HeritageRoots: Developing Interconnected Immersive Experiences for Cultural Preservation and Education

Dmitriy Babichenko[1] and Tod Swanson[2]

[1]School of Computing and Information, University of Pittsburgh, PA, USA

[2]School of Historical, Philosophical and Religious Studies, College of Liberal Arts and Sciences, Arizona State University, Tempe, Arizona, USA

dmb72@pitt.edu

tod.dillon.swanson@gmail.com

Abstract: In this paper, we present technical implementation details, describe the virtual world procedural generation pipeline, and discuss potential uses in cultural preservation, museum exhibits, and education of *HeritageRoots*, an innovative software infrastructure designed for preserving indigenous narratives and oral histories. *HeritageRoots* consists of two interconnected systems - (1) a web-based knowledge graph (KG) data collection and management system which stores, connects, and presents indigenous traditional knowledge (ITK) in the form of narratives, myths, and testimonies from multiple cultures and languages; (2) a virtual environment rendering pipeline which utilizes large language models (LLM), Unity3D, and Meta Quest software development kit (SDK) to procedurally generate virtual worlds from the KG data. Preliminary system evaluation with Ecuadorian Kichwa narratives showed promising results in (1) academic community interest and support, (2) the possibility of developing an infrastructure capable of connecting indigenous narratives with modern scientific knowledge via KGs and (3) procedurally generating virtual worlds from KG.

1. Introduction

Around the world, the traditional knowledge of Indigenous communities (Indigenous Traditional Knowledge, or ITK) is threatened by migration and the profound changes associated with globalization. Cultures that do not have a strong written tradition are especially threatened – as younger generations move away in search of education and jobs, and as globalization forces linguistic shifts to more “global” languages such as English and Spanish, rich oral traditions either disappear completely or become artifacts in university or library archives, accessible only to small groups of academics.

Indigenous communities, with relatively small populations concentrated in rural areas, are particularly vulnerable to the loss of traditional knowledge because globalization fosters mobility to jobs and increasingly requires that these jobs and the higher education needed to obtain them be carried out in international languages. The vulnerable native languages encode the indigenous populations’ long and complex relationships with the land in ways that make each population unique. Their stories embody traditional knowledge of spirits, places, land uses, and ecology (Cajete and Williams, 2020; Corntassel, 2020; Lewis and Sheppard, 2005). Although indigenous populations value their traditions and strive to preserve them, the challenges they face are often overwhelming. There is thus a need for a virtual resource that helps preserve indigenous cultures not as artifacts in a museum but as living traditions of the populations who can transmit ITK to future generations.

One of the main problems for the transmission of oral (and even written) traditions is that native language-dominant elders often become disconnected from younger speakers who must move to cities for education and jobs. Like young people everywhere, their identities are increasingly complex, influenced by global currents from broader Latin America, Asia, Europe, and the US. Indigenous students who have to move away from their home communities to attend schools are more likely to lose their heritage language and identity (HUANG, 2024; Little, 2020). Typically, these more mobile members are able to spend some time in their territories with elders but often not enough time to really learn the traditions. We intend for *HeritageRoots* to be used as both a cultural preservation and an educational tool that could bridge time in school or in an urban setting with periods of time in the territories with elders.

Specific to our project’s pilot, Amazonian Kichwa communities treasure their traditional knowledge, values, and beliefs that have been passed from generations through oral communication and shared experiences. This traditional knowledge establishes spiritual and cultural relationships with the land, the animals, and the plants. Those relationships are reflected in expressions, words, gestures, and practices specific to the Kichwa traditions. Characters in Kichwa narratives have complex similarities and differences across versions from neighboring cultures that cannot be easily captured by static documents or textbooks. Individual narratives connect to each other in complex ways, forming a network of interacting plots, characters, humans, animals, plants, environments, and languages. While oral myth cycles have sometimes been linked to each other in master plots by the scholars who reduce them to writing, this imposed order is often too rigid to capture the fluid and multivalent way in which their characters evoke, presuppose, or relate back to each other. Furthermore, these collections almost never capture the ways in which stories of one language borrow from, adapt, or even playfully mock the stories of neighboring languages.

Many initiatives have been activated to preserve and revitalize indigenous cultures, traditions, and languages (Adlam et al., 2022; Ajani et al., 2024; Meighan, 2022; Peterson et al., 2021; Yeh et al., 2021). While a number of these initiatives involve the use of computational technologies and multimedia to document and archive indigenous languages and knowledge, much of what has been created to date is primarily designed to serve academic communities and does not provide access to either the broader public (e.g., anyone who wishes to learn about a particular culture) or to the indigenous communities struggling to maintain continuity of their ancestral knowledge across generations. Moreover, existing systems and frameworks tend to focus on a single corpus of narratives and do not provide possibilities to connect and map stories, characters, and concepts across neighboring cultures and languages.

