsirikul, S., Sugiyama, T., & Babel, S. Examining the endpoint impacts, challenges, and opportunities of fly ash utilization for sustainable concrete construction. Scientific Reports, 13(1), 18254. DOI: 10.1038/s41598-023-45632-z

Panera, J., Rubio-Jara, S., Domínguez-Rodrigo, M., Yravedra, J., Méndez-Quintas, E., Pérez-González, A., ... & Santonja, M. (2019). Assessing functionality during the early Acheulean in level TKSF at Thiongo

Korongo site (Olduvai Gorge, Tanzania). Quaternary International, 526, 77-98. DOI: 10.1016/j.quaint. 2019.09.013

Papatzani, S., Michail, G., Tzamalis, G., & Skitsas, G. (2022). UNESCO Historic Centre (Chorá) of Patmos Island: Conservation and Reconstruction of a Collapsed Urban House. Heritage, 5(4), 3100-3132. DOI: 10.3390/ heritage5040161

Pexman, K., Lichti, D. D., & Dawson, P. (2021). Automated storey separation and door and window extraction for building models from complete laser scans. Remote Sensing, 13(17), 3384. DOI: 10.3390/rs13173384

Prusinkiewicz, P., Cieslak, M., Ferraro, P., & Hanan, J. (2018). Modeling plant development with L-systems. Mathematical modelling in plant biology, 139-169. DOI: 10.1007/978-3-319-99070-5_8

Quinay, P. E. B., Soliman, J. M. M., & Fader, A. R. F. (2020). Development of simulation-based approach using frame models generated from GIS features and BIM data for application to city seismic response analysis of low-to mid-rise RC structures in Metro Manila. Journal of Earthquake and Tsunami, 14(06), 2050021. DOI: 10.

1142/S1793431120500219

Rossini, F. (2021). Urban design and informal settlements: placemaking activities and temporary architectural interventions in BaSECo compound. URBAN DESIGN International, 1-21. DOI: 10.1057/s41289-021-00168-4

Roxas, C. L. C., Bautista, C. R., Dela Cruz, O. G., Dela Cruz, R. L. C., De Pedro, J. P. Q., Dungca, J. R., ... & Ongpeng, J. M. C. (2023). Design for manufacturing and assembly (DfMA) and design for deconstruction (DfD) in the construction industry: Challenges, trends and developments. Buildings, 13(5), 1164. DOI: 10.33 90/buildings13051164

Sanipour, S., Bahrani, N., & Corkum, A. (2022). Simulation of brittle failure around Canada's mine-by experiment tunnel using 2D continuum-based Voronoi tessellated models. Rock Mechanics and Rock Engineering, 55(10), 6387-6408. DOI: 10.1007/s00603-022-02969-7

Satriano, C., Wu, Y. M., Zollo, A., & Kanamori, H. (2011). Earthquake early warning: Concepts, methods and physical grounds. Soil Dynamics and Earthquake Engineering, 31(2), 106-118. DOI: 10.1016/j.soildyn.

2010.07.007

Sehat, S., & Khatami, A. (2021). Parametric study on application of Voronoi patterns in design of 2-D beams. Advances in Structural Engineering, 24(11), 2375-2389. DOI: 10.1177/1369433221999740

Seike, T., Shoji, Y., Takemura, Y., Kunie, Y., Mercado, R. M., & Kim, Y. (2018). Construction Systems for Extensions and Renovations in a Resettlement Site in the Philippines. Journal of Asian Architecture and Building Engineering, 17(3), 441-448. DOI: 10.3130/jaabe.17.441

Shu, Q., & Ludwig, F. (2023). A circuit analogy based girth growth model for living architecture design. Journal of the Royal Society Interface, 20(202), 20230168. DOI: 10.1098/rsif.2023.0168

Smelik, R. M., Tutenel, T., Bidarra, R., & Benes, B. (2014, September). A survey on procedural modelling for virtual worlds. In Computer graphics forum (Vol. 33, No. 6, pp. 31-50). DOI: 10.1111/cgf.12276

Smelik, R. M., Tutenel, T., de Kraker, K. J., & Bidarra, R. (2011). A declarative approach to procedural modeling of virtual worlds. Computers & Graphics, 35(2), 352-363. DOI:

10.1016/j.cag.2010.11.011

Smelik, R., van Wermeskerken, F., Krijnen, R., & Kuijper, F. (2019). Dynamic synthetic environments: a survey. The Journal of Defense Modeling and Simulation, 16(3), 255-271. DOI: 10.1177/1548512918811954

Smith, M., Thomas, A., Gibbs, K., & Morrison, C. (2020, December). Low-Complexity Workflow for Digitizing Real-World Structures for Use in VR-Based Personnel Training. In International Conference on Intelligent Technologies for Interactive Entertainment (pp. 255-266). *Cham: Springer International Publishing*. DOI: 10.1007/978-3-030-76426-5_17

Soares, N., Martins, C., Gonçalves, M., Santos, P., da Silva, L. S., & Costa, J. J. (2019). Laboratory and in-situ non-destructive methods to evaluate the thermal transmittance and behavior of walls, windows, and construction elements with innovative materials: A review. Energy and Buildings, 182, 88-110. DOI: 10.1016/j.enbuild.2018.10.021

Song, B., Galasso, C., & Garciano, L. (2020). Wind-uplift fragility analysis of roof sheathing for cultural heritage assets in the Philippines.

International Journal of Disaster Risk Reduction, 51, 101753. DOI: 10.1016/j.ijdrr.2020.101753

Stubbs, J. H., & Thomson, R. G. (2016). Architectural conservation in Asia: National experiences and practice. *Routledge*. DOI: 10.4324/9781315683447

Suarez, M., Parke, F., & Castro, F. (2019). A Procedural Approach to Computer-Aided Modelling in Nautical Archaeology. 3D Recording and Interpretation for Maritime Archaeology, 123-134. DOI: 10.1007/978-3-030-03635-5_8

Sun, H., Gao, Y., Zheng, X., Chen, Y., Jiang, Z., & Zhang, Z. (2019). Meso-scale simulation of concrete uniaxial behavior based on numerical modeling of CT images. Materials, 12(20), 3403. DOI: 10.3390/ma12203403

Talton, J. O., Lou, Y., Lesser, S., Duke, J., Mech, R., & Koltun, V. (2011). Metropolis procedural modeling. ACM Trans. Graph., 30(2), 11-1. https://doi.org/10.1145/ 1944846.1944851

Tiburcio-Garcia, E. (2020). Urban Imprints to Historic Churches in Bulacan Towns, Philippines: An Architectural Realization. In Urban and Transit Planning: A Culmination of Selected Research Papers from IEREK Conferences on Urban Planning, Architecture and Green Urbanism, Italy and Netherlands (2017) (pp. 203-213). *Springer International Publishing*. DOI: 10.1007/978-3-030-17308-1_19

Tong, X., & Feng, Y. (2019). A review of assessment methods for cellular automata models of land-use change and urban growth. International Journal of Geographical Information Science, 34(5), 866–898. DOI: 10.1080/13 658816.2019.1684499

Tong, X., & Feng, Y. (2019). How current and future urban patterns respond to urban planning? An integrated cellular automata modeling approach. Cities, 92, 247-260. https://doi.org/10.1016/j.cities.2019.04.004

Van Der Wielen, K. P., & Rollinson, G. (2016). Texture-based analysis of liberation behaviour using Voronoi tessellations. Minerals Engineering, 89, 93-107. DOI: 10.1016/j.mineng.2015.09.008

Venable, C., Javernick-Will, A., Liel, A. B., & Koschmann, M. A. (2021). Revealing (mis) alignments between household perceptions and engineering assessments of post-disaster housing safety in typhoons. International Journal of Disaster Risk

Reduction, 53, 101976. DOI: 10.1016/j.ijdrr.2020.101976

Venable, C., Liel, A. B., Kijewski-Correa, T., & Javernick-Will, A. (2021). Wind performance assessment of postdisaster housing in the Philippines. Natural Hazards Review, 22(4), 04021033. DOI: 10.1061/(ASCE) NH.1527-6996.0000491

Wang, Z., Yang, S., Li, L., Tang, Y., & Xu, G. (2021). A 3D Voronoi clump based model for simulating failure behavior of brittle rock. Engineering Fracture Mechanics, 248, 107720. DOI: 10.1016/j.engfracmech. 2021.107720

Wei, D., Hurley, R. C., Poh, L. H., Dias-da-Costa, D., & Gan, Y. (2020). The role of particle morphology on concrete fracture behaviour: A meso-scale modelling approach. Cement and Concrete Research, 134, 106096. DOI: 10.1016/j.cemconres.2020.106096

Wolper, J., Fang, Y., Li, M., Lu, J., Gao, M., & Jiang, C. (2019). CD-MPM: continuum damage material point methods for dynamic fracture animation. ACM Transactions on Graphics (TOG), 38(4), 1-15. DOI: 10.1145/3306346.3322949

Wu, Z., Sun, H., & Wong, L. N. Y. (2019). A cohesive element-based numerical manifold method for hydraulic fracturing modelling with voronoi grains. Rock Mechanics and Rock Engineering, 52, 2335-2359. DOI: 10.1007/s00603-018-1717-5

Xu, T., Fu, T. F., Heap, M. J., Meredith, P. G., Mitchell, T. M., & Baud, P. (2020). Mesoscopic damage and fracturing of heterogeneous brittle rocks based on three-dimensional polycrystalline discrete element method. Rock Mechanics and Rock Engineering, 53, 5389-5409. DOI: 10.1007/s00603-020-02223-y

Yan, M., & Wu, D. (2023). A New Fracture Simulation Algorithm Based On Peridynamics For Brittle Objects. *IEEE Access*. DOI: 10.1109/ACCESS.2023.3305631

Zafra, R. G., Mayo, J. R. M., Villareal, P. J. M., De Padua, V. M. N., Castillo, M. H. T., Sundo, M. B., & Madlangbayan, M. S. (2021). Structural and thermal performance assessment of shipping container as post-disaster housing in tropical climates. Civil Engineering Journal, 7(8), 1437-1458. DOI: 10.28991/cej-2021-03091735

Zhang, H., Xu, C., Zhou, Y., Shu, J., & Huang, K. (2023). Hybrid phase-field modeling of mesoscopic failure in concrete combined with Fourier-Voronoi stochastic aggregate distribution modelling approach. Construction and Building Materials, 394, 132106. DOI: 10.1016/j.conbuildmat.2023.132106

Zhang, K., Liu, F., Xia, K., Xu, Y., Dong, P., & Yu, C. (2023). On the calibration and verification of Voronoi-based discontinuous deformation analysis for modeling rock fracture. Journal of Rock Mechanics and Geotechnical Engineering, 15(8), 2025-2038. DOI: 10.1016/j.jrmge.2022.12.025

Zhou, G. L., Xu, T., Konietzky, H., Zhu, W., Heng, Z., Yu, X. Y., & Zhao, Y. (2022). An improved grain-based numerical manifold method to simulate deformation, damage and fracturing of rocks at the grain size level. Engineering Analysis with Boundary Elements, 134, 107-116. DOI: 10.1016/j.enganabound.2021.10.005

B. Websites

Acosta, T. J. S., Alvarez, J. P. G., Agar, J. C., Gumaro, J. J. C., Ereno, M. N. C., Villalba, I. B. O., & Quinay, P. E. (2021). Development Of An Application For The Vulnerability Assessment Of Philippine Buildings Against Severe Winds.Conference: 2021 PICE Virtual Midyear National Convention and Technical Conference. Retrived from: https://www.researchgate.

net/publication/352757330_DEVELOPMENT_OF_AN_APPLICATION_FOR_THE_VULNERABILITY_ASSESSMENT_OF_PHILIPPINE_BUILDINGS_AGAINST_SEVERE_WINDS

Atlassian. (2023). What is Lean Methodology?. *Atlassian.* Retrieved from https://www.atlassian.com/agile/project-management/lean-methodology

Asube, L. C. S., Daquiado, J. M., & Lavapiz, B. J. P. (2021). Detection And Spatial Analysis Of Land-use: A Case Of Butuan City With History Of Major Informal Settlements. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 46, 41-48. Retrieved from: https://isprs -archives.copernicus.org/articles/XLVI-4-W6-2021/41/2021/isprs-archives-XLVI-4-W6-2021-41-2021.pdf

Bernardini, A. P. (2024). RBD Building Destruction: A Houdini Project. Retrieved from https://discover.the rookies.co/2024/02/13/rbd-building-destruction-a-houdini-project/

Cairns, M. (2012). 3D Model Deformation using Finite Elements. Retrieved from: https://nccastaff.bourne mouth.ac.uk/jmacey/OldWeb/MastersProjects/MSc12/Cairns/finite_element_deformation.pdf

Chiu, P. H. (2015). The Structure of L-System

(Master's thesis, *University of Cincinnati*). Retrieved from: https://etd.ohiolink.edu/acprod/odb_etd/ws/send_file/send

Casali, Y. (2020). Topological Assessment of Changes in Road Network Systems in Time, under Discrete Flooding Events, and under Classes of Unexpected Disruptions (Doctoral dissertation, *ETH Zurich*). Retrieved from: https://www.research-collection.ethz.ch/handle/20.500.11850/426547

David, A. L. (2023). Sustainability and thermal comfort of bamboo building technologies in the hot humid tropics: Linking mitigation and adaptation. Retrieved from: https://odr.chalmers.se/handle/20.500.12380/307562

DiNicolantonio, E. (n.d.). Using visual effects as a means of establishing or reinforcing scale in 3D visual works. *TigerPrints*. Retrieved from https://tigerprints.clemson.edu/all_theses/4016/

Disaster preparedness: Earthquakes | Habitat for Humanity. (2020). Habitat for Humanity. Retrieved from https://www.habitat.org/our-work/disaster-response/disaster-preparedness-homeowners/earthquakes#:~:text=During%20an%20earthquake&text=Take%20cover%20in%20a%20safe,that%20could%20fal

l%20and%20break.

Domaradzki, J., & Martyn, T. (2018). Fracturing Sparse-Voxel-Octree objects using dynamical Voronoi patterns. Retrieved from https://www.semanticscholar.org/paper/Fracturing-Sparse-Voxel-Octree-objects-using-Domaradzki-Martyn/a2fad747067c6f158d744779166ddbc344e1c337

Dwivedi, R. (2011). Art Directable Tornadoes (Doctoral dissertation, *Texas A & M University*). Retrieved from https://oaktrust.library.tamu.edu/handle/1969.1/ETD-TAMU-2011-05-9417

Earthquake | Definition, Causes, Effects, & facts. (2024, February 21). *Encyclopedia Britannica*. https://www. britannica.com/science/earthquake-geology/Earthquake-magnitude

Elkins, E. B. (2020). Simulating destruction effects in SideFX Houdini (Undergraduate honors thesis, East Tennessee State University). *East Tennessee State Universit*y. Retrieved from https://dc.etsu.edu/honors/524

Etherington, T. R. (2022). Perlin noise as a hierarchical neutral landscape model. Web Ecology, 22(1), 1-6.

Gabrovsek, S. (2017). Agent-based modelling of fragment damage for platform combat utility prediction (Doctoral dissertation, *University of Brighton*). Retrieved from https://research.brighton.ac.uk/en/studentTheses/agent-based-modelling-of-fragment-damage-for-platform-combat-util

Ghorbanian, M., & Shariatpour, F. (2019). Procedural modeling as a practical technique for 3D assessment in urban design via CityEngine. Int. J. Architect. Eng. Urban Plan, 29(2), 255-267. Retrieved from http://ijaup.iust.ac.ir/article-1-502-en.html

Goffredo, E. (2010). A tool for procedural destruction in Houdini shattering dynamics. Masters. *Bournemouth University*. Retrieved from https://nccastaff.bournemouth.ac.uk/jmacey/OldWeb/MastersProjects/MSc2010/04EmanuelleGoffredo/Thesis_Emanuele_Goffredo.pdf

Imai, H., Minowa, C., Lanuza, A. G., Penarubia, H. C., Narag, I. C., Soridum Jr, R. U., ... & Inoue, H. (2015). A full-scale shaking table test on philippine concrete hollow blocks (Chb) masonry houses. Journal of Disaster Research, 10(1), 113-120. Retrieved from https://www.jstage.jst.go.jp/article/jdr/10/1/10_113/_pdf

Johansson-Evegård, E. (2012). Artist friendly fracture modelling. DIVA. Retrieved from https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A485809&dswid=-3300

John, N. K. (2022). National-ish artists: Victorio Edades and the founding of Filipino modern art (Doctoral dissertation, *University of St Andrews*). Retrieved from https://research-repository.st-andrews.ac.uk/handle/10023/29181

Kliment, S. A. (1977). Housing in extreme winds: socio-economic and architectural considerations (Vol. 5). *US Department of Commerce, National Bureau of Standards*. Retrieved from https://www.nist.gov/publications/building-resist-effect-wind-five-volumes-volume-5-housing-extreme-winds-socio-economic

Lappi, M. (2023). Blender Geometry Nodes: node-based procedural modelling for a short film. Theseus. Retrieved from https://www.theseus.fi/handle/10024/808787

Li, G. (2020). Bridge Destruction. Retrieved from https://genlifx.com/houdini/2020/11/24/bridge-destruction/

Liarokapis, F., Voulodimos, A., Doulamis, N., &

Doulamis, A. (Eds.). (2020). Visual Computing for Cultural Heritage. Springer Series on Cultural Computing. Retrieved from: https://link.springer.com/book/ 10.1007/978-3-030-37191-3

Lorenzo, C. M. (2021). A Study on the Philippine’s Gated Communities as Correlated with the Barangay: Development in Metro Manila with Focus on Quezon City. Retrieved from https://www.academia.edu/92392785/ A_Study_on_the_Philippine_s_Gated_Communities_as_Correlated_with_the_Barangay_Development_in_Metro_Manila_with_Focus_on_Quezon_City

Luque Bodet, A. (2022). Node-based particle system (Bachelor's thesis, *Universitat Politècnica de Catalunya*). Retrieved from https://core.ac.uk/ works/150045317

Malaque III, I., Bartsch, K., & Scriver, P. (2015). Learning from informal settlements: provision and incremental construction of housing for the urban poor in Davao City, Philippines. In Living and Learning: Research for a Better Built Environment: 49th International Conference of the Architectural Science Association 2015 (pp. 163-172). Retrieved from https://archscience.org/wp-content/uploads/2015/12/016_Malaque-III_Bartsch_Scriver_ASA2015.pdf

Maribbay, A., & Maribbay, A. (2000). The house building activities of the informal sector: a case study in Las Pinas City, Philippines. eScholarship@McGill. Retrieved from https://escholarship.mcgill.ca/ concern/theses/m326m367z

Monroe, D. C. (2014). A Materials Science Driven Pattern Generation Solution to Fracturing Computer Generated Glass for Films and Games (Doctoral dissertation). Retrieved from https://oaktrust.library.tamu.edu/ bitstream/handle/1969.1/153651/MONROE-THESIS-2014.pdf

Morphocode. (2018, May 9). Intro to L-Systems - MORPHOCODE. MORPHOCODE. Retrieved from https://morphocode.com/ intro-to-l-systems/

Narvaez-Pernes, L., & Santos, M. (2020). Architectural Form and Meaning: Analyzing Perceptual Cues of Power in the Design of Provincial Capital Buildings in Mindanao, Southern Philippines. Banwa A, 13, 1-28. Retrieved from http://ojs.upmin.edu.ph/index.php/banwa-a/article/view/484

Nilsson, S. (2019). What's a seed in a random number generator? Retrieved from https://yourbasic.org/algorithms/random-number-generator-seed/#:~:text=The%20seed%20is%20a%2sstarting,current%20time%20as%20a%20seed.

Nouri, L., Azari, K. T., & Alaghmandan, M. (2023). Development of Algorithmic Applications in Architecture: A Review and Analysis of L-Systems. Bagh-e Nazar, 19(116). Retrieved from https://www.bing.com/ck/a?!&&p=7ade38196a45fb79JmltdHM9MTcxNzAyNzIwMCZpZ3VpZD0yMWI4Njg0Zi1iMmY5LTZhZGMtMDZmNS03YzJjYjNhYjZiMWMmaW5zaWQ9NTIwOA&ptn=3&ver=2&hsh=3&fclid=21b8684f-b2f9-6adc-06f5-7c2cb3ab6b1c&psq=Development+of+Algorithmic+Applications+in+Architecture%3a+A+Review+and+Analysis+of+L-Systems&u=a1aHR0cHM6Ly93d3cuYmFnaC1zai5jb20vanVmaWxlP2FyX3NmaWxlPTE5Mzc5MDQmbGFuZz1lbg&ntb=1

Okun, J. A., Zwerman, S., McKittrick, C., & Sepp-Wilson, L. (2020). Digital Element Creation. In The VES Handbook of Visual Effects (pp. 519-636). *Routledge*. Retrieved from https://www.taylorfrancis.com/chapters/edit/10.4324/9781351009409-7/digital-element-creation-jeffrey-okun-susan-zwerman-christopher-mckittrick-lisa-sepp-wilson

Osundina, B. (2021). Investigation On Mortarless Dry-Stack Interlocking Hollow Block Using Finite Element Modelling; Case Study Of Machinblock Tetrix. Retrieved from https://www.academia.edu/107523799/INVESTIGATION_ON_MORTARLESS_DRY_STACK_INTERLOCKING_HOLLOW_BLOCK_USING_FINITE_ELEMENT_MODELLING_CASE_STUDY_OF_MACHINBLOCK_TETRIX

Ozoa, T. D., Partosa, K. R. L., & Warad, A. K. B. (2021). A Design of a Three-Story Commercial and Apartelle Building for Atty. And Mrs. Andre Villasis Located at Purok Yakal, Tubtubon Sibulan, Negros Oriental. *COLLEGE OF ENGINEERING AND DESIGN SILLIMAN UNIVERSITY*. Retrieved from https://www.academia.edu/53237981/A_Design_of_a_Three_Story_Commercial_and_Apartelle_Building_for_Atty_And_Mrs_Andre_Villasis_Located_at_Purok_Yakal_Tubtubon_Sibulan_Negros_Oriental

Qin, X., Mao, W., Hu, Z. et al. (2024). Procedural modeling and layout method for a generic ancient Chinese city. Multimed Tools Appl, 83, 47021-47048. Retrieved from https://link.springer.com/article/10.1007/s11042-023-16942-1

Rafferty, K. (2014). Digital Element Creation. In The VES Handbook of Visual Effects (pp. 753-884). *Routledge*. Retrieved from https://www.taylorfrancis.com/chapters/edit/10.4324/9781351009409-7/digital-element-creation-jeffrey-okun-susan-zwerman-christopher-mckittrick-lisa-sepp-wilson

Ray, S. R. (2019). Ocho Balay: The Design and Developmental Construction of a Typhooon. Retrieved from https://pea.lib.pte.hu/bitstream/handle/pea/19347/rowell-ray-lim-shih-tezis-eng-2019.pdf

Rhodes-Robinson, J. (2018). Bits+ Pieces: Investigating the Procedural Ideation of Architectural Massing for Early Stage Design (Doctoral dissertation, Open Access *Te Herenga Waka-Victoria University of Wellington*). Retrieved from https://openaccess.wgtn.ac.nz/articles/thesis/Bits_Pieces_Investigating_the_Procedural_Ideati on_of_Architectural_Massing_for_Early_Stage_Design/17072594

Ronnegren, J. (2020). Real time mesh fracturing using 2D Voronoi diagrams. DIVA. Retrieved from https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1452512&dswid=646

Sanipour, S. (2021). Simulation of Brittle Rock Failure Using 2D Continuum-Based Voronoi Tessellated Models. Retrieved from http://hdl.handle.net/10222/80656

Santoso, F. C. (2021). Final Architectural Design Studio Design Of Davao City Vertical Housing With Nearly Zero-Energy Building And Biomimetics Concept On Building Envelope. Retrieved from https://dspace.uii.ac.id/handle/123456789/37228

Schvartzman, S. C. (2013). Accelerated Proximity Queries for Collision Detection and Brittle Fracture. Retrieved from http://hdl.handle.net/10115/12251

SideFX. (2019). RBD Material Fracture. Retrieved from https://www.sidefx.com/docs/houdini/nodes/sop/rbdmaterialfracture.html

Sreshta, L. E. (2019). Survey on user centric approaches to various pre-fracturing techniques in different materials in Houdini. Retrieved from https:// nccastaff.bournemouth.ac.uk/jmacey/MastersProject/MSc19/08/thesis.pdf

Tahir, M. M., Usman, I. M. S., Mohd-Nor, M. F. I., Abdullah, N. G., & Ismail, A. H. (2019). A System Of Sustainable Building Construction Materials Incorporating The Raised Floor Innovation – The Tasik Chini Research Centre Experience. Journal of Design+ Built, 12(1). Retrieved from https://spaj.ukm.my/jsb/index.php/jdb/article/view/434

Terry, J. (2020). What is Lean Methodology?. *Planview*. Retrieved from https://www.planview.com/resources/guide/lean-principles-101/what-is-lean/

ThePro3DStudio. (2023, May 31). Everything you wanted to know about procedural modeling. Retrieved from https://professional3dservices.com/blog/procedural-modeling.html

Veltin, K. (2021). A hybrid finite element/discrete element method of modelling fracturing of brittle rock blocks with applications to block cave fragmentation (Doctoral dissertation, *University of British*

Columbia). Retrieved from https://www.academia.edu/78627809/A_Hybrid_Finite_Element_Discrete_Element_Method_of_Modelling_Fracturing_of_Brittle_Rock_Blocks_with_Applications_to_Block_Cave_Fragmentation

Villà, P. McKenzie, T. (2023). Creating Cracking Concrete Effect Using Houdini. Retrieved from https://Villà & McKenzie/articles/creating-cracking-concrete-effect-using-houdini/

Viswanathan, V. (2010). Creation of a Procedural Crack Generation Tool. Retrieved from https://nccastaff.bournemouth.ac.uk/jmacey/OldWeb/MastersProjects/MSc11/vigneshwar/Road%20Crack%20Generation Thesis.pdf

Voronoi fracture. (2019). Retrieved from https://www.sidefx.com/docs/houdini/nodes/sop/voronoifracture.html

Widiastuti, I., Sudradjat, I., & Gantini, C. (2023). Defining the characteristics of local architecture in Indonesian based on geopolitical and geographical. ResearchGate.https://www.researchgate.net/publication/377625224_Defining_the_characteristics_of_local_architecture_in_Indonesian_based_on_geopolitical_and_geographical_parameters_International_Seminar_on_Vernacular_S ettlements_-ISVS_12

Wisessing, P. (2014). Getting Sandy: Creating Collapsing Sand Effects For An Ode To Love. Retrieved from https://tigerprints.clemson.edu/cgi/viewcontent.cgi?article=2898&context=all_theses

Wu, W. (2023). Material-based Fracturing for Rigid Body Destruction. Retrieved from https://www.wuwayne.com /work/rbd/

Xagoraris, K. (2020). RBD Workflows in Houdini. Retrieved from https://www.katexagoraris.com/

C. Conference Proceedings

Antoniuk, I., Hoser, P., & Strzeciwilk, D. (2018). L-system Application to Procedural Generation of Room Shapes for 3D Dungeon Creation in Computer Games. In Proceedings of the Conference Name (pp. 32-42). DOI: 10.1007/978-3-030-03314-9_32.