Over the past few decades, a tremendous amount of work has been done on representing knowledge using graph structures. Knowledge graphs have been used to represent provider expertise in healthcare (Zhang et al., 2020), extend transparency of black-box models in machine learning (Gaur et al., 2021), map concept knowledge in adaptive learning systems (Shi et al., 2020), identify fake news (Hu et al., 2021) and represent linguistics constructs (Liu et al., 2020). There is, however, a surprising lack of both academic research and digital humanities projects that leverage graph-based concept representation in the area of ITK and cultural preservation. While Native communities would certainly not characterize their traditional knowledge as “folklore”, the technical challenges in presenting ITK resemble those encountered by existing digital Humanities projects in that field. Two digital folklore projects at Tennessee State University (Bacon, 2011) and Utah State University (McNeill, n.d.) focus on tracking oral traditions on the Internet by creating collections of trending memes, hashtags, and urban legends, and analyzing and studying their prevalence in society. While their respective projects provide a tremendous amount of insight into modern folkloric trends, they do not show how these trends relate to or influence each other, nor do they allow for the exploration of the collected digital folkloric artifacts. Several prominent research projects used knowledge graphs to represent relationships between stories, characters, and concepts in corpora of Greek (Pastor-Sánchez et al., 2021), Kurdish (Ahmadi et al., 2020), Finish (Janicki et al., 2023; Kallio et al., 2020), and Danish (Davis et al., 2021) folklore, as well as provide insight into relationships between stories, political complexity, high gods, trade, cultural traits, gender roles, attitudes towards risk, and trust (Michalopoulos and Xue, 2019). However, none of these projects provide a user interface that would allow researchers or general users to interact with the graph data. James, Broadwell, and Tangherlini propose, implement, and describe a graph-based approach in the context of “computational folkloristics” (Abello et al., 2012; “Big folklore: a special issue on computational folkloristics,” 2016), but their knowledge graph search and exploration tools are desktop application-based and are not available to broader audiences.

In the education and learning technologies domains, on the other hand, graph-based concept representation has received a lot of attention, and much work has been done in the areas of concept mapping (Tergan, 2005) and supporting cognitive behaviors in concept map-based learning environments (Wang et al., 2019). A number of companies have developed commercial products to support concept mapping for business purposes (most notably Mural (“Mural,” n.d.), Obsidian (“Obsidian,” n.d.), Figma (“Figma,” n.d.), and Tinderbox (“Tinderbox: The Tool For Notes,” n.d.)), and much research has been done in various areas of human-computer interaction (HCI) and natural language processing (NLP) to develop intuitive user interfaces to generate knowledge maps from text corpora (Krause, 2019; Zuo et al., 2021) and to manually map concepts identified in text notes or in domain-specific use cases (Huang et al., 2021; Tergan, 2005; Xiao et al., 2019).

And finally, we get to games. Serious games, or more specifically, educational games, usually focus on a single topic (or at best, a set of similar topics), such as algebra, physics, or second language acquisition (e.g., DuoLingo). These types of games rarely focus on creating immersive environments and usually put the majority of their development efforts into designing learner models (Emerson et al., 2020; Khenissi et al., 2015, 2014) and creating educational content. In the world of entertainment games, AAA game franchises such as Assassin’s Creed invested tremendous resources to create immersive and reasonably historically accurate virtual worlds (Burgess and Jones, 2022). However, building such meticulously designed worlds involves a large investment of time and money, the latter being a rather scarce resource when it comes to academic institutions and, more importantly, indigenous communities.

Smaller indie game developers have done amazing work in creating serious games for cultural preservation. Never Alone (Kisima Ingitchuna) is a puzzle adventure game made in partnership between the Cook Inlet Tribal Council and E-Line Media is based on the traditional Iñupiaq tale, "Kunuuksaayuka" (“Never Alone - Homepage,” n.d.; “Never Alone - The Story of Kunuuksaayuka (Part One),” 2014; Parkinson, 2014). Mulaka, a 3D adventure game developed by Lienzo (“Lienzo,” n.d.) is based on the narratives and traditions of the indigenous culture of northern Mexico’s Tarahumara (Gonzalez, 2021; Horton, 2019). These are just two examples of a growing number of efforts to create collaborations between indigenous communities, designers, and developers to produce high quality immersive and engaging experiences that tell indigenous narratives and help preserve ITK.

However, even without the AAA-game-level graphics and assets, game development is a costly endeavor. According to a 2023 LinkedIn report, 43% of game development projects are halted during the development phase, and 38% of developers who actually publish their games do not release regular content or updates (“Report: 83% of mobile games fail in the three years after launch | LinkedIn,” 2023). One possible way to alleviate the high costs associated with creating high-fidelity virtual worlds is to procedurally (i.e., algorithmically) generate the environment and the content from existing assets. In recent years, a tremendous amount of work has been done, both in academia and in the game industry, to create pipelines and develop algorithms for procedural content and world generation (Balint and Bidarra, 2022; Grabska-Gradzińska et al., 2021; Liu et al., 2021; Raistrick et al., 2023; Smith et al., 2011; Yannakakis and Togelius, 2011). However, to the best of our knowledge, none of these approaches utilize large data stores and/or KGs to procedurally generate content and environments for serious or entertainment games.

To address some of the aforementioned shortcomings of existing systems, we have developed *HeritageRoots*, an open-access system for collecting, storing, connecting, and presenting ITK in the form of narratives, stories, myths, and multimedia from multiple cultures and languages. Moreover, *HeritageRoots* allows users to connect ITK narratives based on topics, characters, environments, storylines, and other criteria (e.g., a particular animal appears in X stories from X cultures and acts as a positive character in X of the stories and as a negative character in the remaining X stories). Lastly, *HeritageRoots* can leverage the knowledge graph data to partially procedurally generate immersive 3D virtual worlds using Large Language Models (LLM), the Unity3D game engine, and Meta Quest 2/Quest 3 headsets. These virtual environments provide immersive interactive representations of the environments, flora, fauna, characters, and interactions described in indigenous narratives.

The preservation and revitalization of ITK holds immense importance for Indigenous communities, the Indigenous diaspora, museums, and educational institutions worldwide. With globalization and migration trends, traditional knowledge faces significant threats, particularly in cultures reliant on oral traditions and languages. Indigenous communities, often residing in rural areas, are vulnerable as younger generations move away for education and job opportunities, leading to a disconnect between elders and youth. This disconnect risks the loss of rich oral traditions and spiritual connections to the land, animals, and plants unique to each Indigenous population. Museums and educational institutions recognize the urgency of preserving these living traditions, not merely as artifacts but as ongoing sources of knowledge and identity for future generations. We firmly believe that the development of platforms like *HeritageRoots*, focusing on narrative connections, knowledge mapping, and immersive experiences, bridges the gap between modern challenges and the knowledge embedded in Indigenous cultures, fostering understanding across diverse communities and audiences.

2. System Design

2.1 Knowledge Graph

A graph database is a specialized type of database where instead of storing data in the form of spreadsheet-like tables, the data is stored as a collection of nodes where each node represents an object (e.g., story, character, animal). These nodes are linked by edges - connections that represent physical or semantic relationships between pairs or groups of nodes (Figure 1). The example in Figure 1 illustrates that a nodes of type “Animals” (spider monkey and peccary) are connected to the “First mother…” narrative via “APPEARS_IN” relationship, indicating that both of these animals are mentioned in the narrative.

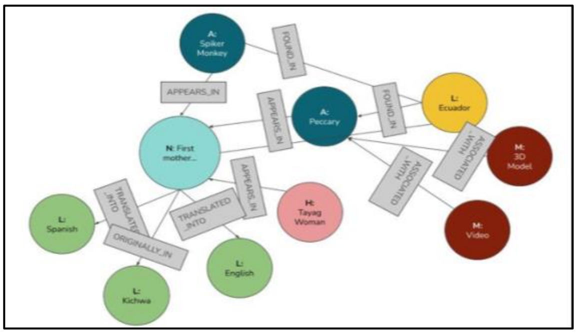

Figure 1: Example of representing semantic relationships with a graph.

This data representation allows a meaningful mapping of stories to concepts, physical objects, locations, characters, and to each other. To store the KG, we are using Neo4J, an open-source graph database. The current version of the knowledge graph represents concepts, objects, and relationships related to narratives, animals, plants, languages, geographic locations, physical objects, and multimedia objects (e.g., 3D models, 360 photographs, images, and videos).