Aryamaan Jain, Jyoti Sunkara, Ishaan Shah, Avinash Sharma, and K S Rajan. (2021). Automated tree generation using grammar & particle system. In Proceedings of the Twelfth Indian Conference on Computer Vision, Graphics and Image Processing (ICVGIP '21). Association for Computing Machinery, New York, NY, USA, Article 26, 1–9. https://dl.acm.org/doi/10.1145/3490035.3490285

Bahrani, N., Li, Y., Hamediazad, F., Sanipour, S., & Amiri, F. (2023, November). Application of Continuum-Based Voronoi Tessellated Models for Simulating Brittle Damage and Failure in Hard Rocks. In Rocscience International Conference (RIC 2023) (pp. 711-719). Atlantis Press. DOI: 10.2991/978-94-6463-258-3_65

Canlas, R. L., Talusan, A. B., Principe, M. T. J., Gonzales, L., DyReyes, V., & Regonios, C. A. J. (2021, December). A comparative finite element analysis of a two-story residential building using concrete hollow blocks and po-lite hollow blocks. In TENCON 2021-2021 IEEE Region 10 Conference (TENCON) (pp. 827-832). *IEEE*. doi: 10.1109/TENCON54134.2021.9707385.

Deussen, O., Hanrahan, P., Lintermann, B., Měch, R., Pharr, M., & Prusinkiewicz, P. (1998, July). Realistic modeling and rendering of plant ecosystems. In Proceedings of the 25th annual conference on Computer graphics and interactive techniques (pp. 275-286). 10.1145/280814.280898

Domokos, G., Jerolmack, D. J., Kun, F., & Török, J. (2020). Plato’s cube and the natural geometry of fragmentation. Proceedings of the National Academy of Sciences, 117(31), 18178-18185. DOI: 10.1073/pnas.2001037117

Garciano, L., Alvarez, I., Colobong, J., Decal, C., & Tan, A. (2013, September). Mapping the Vulnerability of Low-Cost House Roofs in Malate, Metro Manila due to Extreme Wind Speeds. In Proceedings of the Thirteenth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-13) (pp. A-4). The Thirteenth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-13). Retrieved from https://www.semanticscholar.org/paper/MAPPING-THE-VULNERABILITY-OF-LOW-COST-HOUSE-ROOFS-Garciano-Alvarez/8315a0de568d4c2a08e6bc01f42f7b6ea1619dfd

Gomez, R. V. L., & Ozaeta, M. I. M. (2020, April). A Comparative Study of Concrete Hollow Blocks with and without Rice Husk Powder as Partial Replacement to Cement. In Journal of Physics: Conference Series (Vol. 1529, No. 3, p. 032045). *IOP Publishing*. DOI: 10.1088/1742-6596/1529/3/032045

Gonzales, L., DyReyes, V., & Regonios, C. A. J. (2021, December). A comparative finite element analysis of a two-story residential building using concrete hollow blocks and po-lite hollow blocks. In TENCON 2021-2021 IEEE Region 10 Conference (TENCON) (pp. 827-832). IEEE. DOI: 10.1109/TENCON54134.2021.9707385

Kreitzer, M., Ashlock, D., & Pereira, R. (2019). Automatic Generation of Diverse Cavern Maps with Morphing Cellular Automata. 2019 IEEE Conference on Games (CoG), 1-8. DOI: 10.1109/CIG.2019.8847947

Magdics, M. (2009). Real-time generation of l-system scene models for rendering and interaction. In Proceedings of the 25th Spring Conference on Computer Graphics (pp. 67-74). DOI: 10.1145/1980462.1980478

Tan, L. R. E., Acosta, T. J. S., Gumaro, J. J. C., Agar, J. C., Tingatinga, E. A. J., Plamenco, D. A. D., ... & Villalba, I. B. O. (2021, May). Investigation of the effects of the classification of building stock geometries determined using clustering techniques on the vulnerability of galvanized iron roof covers against severe wind loading. In IOP Conference Series: Materials Science and Engineering (Vol. 1150, No. 1, p. 012024). *IOP Publishing*. DOI: 10.1088/1757-899X/1150/1/012024

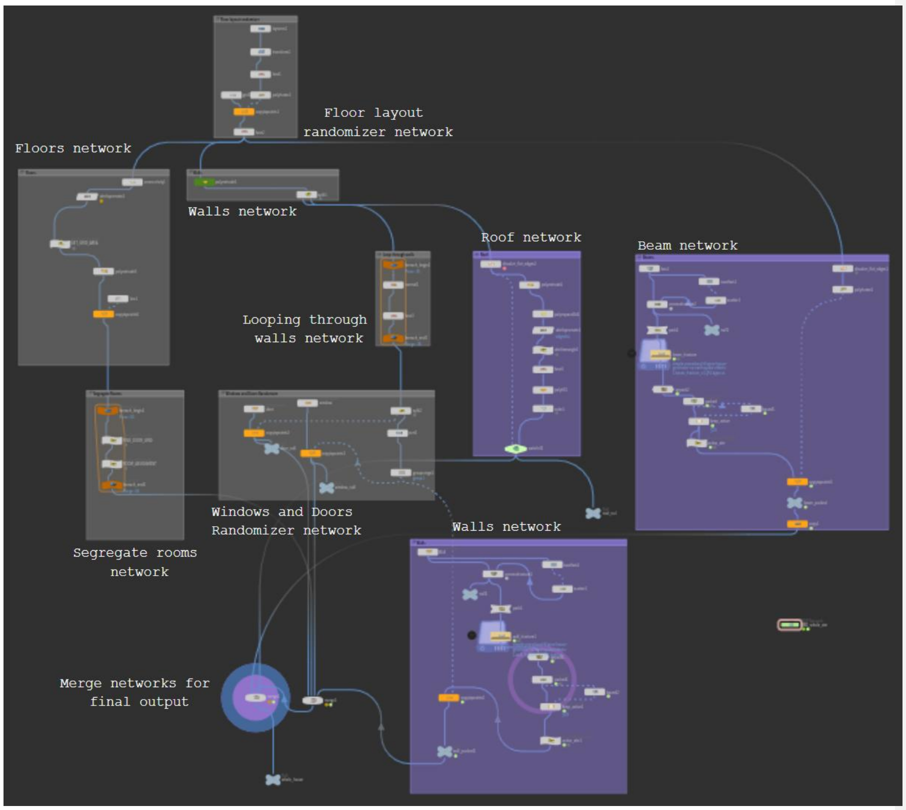
Wu, Z., Mao, Y., & Li, Q. (2021). Procedural game map generation using multi-leveled cellular automata by machine learning. In Proceedings of the 2nd International Symposium on Artificial Intelligence for Medicine Sciences (ISAIMS '21) (pp. 168–172). Association for Computing Machinery. https://doi.org/10.1145/3500931.3500962

Zhixuan Wu, Yuwei Mao, and Qiyu Li. (2021). Procedural Game Map Generation using Multi-leveled Cellular Automata by Machine learning. In Proceedings of the 2nd International Symposium on Artificial Intelligence for Medicine Sciences (ISAIMS '21). Association for Computing Machinery, New York, NY, USA, 168–172. https://dl.acm.org/doi/10.1145/3500931.3500962

APPENDICES

Appendix A

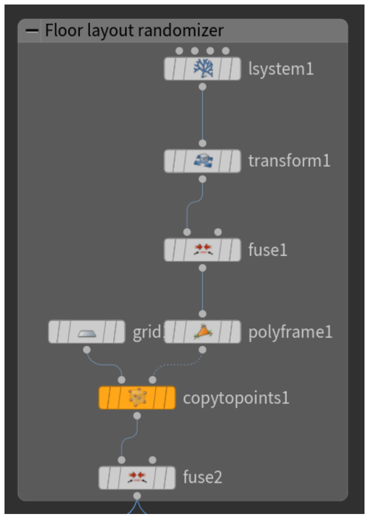
Houdini Geometry Nodes



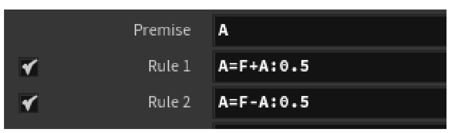
The final nodes for the procedural generation of Philippine houses with earthquake damage effects.

Appendix B

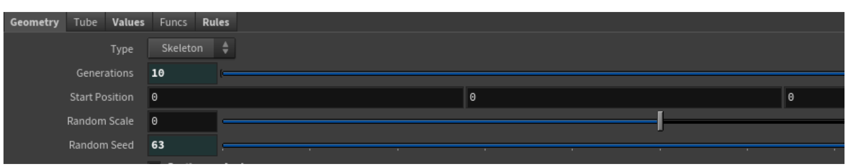
Floor Layout Randomizer Network



The network for the nodes to generate random floor layout.



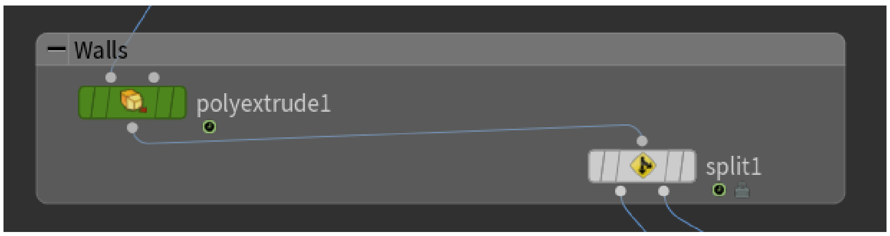
The rules for the "l-system" node for cell generation.



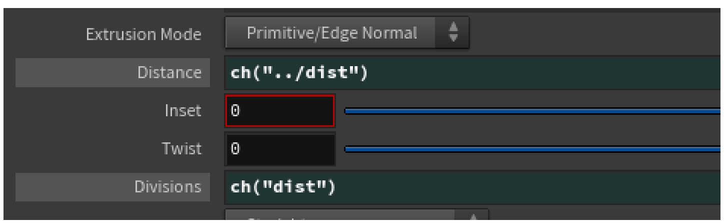
The geometry parameters of the "l-system" node showing sample Generation number and Random Seed.

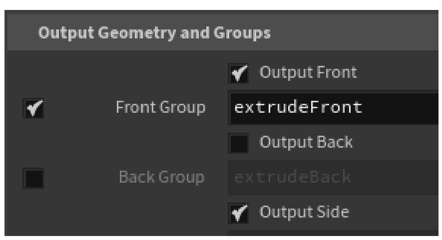
Appendix C

Walls Network



The network for the nodes to generate random floor layout.



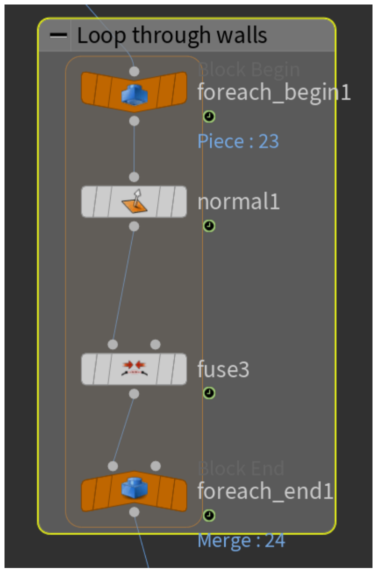


Parameters for "polyextrude1".

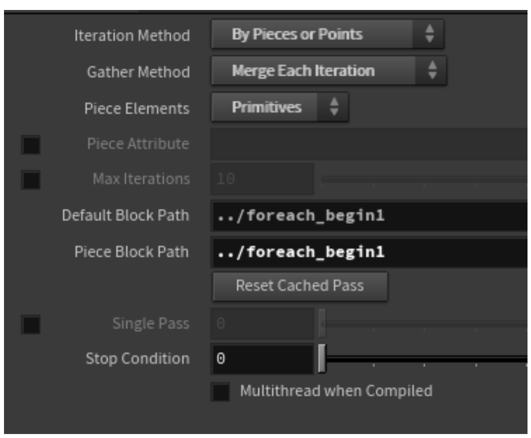
Parameters for "split1".

Appendix D

Looping Through Walls Network



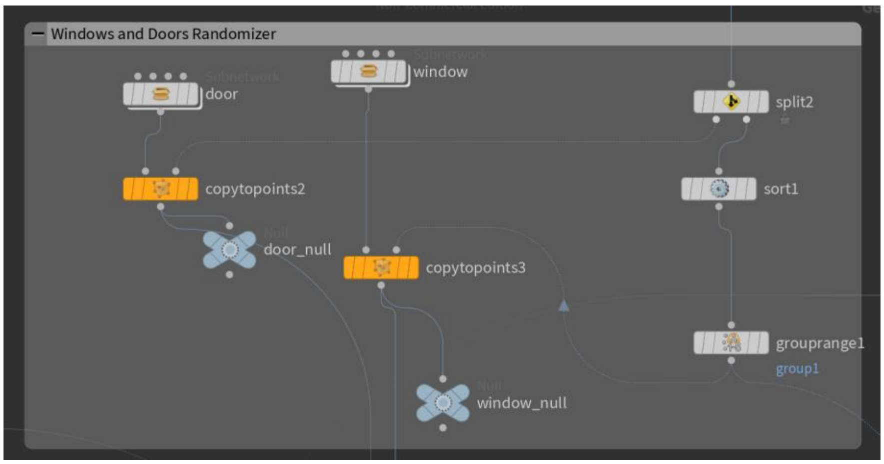
The network for the nodes to loop through the walls.



Parameters for the "foreach_begin" and "foreach_end".

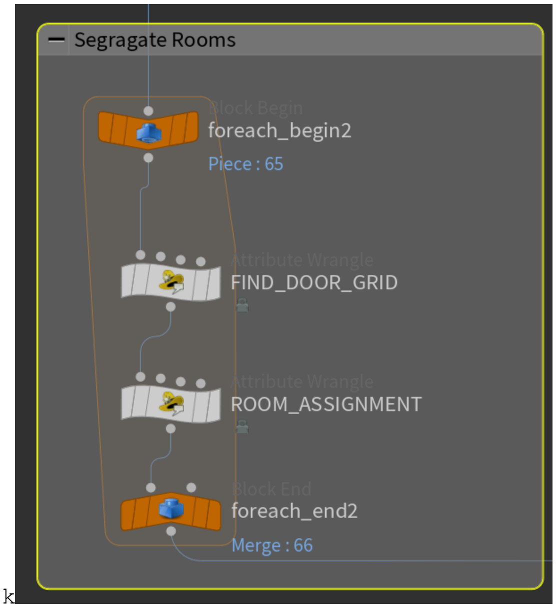
Appendix E

Windows and Doors Randomizer network



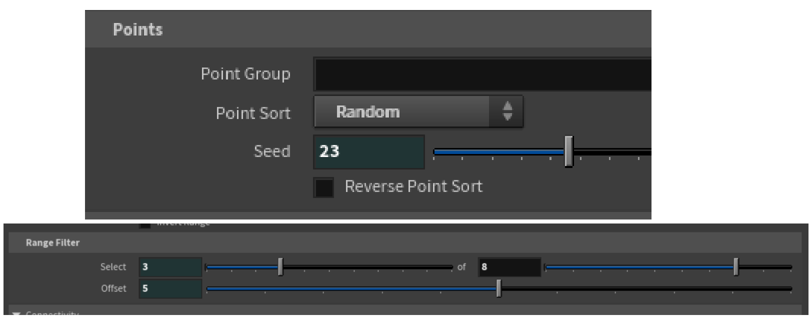
The network for the nodes for door network, window network, and connecting the mentioned network to the house model.

Appendix F



Segregate Rooms Network

The network for the nodes to loop through cells to divide them into rooms.



The parameters for the "foreach_begin" and "foreach_end".

Appendix G

Find Door for “Wrangle” Node Code

```
// Get the center of the bounding box for the geometry piece
vector bbox_center = getbbox_center(0);

// Fetch the door's position. Assuming it's passed correctly
into the wrangle
vector doorPos = detail(0, "doorPos", 0); // Make sure this
attribute is accessible

// Access the stored area attribute
float storedArea = @area;

// Define the distance threshold
float threshold = (storedArea/2); // Adjust this based on the
scene's scale and requirements

// Fetch the floor level from the parameter. Adjust the path as
necessary.
int floorLevel = chi("../dist");


// Calculate the distance between the bbox center and the
door's position
float dist = distance(bbox_center, doorPos);

// Initialize group flags
@group_public_space = 0;
@group_private_space = 0;

// Initialize color attributes for public and private spaces
vector yellow = {1, 1, 0};
vector violet = {1, 0, 1};
vector red = {1, 0, 0};
vector green = {0, 1, 0};
```

```
if (dist < threshold) {
        @group_public_space = 1;
        @Cd = yellow;
    } else {
        @group_private_space = 1;
        @Cd = violet;
    }
```

VEX code for the “Find Door Wrangle” Node.

Appendix H

Code for "room_assignment wrangle" node.

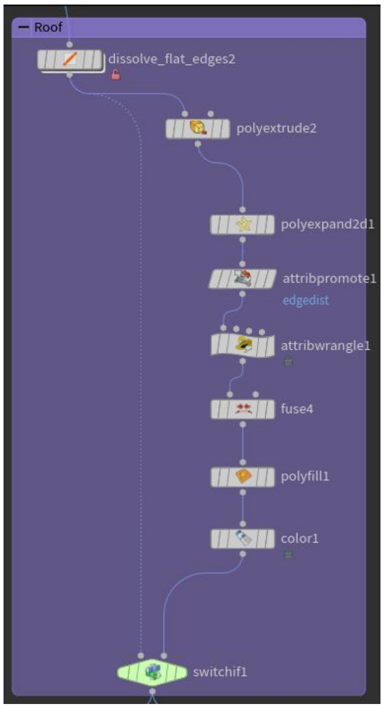
```
// Assuming @P.x is the position in X, and we're using it to
differentiate spaces
int divisionX = 1; // Example division line; adjust based on
the scene

// Initialize color attributes for living room and kitchen
vector red = {1, 0, 0};
vector orange = {1, 0.5, 0};
vector yellow = {1, 1, 0};
vector green = {0, 1, 0};
vector blue = {0, 0, 1};
vector violet = {0.5, 0, 0.5};
vector black = {0, 0, 0};
vector brown = {0.6, 0.3, 0.1};


int temp = floor(@P.x);

// Check if the point is in the public space group
if (@group_public_space) {
    // Now divide the public space based on some condition,
here using @P.x
    if (temp < divisionX) {
        @Cd = red;
        @group_living_room = 1;
    } else {
        @Cd = orange;
        @group_kitchen = 1;
    }
} else {
    if (temp < divisionX) {
        @group_bedroom_1 = 1;
        @Cd = yellow;
```

```
    } else {
        @group_bedroom_2 = 1;
        @Cd = green;
    }
}
```

VEX code for the “room_assignment Wrangle” Node.

Appendix I

Roof Network

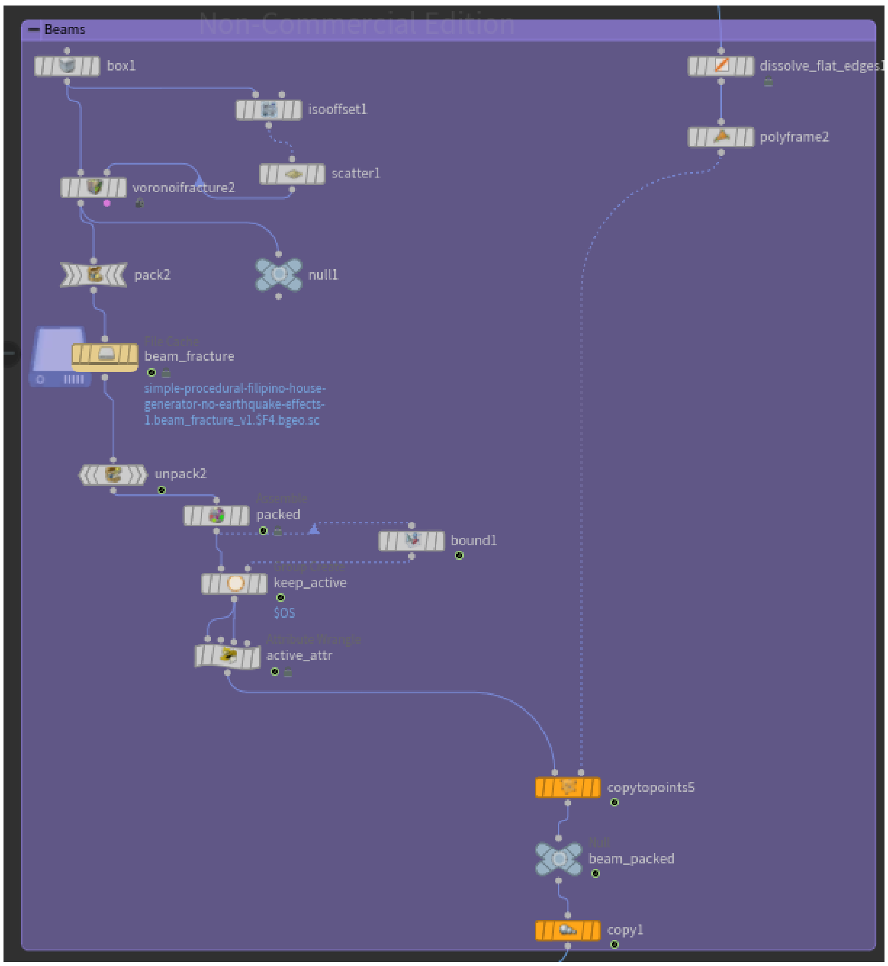


The network for the nodes to generate roof.

The parameters for “polyextrude” and “attribwrangle”.

Appendix J

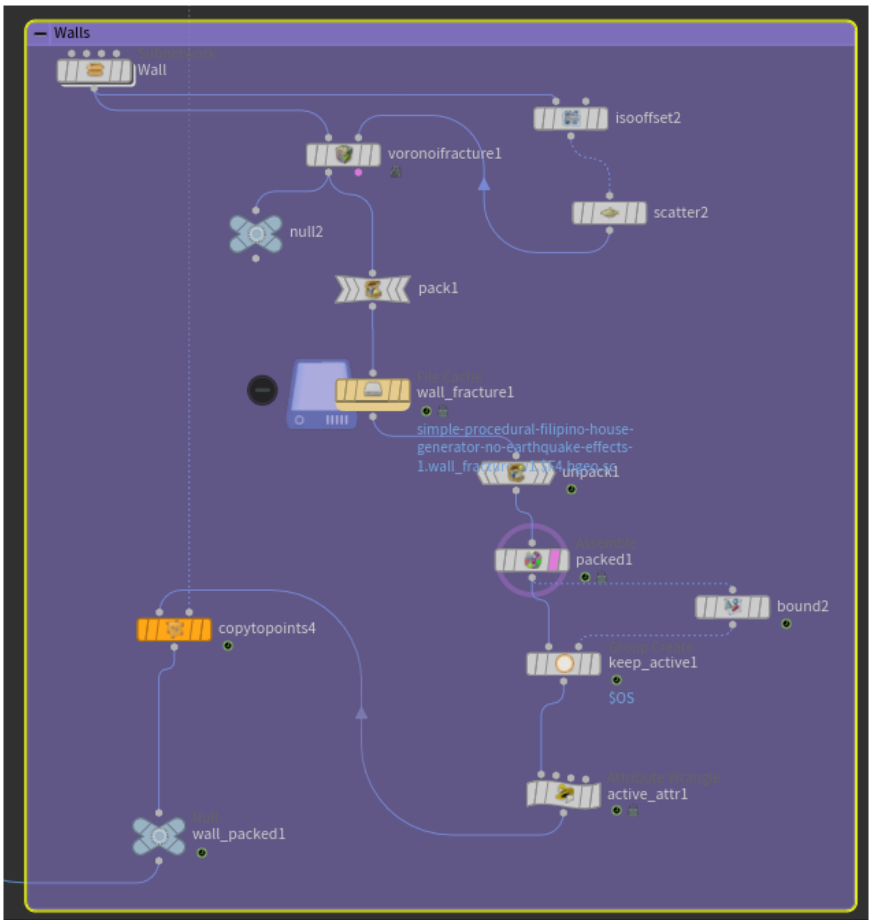
Beams Network



The network for the nodes to generate the beams.