2.2 Web-Based Data Management Module

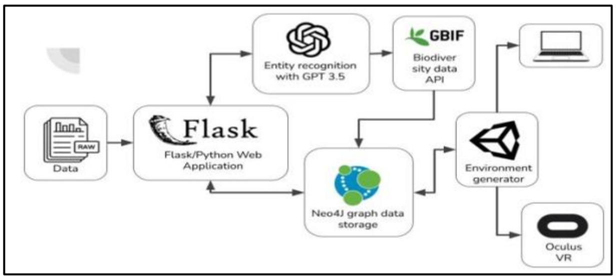

Figure 2: *HeritageRoots* system diagram.

HeritageRoots system consists of two primary modules - a web-based data processing, storage, and visualization module (Module 1), and a stand-alone virtual world Unity3D-based generation module (Module 2).

We developed Module 1 in Python using the Flask web server. The graph data is stored in a Neo4j database, and the graphs are visualized using the D3js Javascript data visualization library. There are two modalities for importing data into the system - a web-based user interface and a data import pipeline from comma-separated values (CSV) files.

To add a narrative to *HeritageRoots*, the user can either copy and paste the narrative's text into a web-based form or upload a file in text, PDF, or Microsoft Word formats. *HeritageRoots* uses OpenAI's Generative Pre-Trained Transformer (GPT) 4 application programming interface (API) to analyze the provided text to recognize the entities, activities, and dialogues described in Table 1.

Table 1: Entities, concepts, activities, and dialogues extracted from text via ChatGPT API.

Recognized Entity	Description
Semantic concept	A semantic concept refers to an ideas and inherent meanings of a word, phrase, or symbol as understood by individuals within a linguistic or cultural framework. Examples of concepts may include words like "mother", "queen", "leader"
Animal	Animals mentioned in a given narrative, including their Linnaean taxonomy
Plant	Plants mentioned in a given narrative, including their Linnaean taxonomy
Named entities	Proper nouns, names of people or places
Physical objects	Ex: house, bowl, blowpipe
Action Verbs	Action verbs represent actions that a character performs within a narrative. For example, a toucan [sits on a branch], [flies], [speaks], [complains]. *HeritageRoots* uses these action verbs to generate animation state machines for Unity3D to represent behaviors of corresponding NPCs.
Utterances	Utterances, monologues, speeches, and dialogues produced by characters within a narrative

Once *HeritageRoots* saves the uploaded narrative in the Neo4j database, the system redirects the user to an interface where identified entities, actions, and dialogs are highlighted and color-coded (Figure 3). The user interface (UI) allows users to make changes to connections, identify entities that were missed by GPT 4, and create additional entities and connections.

The current version of *HeritageRoots* also supports a search functionality that allows users to search by animal, plant, narrative, or geographic location. The result is displayed as an interactive graph (Figure 3) where users can explore connections between nodes, as well as to view the details of each node by and connections associated with each node by clicking on a node of interest.

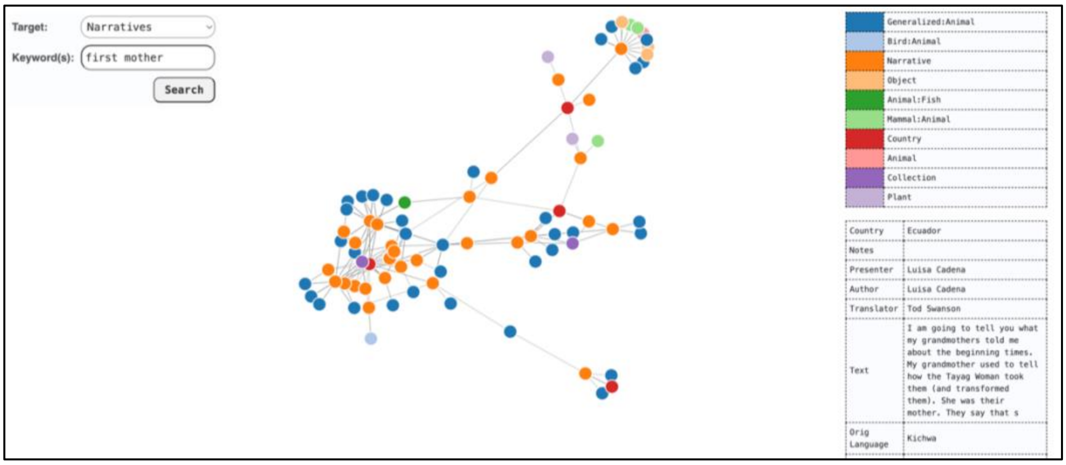

Figure 3: HeritageRoots search results as an interactive graph.

2.3 World Generator Module

The World Generator Module (Module 2) is a set of Unity3D editor tools designed to allow users to procedurally generate terrains, place vegetation and objects, and create animator state machines for NPC animation.

The web-based data management module (Module 1) provides users with the option to generate an API key for every narrative available in the system. The data can be accessed via a RESTful API endpoint, which returns narrative data as a JavaScript Object Notation (JSON) document. That JSON document includes all information available not just for a given narrative, but also on all animals, plants, objects, and media that are linked to it via the KG edges.

In Unity3D, the user can enter the API URL into the desired editor tool (Figure 4). The tool will download all relevant assets linked in the KG, generate a pattern of Perlin noise over the terrain (Burch et al., 2020; Emmanuel et al., 2019; Pop et al., n.d.), and place the assets (e.g. trees, plants, houses) onto the terrain according to user-specified parameters. In the current implementation, we download relevant assets using a standard HTTP request.

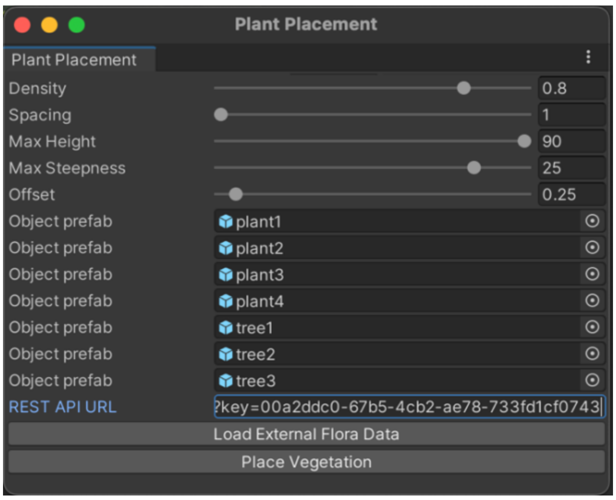

Figure 4: Unity3D module/tool for procedurally placing flora from KG / RESTful API data.

Let us consider the following example. A user (a VR developer) starts with a Unity scene that contains a blank terrain (Figure 9). In the "Plant Placement" editor tool, users can specify vegetation density, minimum required spacing between plants, maximum altitude and maximum steepness at which plants are allowed to be placed on the terrain, and an offset value to make the plan placement appear more random.

A narrative associated with the provided API key (in the REST API URL field, Figure 7) mentions six plants and is subsequently linked to each of these plants in the KG via a graph edge. Each of these plants, in turn, is linked in the KG to a media node containing a 3D model of that plant.

When the user clicks "Load External Data", the system will (1) read data from the *HeritageRoots* RESTful API, (2) download plant assets associated with the specified narrative, (3) generate a pattern of Perlin noise over the terrain, and (4) place plant assets onto the terrain according to the Perlin noise pattern (Emmanuel et al., 2019) and user-provided placement specifications (Figure 7). Perlin noise is a type of mathematical function that creates natural-looking patterns of randomness and is often used in computer graphics to generate realistic textures like clouds, terrain, or marble. Imagine looking at a bumpy surface where the bumps are smooth and gradual, not too sharp or jagged. Perlin noise is like a recipe for creating such surfaces, blending different frequencies of noise to produce a smooth, flowing pattern that mimics natural variations in the real world.

Lastly, the current iteration of Module 2 is capable of generating Unity3D animation state machines from the KG data. The current pipeline uses ChatGPT 4 API to identify animals in narrative texts, as well as to extract all action verbs associated with the animal's activities/actions within the narrative's context. Consider the following text: "*The* ***toucan*** *flew from branch to branch. After sitting for a few minutes, it flapped its wings and hopped to a lower branch and spoke.*" *HeritageRoots* will identify characters' actions and after stemming and lemmatization, return a JSON document accessible via *HeritageRoots'* RESTful API (Table 2). Our Unity3D editor tool parses the document and creates an animator state machine (Figure 8c) that can be used with any appropriately rigged 3D model.


```
{
    "label": "Animal",
    "name": "toucan",
    "states": ["idle","hop","fly","flapwings","speak","sit"],
    "transitions": [
        [ "idle", "hop" ],
        [ "idle", "fly" ],
        [ "idle", "flapwings" ],
        [ "idle", "speak" ],
        [ "idle", "sit" ]
    ]
}
```


Figure 5: Example of JSON generated from the identified entities and action verbs after stemming and lemmatization