Appendix K

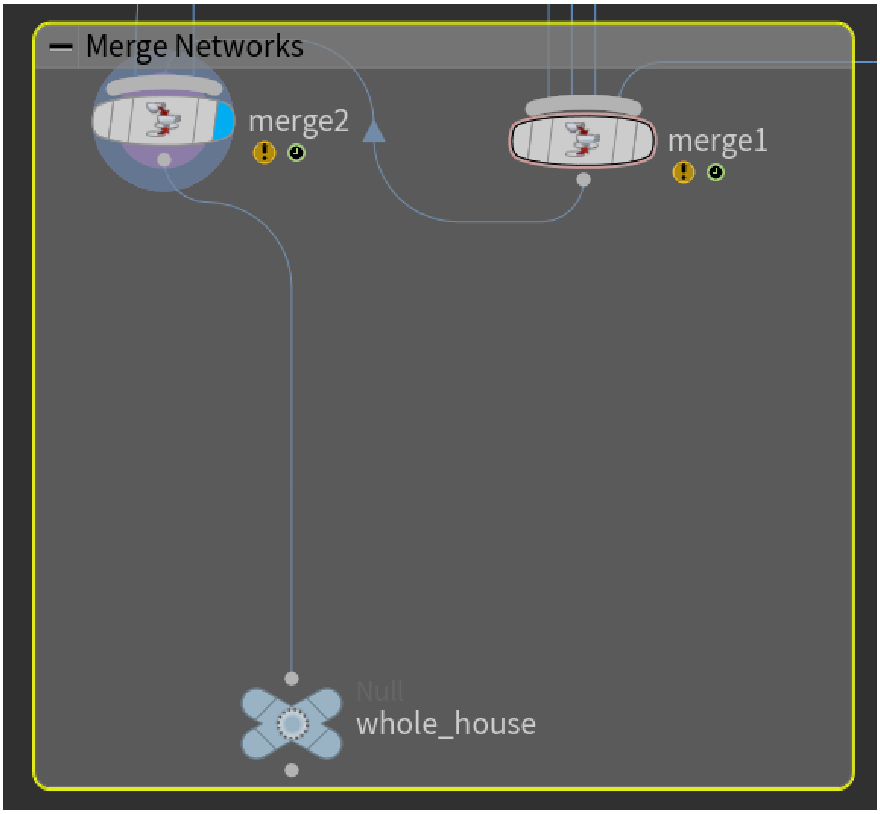
Walls Network



The network for the nodes to generate the walls.

Appendix L

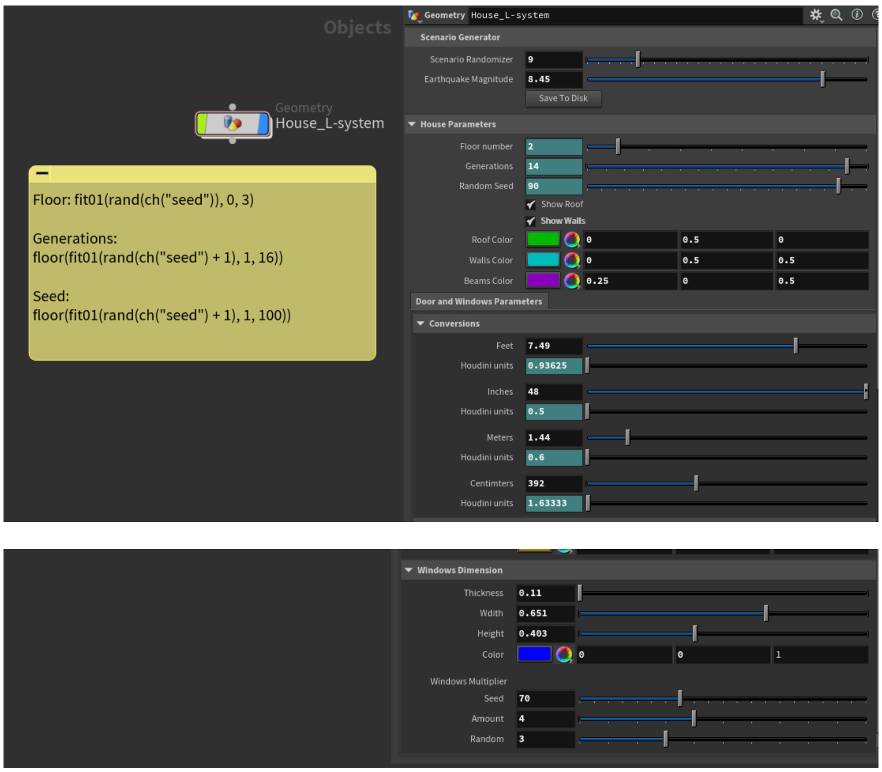
Merge Network



The network for the nodes to merge all the network.

Appendix M

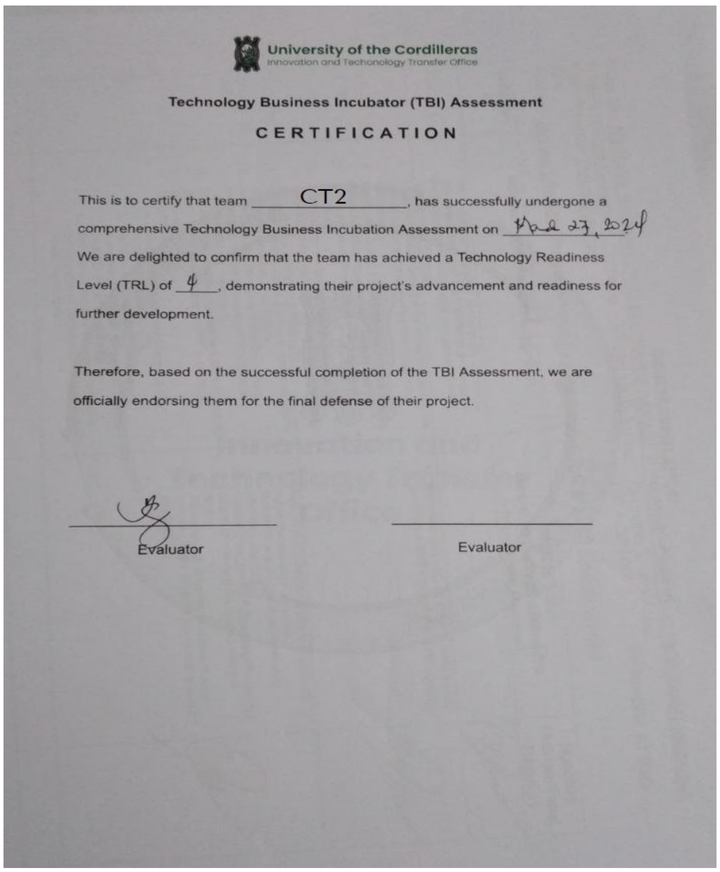
Final Geometry Nodes and Parameters



Final Geometry node and procedural parameters.

Appendix N

TBI Assessment



University of the Cordilleras
Innovation and Techonology Transfer Office

Technology Business Incubator (TBI) Assessment

CERTIFICATION

This is to certify that team ___CT2___, has successfully undergone a comprehensive Technology Business Incubation Assessment on __March 27, 2024__ We are delighted to confirm that the team has achieved a Technology Readiness Level (TRL) of _4_, demonstrating their project's advancement and readiness for further development.

Therefore, based on the successful completion of the TBI Assessment, we are officially endorsing them for the final defense of their project.

Evaluator

Evaluator

A scanned image of the TBI Assessment Certificate, provided by the UC Innovation and Technology Transfer Office.

Appendix O

ACM Paper

RESQUAKE: Simulating Post-earthquake Damage in Philippine Homes Using Procedural Modeling

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ABSTRACT

Traditional post-earthquake training often relied on predefined scenarios that lacked the realism necessary to prepare trainees for the unpredictable scenarios of actual earthquakes. This research addressed this problem by introducing procedural modeling to create diverse models for simulations that reflected real-life post-earthquake situations. By leveraging procedural modeling, the researchers aimed to develop a comprehensive framework for procedurally generated post-earthquake models for rescue training operations on Philippine houses. Utilizing Houdini, a procedural modeling software, the researchers initially created a model incorporating standard architectural features of Philippine homes. These models were then refined under various earthquake scenarios, adjusting key parameters like magnitude. Preliminary results indicated that procedural modeling significantly enhanced the diversity of post-earthquake models for training scenarios, offering a more dynamic environment. Generating more training simulation environments rather than manually sculpting each led to a broader range of scenarios without a corresponding increase in time and resources needed to create them. This research held the potential to greatly enhance post-earthquake preparedness and response efforts in the Philippines and possibly other earthquake-prone regions.

Categories and Subject Descriptors

I.6.5 [**Simulation and Modeling**]: Model Development – *Modeling methodologies*

General Terms

Computing methodologies

Keywords

Procedural Modeling, Post-earthquake, Houdini

1. INTRODUCTION

Situated on the seismically active "Pacific Ring of Fire," the Philippines faced ongoing earthquake risks, underscoring the need for comprehensive disaster preparedness and agile response strategies. Effective post-disaster response, especially in the vital first 48 hours following an earthquake, is essential for saving lives and reducing damage [1,2]. The complexity and lack of in-depth understanding of post-disaster management call for enhanced strategies [3,4,5] in alignment with the United Nations (UN) Sendai Framework for Disaster Risk Reduction (DRR) goals of reducing hazard exposure, and improving preparedness and response [6]. To address this, the research titled "Resquake: Simulating Earthquake Damage In Philippine Homes Using Procedural Modeling" aimed to employ procedural modeling (PM) to innovate and diversify post-earthquake rescue operations. By utilizing PM techniques such as L-system, Voronoi, Material Fracture, and others, the study generated a multitude of models, which were detailed in the paper. The objective was to generate wide range of earthquake-damaged residential structures models to improve disaster response effectiveness, particularly in the critical initial hours post-disaster.

2. METHODOLOGY

The methodology of the study will be discussed in this section. Figure 1 presents the flowchart illustrating the study's methodology.

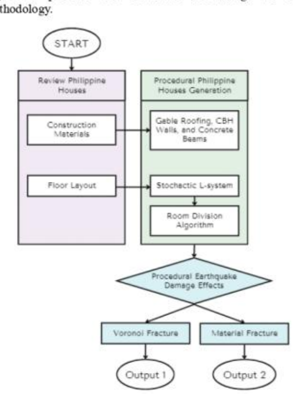

Figure 1. Resquake Methodology Process Diagram

First Page of the ACM Paper.

The researchers conducted a literature review to identify the common construction materials of Philippines houses. Then, examined existing floor layouts sourced from real estate websites.

The researchers then employed procedural generation techniques to create detailed models of Philippine houses. This involved integrating specific architectural features such as gable roofing, concrete hollow block (CHB) walls, and concrete beams. The complexity of floor layouts was addressed using stochastic L-systems. Additionally, a room division algorithm was implemented to partition the generated spaces into distinct rooms.

By incorporating procedural modeling techniques specifically Material Fracture and Voronoi Fracture, earthquake damages were simulated in the generated houses. The researchers systematically evaluated each procedural modeling technique, considering caching time per 100 frames.

3. RESULTS AND DISCUSSION

This section presents the outcomes of the procedural generation of Philippine houses along with the post-earthquake damage effects on these models. It will detail the procedural generation and demonstrate the variability and efficiency of this approach. Through a comparative analysis, the resilience of the generated structures against earthquakes will be evaluated based on the Richter scale magnitude.

3.1 Characteristics of Philippine Houses

3.1.1 Construction Materials

In analyzing the architecture of urban residential areas within the Philippines, a distinct pattern emerged, characterized by a reliance on concrete materials and designs tailored to local climate and urban demands. The structural framework, notably beams, columns, and walls, predominantly utilize reinforced concrete and concrete hollow blocks (CHB), highlighting a national preference for these materials due to their durability and accessibility [7, 8,9]. Moreover, the roofing of these residences further demonstrates an adaptation to local conditions, employing materials such as tin and designs like gable roofs to offer practical, cost-effective solutions for weather protection and aesthetic preferences [10,11]. An extensive survey across 15 municipalities elucidated the diversity in roof designs, with gable, mono-slope, and hip roofs dominating the landscape, accounting for significant portions of the observed structures [12]. This comprehensive analysis formed a solid foundation for developing 3D models that accurately reflected Philippine residential architectures. Incorporating reinforced concrete, CHB, and tin gable-shaped roofing into 3D models ensured an authentic representation of the Philippines' common residential architecture.

3.1.2 Floor Layout

A floor plan from [13] showed that a basic Filipino floor layout was divided into public and private spaces. The public space comprised the living room, dining area, and kitchen. It was also evident that the entrance was where the door was located. The private space consisted of two bedrooms and a bathroom.

A comprehensive two-story floor plan adapted from [14] delineated the spatial distribution between public and private areas within a Philippine residential structure. The ground floor was exclusively allocated for public use, encompassing the kitchen, living, and dining areas. Conversely, the second floor was devoted to private spaces, primarily the bedrooms.

The floor layouts from [13] and [14] illustrated the division between public and private spaces in Philippine Homes. These plans served as a blueprint for generating 3D models, ensuring an accurate representation of typical Philippine residential architecture in procedural model creation.

3.2 Philippine Houses Generation

Procedural modeling was an automated computer graphics technique that employed algorithms and rules to generate complex models and textures, enabling the efficient creation of extensive environments like cities and landscapes with minimal manual effort [15,16,18]. Specifically, procedural modeling was utilized to achieve the diverse generation of Philippine houses and to apply different earthquake magnitude effects to those structures, showcasing its applicability in simulating real-world scenarios and architectural diversity. After examining the common characteristics of Philippine houses, those features served as the foundational model for procedurally generated houses.

3.2.1 Floor Layout Generation

In exploring innovative methodologies for floor layout generation, the utilization of Lindenmayer Systems (L-systems) presents a compelling avenue for random architectural design automation [17]. Leveraging their rule-based generation capabilities to automate and diversify design possibilities [15,17,18]. The implementation of the L-system in this study was defined by a set of production rules aimed at generating floor layouts through a stochastic approach.

$$A \rightarrow F{+}A{:}0.5$$

$$A \rightarrow F{-}A{:}0.5$$

In these rules, A represents the starting variable, F denotes a forward movement — and + symbolizes turns in left and right directions with an equal probability of 0.5 for each. This stochastic approach to L-system-based floor layout generation not only automates the design process but also introduces a level of variation that is difficult to achieve through manual design methods [18,19].

Figure 2. Random Floor Layout Generated Using L-system

Figure 2 showed a random sample of 5 different floor layouts that were generated using an L-system through a stochastic approach. Each of the 5 layouts was unique, indicating that the system could generate a wide variety of floor plans.

3.2.2 Interior Generation

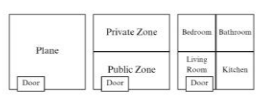

Figure 3. Algorithm for 1-Storey House Division

Figure 3 illustrates a Floor layout Division algorithm for floor area division within a house, categorizing spaces into Public and

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Private zones. The Public space was defined by the door position, branching into a Living Room and Kitchen, while the Private space comprised a Bedroom and Bathroom.

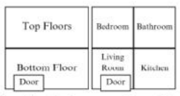

Figure 4. Algorithm for 2 or more Storey House Division

Figure 4 detailed a corresponding Floor layout Division algorithm for multi-story houses, applicable when the floor number exceeded one. It categorized the first floor entirely as a Public space, which included a Living Room and Kitchen, typically near the entrance. The algorithm then designated the remaining floors exclusively as Private spaces, composed of Bedrooms and Bathrooms.

Figures 3 and 4 presented a rule-based algorithm that was employed in a procedural modeling system for generating architectural floor plans. Essentially, the process followed a treemap subdivision with some intersection and dimensioning operations to deal with the division of the rectangular polygon.

3.3 Simulating Earthquake Damage

This section examined the application of procedural generation techniques for the realistic simulation of earthquake damage on generated house models, facilitating the efficient creation of models encompassing a spectrum of earthquake impacts, from minor damages to substantial structural failures.

3.3.1 Voronoi Fracture

Figure 5. Voronoi

Voronoi diagrams are employed to simulate the fracture process in concrete. These simulations help in understanding the crack morphology and stress-strain responses in concrete, illustrating how the Voronoi-based models can influence crack initiation and growth [20]. The level of detail in Voronoi fracture simulations can be quite high, with the ability to model complex crack patterns and interactions within heterogeneous materials like concrete. These models account for the realistic representation of aggregates, enabling detailed analysis of fracture mechanisms under various loading conditions, including static and dynamic tensile loads [21]. The Voronoi Fracture parameters could be adjusted to represent different intensities and types of seismic damage, from fine cracks indicative of minor tremors to extensive fragmentation resulting from a major quake. The study demonstrated that using a density volume, derived from an object's geometry with IsoOffset, to scatter points was an adaptable approach for generating cell points. Modifying the density inside the volume prior to scattering facilitated the accumulation of more points in designated areas of the object. Consequently, in regions where the point density was higher, the Fracture SOP was configured to produce a larger number of smaller fragments.

3.3.2 RBD Material Fracture

Figure 6. Material Fracture Pattern

The process of RBD material fracture in Houdini involved using various tools and solvers provided within the software to simulate the physical behavior of materials under stress or impact. The parameters governing the fracture simulations, such as force, direction, and material type, could be finely tuned to simulate specific earthquake scenarios. This level of control ensures that the simulated damage closely matches real-world observations or theoretical predictions [22]. The Fracture Level will control how many cuts your object will have. Increasing this number will add more fractures to the existing fractured pieces, breaking each chunk into smaller pieces [22].

3.3.3 Testing

In the house model generation, it was observed that procedural generation techniques offered a significant speed advantage. Specifically, the study achieved significantly faster layout generation by employing simpler rules, such as stochastic distributions A=F+A:0.5 and A=F-A:0.5, as detailed in Section 2.2.1. However, it was important to note that while L-systems with defined rules could offer advantages such as enhanced randomness and the capacity to manage complex shapes, they also presented certain limitations. These limitations encompassed the fact that increased seeding could lead to the creation of plant branch patterns. Despite these challenges, L-systems might still have been a viable option for projects where such attributes were deemed less critical. However, within the scope of that study, the algorithm had proven efficient for initiating procedural generation of residential layouts with considerations for post-earthquake damages.

Figure 7. Samples of Procedurally Generated Houses

In terms of performance, the procedural generation method had demonstrated the capability to generate 46 quality models out of 50. This indicated a relatively high success rate, yet it also highlighted the potential for refining the model generation process to reduce the occurrence of inadequate outcomes.

The researchers had then compared the efficiency of Voronoi and Material Fracture procedural modeling techniques in Houdini SideFX for simulating fractures in a house's beams and walls. These methods were evaluated based on the time required to save the data to disk and the caching time per 100 frames.

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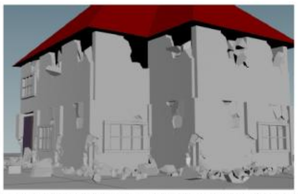

Figure 8. Earthquake Damages Using Procedural Modeling

The Voronoi Fracture method, known for generating natural-looking fractures, was applied to the house's beams and walls. It quickly computed break patterns by creating Voronoi cells around distributed points within the object's volume. Conversely, the Material Fracture technique, which accounted for the material's physical properties, offered a more realistic fragmentation, which was important for detailed visualizations.

Table 1. Data Storing Efficiency Comparison

Procedural Modelling Technique	Beam	Wall
Material Fracture	5.26 seconds	4.74 seconds
Voronoi Fracture	2.45 seconds	1.76 seconds

In terms of data storing efficiency in Table 1, Voronoi Fracture outperformed Material Fracture, taking 2.45 seconds for beams and 1.76 seconds for walls, compared to the 5.26 and 4.74 seconds taken by Material Fracture, respectively. This suggests that Voronoi Fracture is a more efficient technique in terms of processing time for these specific applications.

Table 2. Caching Time Efficiency Per 100 Frames Comparison

Procedural Modelling Technique	Whole House	Beam	Wall
Material Fracture	23.14 seconds	4.41 seconds	11.9 seconds
Voronoi Fracture	8.73 seconds	4.18 seconds	4.34 seconds

According to Table 2, the Voronoi fracture procedural modeling technique demonstrates significantly higher efficiency when compared to the Material fracture method. The time taken to process 100 frames for a whole house is 8.73 seconds with the Voronoi fracture, which is much less than the 23.14 seconds required for the Material fracture. When it comes to a beam, the Voronoi fracture method only needs 4.18 seconds, whereas the Material fracture takes 4.41 seconds, showing a slight but notable efficiency gain. In the case of a wall, the Voronoi fracture's time efficiency is 4.34 seconds compared to the Material fracture's 11.9 seconds. These gaps highlight the Voronoi fracture's superior efficiency, with time savings of 14.41 seconds for a whole house, 0.23 seconds for a beam, and 7.56 seconds for a wall.

4. CONCLUSION

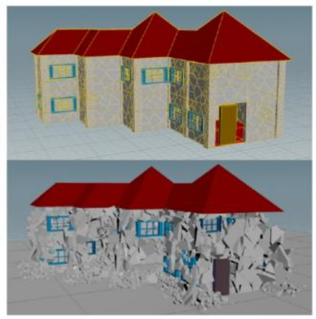

Figure 9. Earthquake Damages Using Procedural Modeling

5. REFERENCES

[1] Cartusiano, R., & Cruz, F. (2023). Las Piñas Flood Monitoring System with Alternate Route Using Bayesian Network via Mobile Application. 2023 15th International Conference on Computer and Automation Engineering (ICCAE). DOI: 10.1109/ICCAE56788.2023.10111369.

[2] Hooshangi, N., Mahdizadeh Gharakhanlou, N., & Alesheikh, A. A. (2021). Determining the number of rescuers in post-earthquake rescue operations using the agent-based modeling (case study: Tabriz city).

[3] Valaei Sharif, S., Habibi Moshfegh, P., & Kashani, H. (2023). Simulation modeling of operation and coordination of agencies involved in post-disaster response and recovery. Reliability Engineering & System Safety, 235, 109219. https://doi.org/10.1016/j.ress.2023.109219

[4] Cook, A. D. B., Shrestha, M., & Htet, Z. B. (2018). An assessment of international emergency disaster response to the 2015 Nepal earthquakes. International Journal of Disaster Risk Reduction, 31, 535-547. https://doi.org/10.1016/j.ijdrr.2018.05.014

[5] Zhang, Z., Cui, P., Hao, J., Li, N., Zeng, Z., Liu, Y., Zou, Q., Huang, C., & Wu, S. (2021). Analysis of the impact of dynamic economic resilience on post-disaster recovery "secondary shock" and sustainable improvement of system performance. Safety Science, 144, 105443. DOI: https://doi.org/10.1016/j.ssci.2021.105443

[6] UNDRR. Sendai framework for disaster risk reduction. Available:https://www.unisdr.org/we/coordinate/sendai-framework [Accessed 12 Dec 2023].

[7] Lejano, B., Cacanando, C., Abary, A., Ang, T., & Ty, R. (2021, July 7-9). Strength analysis of physically treated rattan as reinforcement of concrete beam. DLSU Research Congress 2021, De La Salle University, Manila, Philippines.

[8] Ongpeng, J., Gapuz, E., Andres, J. J. S., Prudencio, D., Cuadlisan, J., Tadina, M., ... & Pabustan, A. (2020, May).

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Alkali-activated binder as stabilizer in compressed earth blocks. In IOP Conference Series: Materials Science and Engineering (Vol. 849, No. 1, p. 012042). IOP Publishing.

[9] Canlas, R. L., Talusan, A. B., Principe, M. T. J., Gonzales, L., DyReyes, V., & Regonios, C. A. J. (2021, December). A comparative finite element analysis of a two-story residential building using concrete hollow blocks and po-lite hollow blocks. In TENCON 2021-2021 IEEE Region 10 Conference (TENCON) (pp. 827-832). IEEE.

[10] Seike, T., Shoji, Y., Takemura, Y., Kunie, Y., Mercado, R. M., & Kim, Y. (2018). Construction Systems for Extensions and Renovations in a Resettlement Site in the Philippines. Journal of Asian Architecture and Building Engineering, 17(3), 441-448.

[11] Pantua, C. A. J., Calautit, J. K., & Wu, Y. (2019, July). A novel Fluid-Structure Interaction modelling and optimisation of roofing designs of buildings for typhoon resilience. In IOP Conference Series: Materials Science and Engineering (Vol. 556, No. 1, p. 012057). IOP Publishing.

[12] Tan, L. R. E., Acosta, T. J. S., Gumaro, J. J. C., Agar, J. C., Tingatinga, E. A. J., Plamenco, D. A. D., ... & Villalba, I. B. O. (2021, May). Investigation of the effects of the classification of building stock geometries determined using clustering techniques on the vulnerability of galvanized iron roof covers against severe wind loading. In IOP Conference Series: Materials Science and Engineering (Vol. 1150, No. 1, p. 012024). IOP Publishing.

[13] Pinoyeplans (2020, June 6) SMALL HOUSE DESIGN SERIES : SHD-2014008. https://www.pinoyeplans.com/listing/small-house-designs-series-shd-2014008/

[14] Philconprices (2023) New house construction cost philippines. Retrieved from https://philconprices.com/tag/new-house-construction-cost-philippines/

[15] Guo, J., Jiang, H., Benes, B., Deussen, O., Zhang, X., Lischinski, D., & Huang, H. (2020). Inverse procedural modeling of branching structures by inferring L-systems. ACM Transactions on Graphics. https://doi.org/10.1145/3394105

[16] Hu, Y., Dorsey, J., & Rushmeier, H. (2019). A novel framework for inverse procedural texture modeling. ACM Transactions on Graphics (TOG), 38, 1 - 14. https://doi.org/10.1145/3355089.3356516.