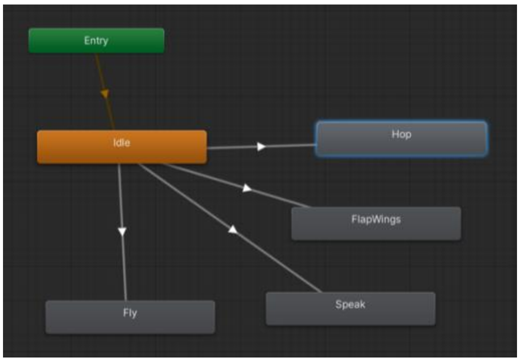

Figure 6: Animator state machine created in Unity3D from JSON shown in Figure 5

3. Technical/Feasibility Evaluation

Our team has evaluated the *HeritageRoots* data pipeline and world generation framework by building a KG with data from three different sources. First, we scraped Wikipedia data related to plants, mammals, birds, insects, and mollusks native to Brazil and Ecuador using a custom Python script. Once we imported flora and fauna data into the *HeritageRoots* KG, we imported narratives from a collection of Amazonian Kichwa language material recorded over the years by Dr. Tod Swanson in collaboration with the Iyarina Center for Learning run by

Fundación Cotococha, an indigenous-led foundation in Napo Province of Ecuador. An experienced team of Kichwa staff members from the Center worked in tandem with Native elders to translate and annotate narratives. A team of undergraduate students imported 12 translated and transcribed Kichwa narratives into *HeritageRoots'* KG. Lastly, our team has downloaded two publicly available Brazilian folklore collections (Albuquerque et al., 2007; Eells, 2008) from the Project Gutenberg website and imported a total of 15 Brazilian narratives into the KG. With all narratives, we verified that the system created appropriate edges and that ChatGPT correctly recognized appropriate entities (e.g., animals, plants, objects) in the narratives' text. This process created a total of 14,418 nodes and 29,452 edges. We checked the validity of relationships (edges) with a Python script to ensure that correct taxonomy had been created for all animals and plants. We manually checked the validity of relationships between narratives and other objects in the KG. The validation showed that 52 edges were not created (an animal or a plant did not get connected to an appropriate taxonomy) and ChatGPT did not recognize 7 animals and 13 plants in the uploaded narratives.

To evaluate procedural plant placement, we uploaded 3D models of three generic tropical plants and three trees (purchased from the Unity Asset Store) as "Media" nodes into the KG and connected them to a Kichwa narrative titled "The First Mother Turns Her Children into Animals.". In Unity, we created a blank scene with a standard first-person controller (FPC) and a simple terrain (Figure 7). We asked seven undergraduate university students with no game development experience in Unity or other game engines to use the *HeritageRoots* world generation tools to populate the blank terrain with flora linked to "The First Mother…" narrative (Figure 8). Every participant was able to populate the scene with flora without any instruction; the maximum time it took one of the participants to navigate the system was 1 minute and 45 seconds (mean time of 1 minute and 3 seconds).

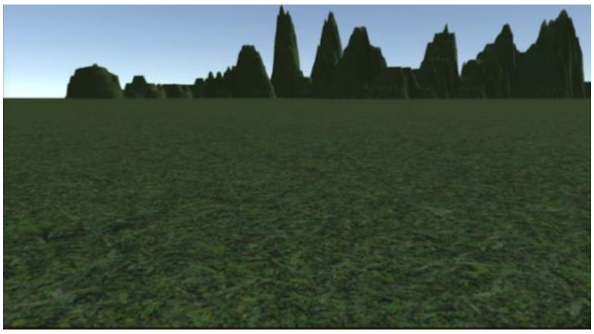

Figure 7: FPC view of a blank terrain in Unity3D, Game view.

Figure 8: FPC view of a terrain populated with flora using *HeritageRoots* world generation tools, Unity3D, Game view.

4. Limitations

In presenting this work, it is important to acknowledge its limitations. We would like to reiterate that this was not meant to be a research paper but rather a technical paper presenting and assessing the feasibility of an idea for a data pipeline that would allow procedural generation of immersive virtual worlds for cultural preservation and education.

One of the major potential limitations of this work is accessibility - the current iteration of *HeritageRoots* does not address potential barriers to access for indigenous communities, such as limited internet connectivity, lack of digital literacy, or availability of necessary devices like computers or VR headsets. To alleviate the impact of this particular limitation, we ensured that the web-based part of *HeritageRoots* is accessible with 3G internet connectivity and works on older mobile device and desktop browsers, with Google Chrome version 52 (2016) and Apple Safari version 9.1.2 (2016). In addition to creating immersive environments builds for Meta Quest III, we are also working on MacOS and Microsoft Windows builds to ensure wider access.