[17] Antoniuk, I., Hoser, P., & Strzęciwilk, D. (2018). L-system Application to Procedural Generation of Room Shapes for 3D Dungeon Creation in Computer Games. Advances in Intelligent Systems and Computing, 375–386. doi:10.1007/978-3-030-03314-9_32

[18] Krs, V. (2019). Optimization and Control in Procedural Modeling. . https://doi.org/10.25394/PGS.8290055.V1.

[19] Adão T, Pádua L, Marques P, Sousa JJ, Peres E, Magalhães L. Procedural Modeling of Buildings Composed of Arbitrarily-Shaped Floor-Plans: Background, Progress, Contributions and Challenges of a Methodology Oriented to Cultural Heritage. Computers. 2019; 8(2):38. https://doi.org/10.3390/computers8020038

[20] Naderi, S., Tu, W., & Zhang, M. (2021). Meso-scale modelling of compressive fracture in concrete with irregularly shaped aggregates. Cement and Concrete Research. https://doi.org/10.1016/j.cemconres.2020.106317.

[21] Naderi, S., & Zhang, M. (2021). Meso-scale modelling of static and dynamic tensile fracture of concrete accounting for real-shape aggregates. Cement and Concrete Composites. https://doi.org/10.1016/j.cemconcomp.2020.103889.

[22] RBD material fracture 3.0 geometry node. RBD Material Fracture. (n.d.). https://www.sidefx.com/docs/houdini/nodes/sop/rbdmaterialfracture.html

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Appendix P

Conducted Webinar Report

University of the Cordilleras
College of Information Technology and Computer Science

Thesis Writing 2
Report for the Conducted Webinar

Name of Students: 1. Clemente, Tyra P.
2. Sabino, Tyraxl D.
3. Chantioco, Charles

Title of the Webinar: "The Key Arsenal for Efficient 3D Creation: Unlock the Power of Procedural Modeling"

Date and Time of the Webinar: April 12, 2024, at 10 AM.

Webinar Link/Details:

Meeting ID: 845 7423 5872
Passcode: procgen

https://us06web.zoom.us/j/84574235872?pwd=OjQiQq5ziIPJ0scbW1p5gTyqHgVzEJ.1

Outline of the Topics Covered:

I. Traditional 3D modeling and Procedural Modelling
   a. Definitions of 3D Modelling
      i. Research about 3D Modelling
   b. Techniques of 3D Modelling
      i. Polygonal Modelling
      ii. Nurbs Modelling
      iii. Sculpting
   c. Application of 3D Modelling
      i. Entertainment
      ii. Design and Engineering
      iii. Education
   d. Challenges of 3D Modelling
      i. Precision and Detail
      ii. Technical Skills
      iii. Time-Consuming

First Page of the Conducted Webinar Report

- e. Definition of Procedural Modelling
  - i. Research about Procedural Modelling
  - ii. Key Feature of Procedural Modelling
  - iii. Application of Procedural Modelling

II. Procedural Modeling Techniques

- a. Cellular Automata
  - i. The ruleset for grid map generation
- b. L-system
  - i. Founder Astrid Lindermayer
  - ii. Algorithm and ruleset
  - iii. Discussion of the Dragon Curve generation
- c. Particle System
- d. Voronoi
  - i. United States of Voronoi
  - ii. Try voronoi link
- e. Perlin Noise
  - i. Minecraft using Perlin noise
- f. Fractal Algorithms
- g. Disney Animation Studio Zootopia and Procedural Modeling
  - i. Animation studio problem with the character rigging
  - ii. Houdini

III. The Key Arsenal for Efficient 3D Creation

- a. L-system
  - i. Base Study by Isabella Antoniuk
  - ii. Nodes and Parameters in Houdini
  - iii. Demo
  - iv. Sample Floor Layout
- b. Voronoi
  - i. Base Study by Shenrun Pan
  - ii. Demo
- c. Thesis Presentation
  - i. Procedural Techniques used
  - ii. Model Showcase
- d. Benefits of Procedural Modeling
  - i. Efficiency and speed
  - ii. High degree of control and flexibility
  - iii. Realism and Detail
  - iv. Reusability and Consistency
  - v. Cost-effectiveness

Second Page of the Conducted Webinar Report

List of Participants:

1. Carl Justin Masedman
2. Thelma Palaoag
3. Yohann Mar C. Gayao
4. Shania B. Baday
5. De Castro, Joef Pierson M.
6. Renz Jay P. Bayeng
7. Rebekah Jasmin A. Arcinas
8. Jeanikka Merjoy Lumague
9. Ryzel Erin G. Felizco
10. Rhowella Cy Appi Lagasi
11. Neil Mark Vinuya Saludez
12. Audrey Kyle B. Villar
13. Pearly Joy D. Aduana
14. Lourielle O. Egan
15. Ray Shine Derek Balaswit
16. Peter Ray Aguindang
17. Daniela De Guzman
18. Tj B. Cariño
19. Michaela P. Yaban
20. Elchan Rivero
21. Clary Anne B. Alidao
22. Zoe Kylie Matias
23. Tyra Clemente
24. Eleigh Langgoyan
25. John Jemuel Pajanel
26. Michaela Pineda Yaban
27. Athea Dang-il
28. America Eloise P. Slay
29. Aleeyah Noelle M. Depalog
30. Cris Angelo Bernales
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35. Clary Anne Alidao
36. Lorraine Bellong
37. Levan S. Tagubar
38. Genesis Hope L. Bucasan
39. Salcedo, Trischa May V.
40. Khyle Kent Alviz
41. Aldith Mirador
42. John Trevanian Abellera
43. Yssabelle Ermitanio
44. Jo Wendell Dasco
45. Aldrin Joshua T. Bobita
46. Pearly Joy D. Aduana
47. Tyraxl Sabino
48. Charles Chantioco
49. Audrey Villar
50. Yssabeller Ermitanio
51. Creflo Basera
52. Francheska Romero
53. Lurimar Atonen
54. Bill Malitao
55. Avila, Jensen Harold
56. Meynard Baucas
57. Bod-oy Colston
58. Estrada, Sherwin
59. Montalban, Lloyd
60. Ocampo, Christella Marie
61. Aldith Mirador
62. Ryzel Felizco
63. Carl Justin Masedman
64. Jach Hardin
65. Kenneth Bernal
66. Rosa Navaro
67. Mark Sakobird
68. Kobe Bayad
69. Rhowella Lagasi
70. Mathias Von Erev
71. Arvin Vargas
72. Gani Pasion
73. Joriz Ancheta
74. Jose Galang
75. Hong Hae In

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76. Clyde Pizzarro
77. Beau Yujeco Tortal
78. Jd Cabigas Quema
79. Trace Keon Carandang
80. Kevin Noe Matapang
81. Arlo Galang
82. Tyree Eron Lakandula
83. Landon Pérez
84. Leo Caponga
85. Brycen Kenyon Mariano
86. Dominic Dylon Cruz
87. Zumac Xiomarys Mañalac
88. Maia Singson
89. Engracia Yoshida Matias
90. Diana Alupay
91. Shaniya Elefante
92. Chelsea Brandy Dulalas
93. Ryann Zafra
94. Dania Chávez
95. Kaylie Deina Macalipay
96. Mikaela Leyco
97. Christine Pichicoy Cachuela
98. Jacqueline Kayleigh Vital
99. Melanie Loren Estolas
100. Shai Supsup
101. Ashleigh Bryssa Cuevas
102. Angela Olinne Clemente
103. Cyrin Joy Athaliah Clemente
104. Orlando Manzano
105. Evangeling Paasa
106. Rosalina Manzano

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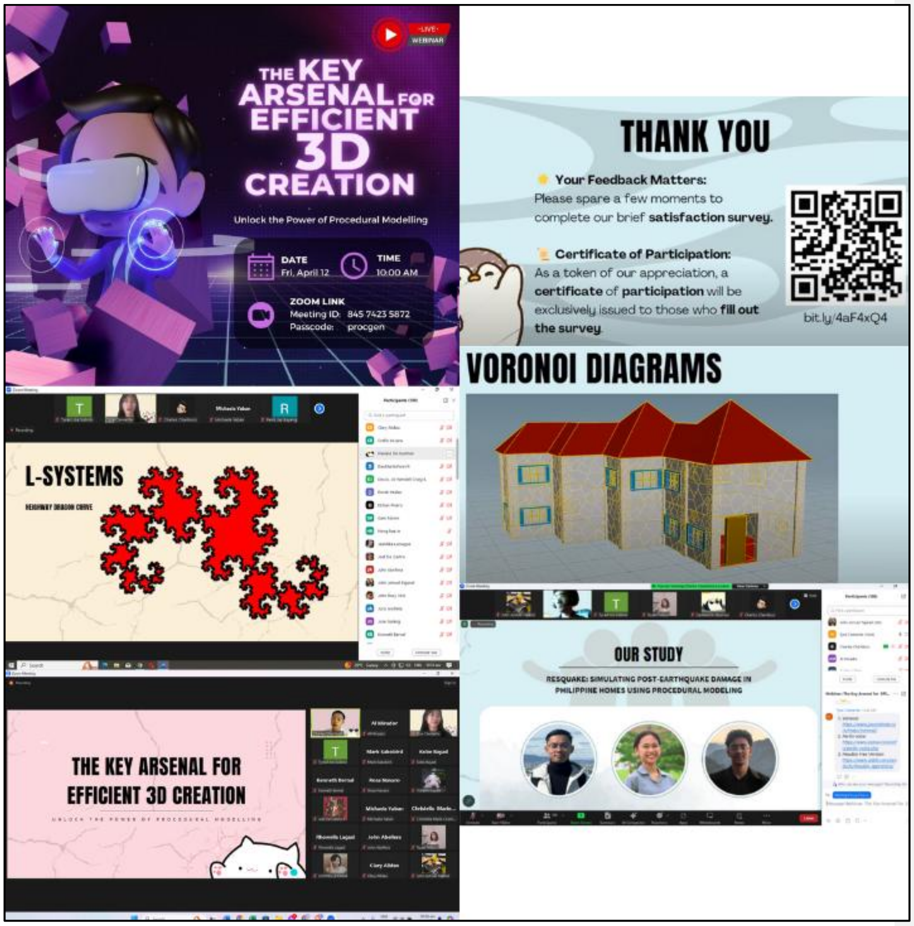
Screenshots of the webinar:



A report on the webinar conducted titled "The Key Arsenal for Efficient 3D Creation: Unlock the Power of Procedural Modeling.

Appendix Q

Consultation Form

THESIS PROGRESS REPORT

Thesis Title: RESQUAKE: SIMULATING POST-EARTHQUAKE DAMAGE IN PHILIPPINE HOMES USING PROCEDURAL MODELING
Names : (1) CHANTIOCO, Charles S. (2) CLEMENTE, Tyra Generose P. (3) SABINO, Tyraxl Joe D.
Thesis Instructor: 6:10 – 7:30 MWF 2ND Trimester, AY 2023-2024
Adviser : FORYASEN, Zen Lee Panel Members: (1) QUITALEG, Anna Rhodora (2) GAYYED, Arnemie

Date/Time	Adviser/Panel Member Suggestion	Progress/Status (Based on the Evaluation of the Adviser/Panel Member)	Signature (Adviser/Panel Member)
Jan 23 06:09 PM	Update SOP 1: what are the characteristics of a model Philippine urban residential structure	- Paper: Need to Adopt ~~thor~~ Institutional format - System: unverified	
Feb 2 2024 5:00PM	- Change in-text citation - Remove sentences that shows related problems but will not be solved by your app - Repeating some sentences	- Paper: ch 1: minor revisions - System: not verified	
Feb 16, 2024 2:30 PM	- Reference for floor layouts - fix citations - rewordings for ACM	- Research Progress: Steady, no problems with design - system: first major component completed	

THESIS PROGRESS REPORT

Thesis Title: REQUAKE: SIMULATING POST-EARTHQUAKE DAMAGE IN PHILIPPINE HOME USING PROCEDURAL MODELING
Name(s) : (1) Tyra Generose P. Clemente (2) Tyraxl Joe D. Sabino (3) Charles S. Chantioco
Thesis Instructor: Thelma Palaoag 6:10 – 7:30 MWF 2ND Trimester, AY 2023-2024
Adviser : Zen Lee Foryasen Panel Members: (1) Anna Rhodora Quitaleg (2) Arnemie Gayed