Another limitation lies on the fine line between cultural preservation and cultural appropriation, especially when using advanced technologies like AI, machine learning, and VR. We acknowledge that in this paper we have not discussed or addressed ethical considerations and strategies to ensure respectful representation and collaboration with indigenous communities throughout the development and use of *HeritageRoots*. Lastly, given the sensitive nature of indigenous cultural knowledge, we have not yet developed robust protocols for data privacy, ownership, and consent.

5. Discussion and Future Work

The *HeritageRoots* system has the potential to address a critical need for the preservation and transmission of Indigenous Traditional Knowledge (ITK) in the face of globalization and cultural erosion. By leveraging advanced technologies such as KG, natural language processing, and procedural content generation, *HeritageRoots* aims to bridge the gap between traditional oral knowledge and modern digital tools. The system's design encompasses a web-based data management module for narrative processing and visualization, as well as a Unity3D-based world generator module for creating immersive virtual environments.

While our evaluation was admittedly shallow and only focused on assessing technical feasibility of the system, we were able to establish that the data pipeline in its current form is capable of representing complex relationships between narratives, characters, environments, and physical objects. This interconnectedness allows users to explore the rich tapestry of ITK in a holistic and interactive manner. Furthermore, the Unity world generation module in combination with HeritageRoots' RESTful API is capable of generating "starter" environments based on indigenous narratives for users with little to no game/VR development experience.

Moving forward, we plan on establishing collaborative partnerships with indigenous communities for co-designing and co-developing the *HeritageRoots*. Incorporating community feedback, cultural protocols, and traditional knowledge systems into the system's design and governance structures is paramount. We will also work on enhancing language support for indigenous languages. We plan on seeking partnerships with non-profit organizations such as *WikiTongues* to integrate tools for language revitalization, transcription, and translation within the platform to empower communities to preserve and promote their linguistic heritage.

Furthermore, we will work on establishing a robust ethical framework for data governance, consent management, cultural sensitivity, and respectful representation, as well as implement Implementing protocols for community-driven data ownership, access control, and data sovereignty to build trust and transparency.

Lastly, we have already begun working on conducting research and evaluation studies on the platform's effectiveness, user experience, learning outcomes, and cultural impact.

6. Conclusion

Based on preliminary evaluation, we believe that *HeritageRoots* has the potential to serve as a transformative tool for safeguarding indigenous cultures, promoting intergenerational knowledge transfer, and fostering global appreciation for cultural diversity. By embracing a participatory and ethical approach, the platform can contribute to the broader goals of cultural sustainability, social justice, and inclusive technology development.

Acknowledgements

We would like to thank the University of Pittsburgh Center for Latin American Studies and the Kenneth P. Dietrich School of Arts & Sciences Digital Narrative and Interactive Design program for providing seed funding for this project. We would also like to thank the amazing staff of Iyarina Center for Learning, a research center in the Ecuadorian Amazon dedicated to integrating indigenous knowledge and the academic arts and sciences. Belgica Dagua Toqueton, Elodia Dagua Toqueton, Elizabeth Swanson Andi, Cindy Sisa Andi Aguinda, Klever Vargas Andi, and Pamela Tapuy Grefa have made this project possible through sharing their knowledge, Kichwa narratives, cultural experiences, and supporting our team in field research.

References

Abello, J., Broadwell, P., Tangherlini, T.R., 2012. Computational folkloristics. Commun. ACM 55, 60–70.

Adlam, C., Almendariz, D., Goode, R.W., Martinez, D.J., Middleton, B.R., 2022. Keepers of the flame: supporting the revitalization of Indigenous cultural burning. Soc. Nat. Resour. 35, 575–590.

Ahmadi, S., Hassani, H., Abedi, K., 2020. A corpus of the Sorani Kurdish folkloric lyrics, in: Proceedings of the 1st Joint Workshop on Spoken Language Technologies for Under-Resourced Languages (SLTU) and Collaboration and Computing for Under-Resourced Languages (CCURL). pp. 330–335.

Ajani, Y.A., Oladokun, B.D., Olarongbe, S.A., Amaechi, M.N., Rabiu, N., Bashorun, M.T., 2024. Revitalizing Indigenous Knowledge Systems via Digital Media Technologies for Sustainability of Indigenous Languages. Preserv. Digit. Technol. Cult.

Albuquerque, M. e, Netto, H.C., Dolores, C., Assis, 1839-1908 Machado de, 2007. Brazilian Tales.

Bacon, J., 2011. The digital folklore project: tracking the oral tradition on the world wide web (PhD Thesis). East Tennessee State University.

Balint, J.T., Bidarra, R., 2022. Procedural generation of narrative worlds. IEEE Trans. Games 15, 262–272.