Date/ Time	Adviser/Panel Member Suggestion	Progress/Status (Based on the Evaluation of the Adviser/Panel Member)	Signature (Adviser/Panel Member)
March 6	1. Ensure a smooth transition between paragraphs to effectively build upon the knowledge presented in the Related Literature Review and enhance the coherence of the study	1. Added transition on paragraphs to build up the RRL of the study	Mr. Foryasen
March 13	1. Logic Explanation: Describe the reasoning behind the chosen and parameters that support the methodology. 2. Research Question 3(Q3) Response: Address how the integration of components and systems was approached to answer the research question effectively. 3. Methodology Justification: Explain the basis and rationale for the selected methodology, highlighting any specific processes or models used.	1. Identified and utilized external references to validate and support the methodology.	Mr. Foryasen

THESIS PROGRESS REPORT

Thesis Title: REQUAKE: SIMULATING POST-EARTHQUAKE DAMAGE IN PHILIPPINE HOME USING PROCEDURAL MODELING
Name(s) : (1) Tyra Generose P. Clemente (2) Tyraxl Joe D. Sabino (3) Charles S. Chantioco
Thesis Instructor: Thelma Palaoag 6:10 – 7:30 MWF 2ND Trimester, AY 2023-2024
Adviser : Zen Lee Foryasen Panel Members: (1) Anna Rhodora Quitaleg (2) Arnemie Gayed

March 21	1. Company Profile: Define the target audience clearly, specifying groups or organizations. 2. Techniques and Resources: Detail the utilized techniques and resources, emphasizing those underlined in the document. 3. SOP Revision: Rewrite and reorder SOPs, introducing a new SOP 2 with broader criteria to enhance efficiency testing. 4. Data Presentation: a) House Generation and Effects: Display principles in a table. b) Technique Comparison: Use tables to compare techniques, focusing on Voronoi and RBD in earthquake effects. c) Earthquake Imagery: Include side-by-side comparisons of earthquake imagery and model predictions.	1. Refined the company profile to specifically target the intended audience. 2. Detailed the data and techniques used, providing specificity. 3. Updated the Standard Operating Procedures(SOPs) and revised the related literature review. 4. Documented all nodes, parameters, and variables in the project's results and discussion section.	Mr. Foryasen
April 26	1. Add recommendations on how to improve the study via methodology 2. Create a section based on Research Questions	1. The recommendation for Methodology was Improved 2. A research Questions section was added	Mr. Foryasen

THESIS PROGRESS REPORT

Thesis Title: REQUAKE: SIMULATING POST-EARTHQUAKE DAMAGE IN PHILIPPINE HOME USING PROCEDURAL MODELING
Name(s) : (1) Tyra Generose P. Clemente (2) Tyraxl Joe D. Sabino (3) Charles S. Chantioco
Thesis Instructor: Thelma Palaoag 6:10 – 7:30 MWF 2ND Trimester, AY 2023-2024
Adviser : Zen Lee Foryasen Panel Members: (1) Anna Rhodora Quitaleg (2) Arnemie Gayed

	3. Create an Intro for Discussion of Findings 4. Specify Software Development Methodology 5. Create a section title for the Conclusion 6. Fix citations	3. An introduction for Discussion of Findings was added 4. Software Development Methodology was modified and specified 5. A Section title for the Conclusion was added 6. Citations have been checked and formatted according to the specified style	
May 4	1. Chapter 3 add introduction in first paragraph 2. Explain how you selected the basis papers, why they are selected, how they were used 3. How is the efficiency tested? on what efficiency context?	1. A chapter 3 introduction was added 2. The basis of papers was selected specifically for their usage 3. Efficiency testing was tested more	Mr. Foryasen
May 6	1. Add header and footer template 2. Include in the limitations that the study's output is not a stand-alone software 3. Explain the parameters and the effect 4. Proper table formatting 5. New page for every chapter 6. Missing DOI in references	1. Header and Footed template was added 2. A limitation was added to the study 3. Parameters and effects were explained 4. Table Formatting was revised 5. Chapter formatting was fixed	Mr. Foryasen

THESIS PROGRESS REPORT

Thesis Title: REQUAKE: SIMULATING POST-EARTHQUAKE DAMAGE IN PHILIPPINE HOME USING PROCEDURAL MODELING

Name(s) : (1) Tyra Generose P. Clemente (2) Tyraxl Joe D. Sabino (3) Charles S. Chantioco

Thesis Instructor: Thelma Palaoag 6:10 – 7:30 MWF 2ND Trimester, AY 2023-2024

Adviser : Zen Lee Foryasen Panel Members: (1) Anna Rhodora Quitaleg (2) Arnemie Gayed

		6. DOI references was added	
May 11	1. Mention that the simulation only affects the walls 2. Specify what kind of earthquake is applied on the simulation	1. A limitation was added to the study	
May 20	1. Check for double spacing and odd justification. 2. Add foundational research on the study's importance. 3. Define terms without citations. 4. Add URLs below images sourced from the web. 5. Add (PM) after the first occurrence of "procedural modeling technique." 6. Fix and change the flowchart in methodology to a conceptual/theoretical framework. 7. Include an illustration and description of Lean Methodology (LM) with its phases. 8. Remove phases subtitles (e.g., Phase 1) and underline phase titles (e.g., Define Values). 9. Remove techniques subtitles (e.g., Technique 1).	1. The formatting of the manuscript was fixed 2. A study importance was added 3. Terms definition was revised 4. Image URL was added 5. Flowchart was revised 6. Phases was removed and changed to the actual Phase Name 7. Technique Subtitles were removed 8. Tables for characteristics of Philippine homes were added to the findings 9. Table 4 was changed to Figure 10. The Conclusion was made to be concise and brief	Ms. Gayyed

THESIS PROGRESS REPORT

Thesis Title: REQUAKE: SIMULATING POST-EARTHQUAKE DAMAGE IN PHILIPPINE HOME USING PROCEDURAL MODELING

Name(s) : (1) Tyra Generose P. Clemente (2) Tyraxl Joe D. Sabino (3) Charles S. Chantioco

Thesis Instructor: Thelma Palaoag 6:10 – 7:30 MWF 2ND Trimester, AY 2023-2024

Adviser : Zen Lee Foryasen Panel Members: (1) Anna Rhodora Quitaleg (2) Arnemie Gayed

	10. Change sources subtitles (e.g., Sources to "academic repositories" and include how research questions were answered through RRLs and sources. 11. Include tables for characteristics of PH homes in findings. 12. Correct RBD to RDB. 13. Change Table 4 to Figures. 14. Make the conclusion brief.		
May 22	1. Remove figure labels above/below images. 2. Left-indent photos except in the appendix. 3. Remove subtopics in Discussion of Findings, use transitional text. 4. Correct table format. 5. Summarize sections that are too long. 6. Ensure the appendix is not in black.	1. Words with "above" and "below" was removed 2. Indentation was fixed 3. Subtopics in the Discussion of Findings was revised 4. Appendix color was changed	Mrs. Quitaleg
May 27	1. Change research design to testing/experimental research development. 2. Clarify "define value" phase and researcher actions. 3. Revise Lean Methodology: discuss each phase, then researcher actions.	1. Research Design was revised and changed 2. Different phases were revised 3. Discussion of Findings was fixed based on the suggestion of panel member suggestion 4. Table image was converted	Ms. Gayyed

THESIS PROGRESS REPORT

Thesis Title: REQUAKE: SIMULATING POST-EARTHQUAKE DAMAGE IN PHILIPPINE HOME USING PROCEDURAL MODELING

Name(s) : (1) Tyra Generose P. Clemente (2) Tyraxl Joe D. Sabino (3) Charles S. Chantioco

Thesis Instructor: Thelma Palaoag 6:10 – 7:30 MWF 2ND Trimester, AY 2023-2024

Adviser : Zen Lee Foryasen Panel Members: (1) Anna Rhodora Quitaleg (2) Arnemie Gayed

	4. Remove comparative aspect from the first paragraph of the Discussion of Findings. 5. Create a flowchart without comparative analysis. 6. Convert table to image showing magnitude comparison. 7. Replace comparative design with combined analysis of RRLs, images, and experimental design. 8. Add a legend explaining 'A' and 'F' in the L-system formula. 9. Specify the total number on page 71. 10. Strengthen the argument for the effectiveness of the L-system.	5. The argument of L-system effectiveness was strengtened	
June 24	1. Change "we/our/us" to "the researchers" throughout Chapters 1 to 5. 2. Use single spacing for image source links under the images. 3. Add source for the axiom. 4. Adjust paragraph lengths to maximize use of white space. 5. Clarify why SOP 2 is underlined in Chapter 4 and address as needed. 6. Move the codes to the appendices.	1. The format of the manuscript was revised to 3rd person 2. Single spacing was used 3. Axiom sources were added 4. Whitespace was reduced and removed 5. Codes were moved to appendices	Ms. Gayyed

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	7. Update the images list to reflect changes after removing the codes. 8. Fix the appendices.		
July 11	1. Italicize the URL of photos 2. Methodology Format 3. The flowchart should only answer Yes or No 4. Change Research Design 5. Make a legend for L-system 6. Make a table for magnitude comparison 7. Fix reference format 8. Fix appendix bold captions	1. Italicized and made the URL under the figures 2. Update the methodology flowchart 3. Updated the research design 4. Fixed the references and removed the bold captions in the appendices	Ms. Gayyed
July 18	1. Provide an explanation for Table 1. 2. Remove repeated sentences in Table 2. 3. Adjust Figure 17 to move up and ensure it does not cut the table. 4. Always place Voronoi on the right and RBD on the left. 5. Correct the paragraph for Table 8. 6. Make the conclusion in Chapter 3 concise.	1. Added an explanation to table 1 2. Removed the repeated sentence and adjusted figure 17 3. Placed Voronoi figures on the right side of the paper throughout the paper 4. Corrected the grammar	Ms. Gayyed

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July 29	1. Conclude with a basic inference. 2. Fix hanging pages. 3. Verify with user input rather than assuming functionality. 4. Explain the effectiveness or combination clearly: What is the impact or significance? 5. RBD: Windows and roof. 6. Voronoi: Door and roof. 7. Implement a randomizer for wind force.	1. Conclusion is written more brief and concise 2. Fixed the hanging pages 3. Added wind force	Mr. Foryasen
July 30	1. Obtain a minimum of three Civil Engineering statements regarding the model.	1. Done with interviewing one civil engineer	Ms. Reformado
August 2	1. Fix spacing 2. Don't leave hanging sentences 3. Add a column for house description 4. Make sure the images are clear 5. Fix grammar and maintain left alignment	1. Spacing is fixed and there are no more hanging sentences. 2. Added a column for house description 3. Added more figures to show screenshots better 4. Updated the grammar of sentences and fixed left-alignment	Mrs. Quitaleg

Note 1. This document shall be under the care of the student(s) and shall be handed to the Thesis adviser/panel during consultations, then submitted to the Thesis instructor on the 3rd and 18th of each month.

These are the images of the progress report and consultation meeting of the researchers with their adviser, panel member and chairperson.

CURRICULUM VITAE

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PERSONAL INFORMATION

Birthdate:	November 21, 2002
Civil Status:	Single
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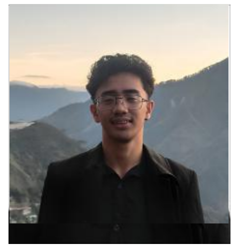
EDUCATIONAL ATTAINMENT

Tertiary:	Bachelor of Science in Computer Science, University of the Cordilleras (Present)
Secondary:	Information and Communications Technology, University of the Cordilleras, 2021

WORK HISTORY
Internship
Accenture, Inc.
University of the Cordilleras
March 2024 - Present

CS SKILLS AND CERTIFICATIONS
1. Certification: JavaScript Algorithms and Data Structures
2. Front End Skills: Javascript, React, HTML5 and CSS3
3. Back End Skills: Javascript, Typescript, Node, PHP, and Java
4. Database: Firebase, MySQL, JDBC, SQL
5. Developer tools: Github, VSCode, Android Studio, Figma

CURRICULUM VITAE



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PERSONAL INFORMATION

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EDUCATIONAL ATTAINMENT

Tertiary:	Bachelor of Science in Computer Science, University of the Cordilleras, (Present)
Secondary:	Science, Technology, Engineering, and Mathematics, University of the Cordilleras, 2021

CS SKILLS AND CERTIFICATIONS

1. Certification: Building an Ubuntu Server
2. Back End Skills: Java, Python, R language, Kotlin
3. Developer tools: Github, Android studio, Houdini Apprentice, GameMaker, VSCode, Figma
4. Database: MySQL
5. Multimedia: Knowledgable in Filmora

CURRICULUM VITAE

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PERSONAL INFORMATION

Birthdate:	July 13, 2001
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EDUCATIONAL ATTAINMENT

Tertiary:	Bachelor of Science in Computer Science, University of the Cordilleras, (Present)
Secondary:	Science, Technology, Engineering, and Mathematics, University of the Cordilleras, 2019

CS SKILLS AND CERTIFICATIONS

1. Back End Knowledge: Java, Python, SQL, Kotlin
2. Database Knowledge: MySQL
3. Developer tools: Git, Github, Android Studio
4. GameDevelopment Knowledge: GameMaker Studio
5. Multimedia: Basic Video Editing with Adobe Premiere