Big folklore: a special issue on computational folkloristics, 2016. . J. Am. Folk. 129, 5–13.

Burch, M., Wallner, G., Arends, S.T., Beri, P., 2020. Procedural city modeling for AR applications, in: 2020 24th International Conference Information Visualisation (IV). IEEE, pp. 581–586.

Burgess, J., Jones, C., 2022. Exploring player understandings of historical accuracy and historical authenticity in video games. Games Cult. 17, 816–835.

Cajete, G.A., Williams, D.R., 2020. Eco-aesthetics, metaphor, story, and symbolism: An Indigenous perspective: A conversation. Res. Handb. Childhoodnature Assem. Child. Nat. Res. 1707–1733.

Corntassel, J., 2020. Restorying Indigenous landscapes: Community regeneration and resurgence. Plants People Places Roles Ethnobot. Ethnoecology Indig. Peoples' Land Rights Can. Beyond 350–361.

Davis, E., Danforth, C.M., Mieder, W., Dodds, P.S., 2021. Computational paremiology: Charting the temporal, ecological dynamics of proverb use in books, news articles, and tweets. ArXiv Prepr. ArXiv210704929.

Eells, E.S., 2008. Fairy Tales from Brazil: How and Why Tales from Brazilian Folk-Lore.

Emerson, A., Cloude, E.B., Azevedo, R., Lester, J., 2020. Multimodal learning analytics for game-based learning. Br. J. Educ. Technol. 51, 1505–1526.

Emmanuel, K.S., Mathuram, C., Priyadarshi, A.R., George, R.A., Anitha, J., 2019. A Beginners Guide to Procedural Terrain Modelling Techniques, in: 2019 2nd International Conference on Signal Processing and Communication (ICSPC). IEEE, pp. 212–217.

Figma: the collaborative interface design tool. [WWW Document], n.d. . Figma. URL https://www.figma.com/ (accessed 5.30.23).

Gaur, M., Faldu, K., Sheth, A., 2021. Semantics of the black-box: Can knowledge graphs help make deep learning systems more interpretable and explainable? IEEE Internet Comput. 25, 51–59.

GBIF API Reference :: Technical Documentation [WWW Document], n.d. URL https://techdocs.gbif.org/en/openapi/ (accessed 2.6.24).

GBIF [WWW Document], n.d. URL https://www.gbif.org/ (accessed 2.6.24).

Gonzalez, R., 2021. Deterritorialization/Reterritorialization of Raramuri Knowledge: Within the Landscapes of Mulaka (M.A.). University of Missouri - Columbia, United States -- Missouri.

Grabska-Gradzińska, I., Nowak, L., Palacz, W., Grabska, E., 2021. Application of graphs for story generation in video games, in: Proceedings of the 2021 Australasian Computer Science Week Multiconference. pp. 1–6.

Horton, L., 2019. Collaborative game development with Indigenous communities; A theoretical model for ethnocultural empathy.

Hu, L., Yang, T., Zhang, L., Zhong, W., Tang, D., Shi, C., Duan, N., Zhou, M., 2021. Compare to the knowledge: Graph neural fake news detection with external knowledge, in: Proceedings of the 59th Annual Meeting of the Association for Computational Linguistics and the 11th International Joint Conference on Natural Language Processing (Volume 1: Long Papers). pp. 754–763.

Huang, R., Yan, P., Yang, X., 2021. Knowledge map visualization of technology hotspots and development trends in China's textile manufacturing industry. IET Collab. Intell. Manuf. 3, 243–251.

HUANG, Y.-W., 2024. Language loss and translingual identities near the Navajo land. Int. J. Lang. Stud. 18.

Janicki, M., Kallio, K., Sarv, M., 2023. Exploring Finnic written oral folk poetry through string similarity. Digit. Scholarsh. Humanit. 38, 180–194.

Kallio, K., Mäkelä, E., Janicki, M.M., 2020. Historical oral poems and digital humanities: Starting with a finnish corpus. FF Netw.

Khenissi, M.A., Essalmi, F., Jemni, M., Kinshuk, 2015. Learner modeling using educational games: A review of the literature. Smart Learn. Environ. 2, 1–16.

Khenissi, M.A., Essalmi, F., Jemni, M., others, 2014. Review of learner modeling using educational games, in: International Conference on Computer Supported Education. SciTePress, pp. 147–152.

Krause, T., 2019. ANNIS: A graph-based query system for deeply annotated text corpora.

Lewis, J.L., Sheppard, S.R., 2005. Ancient values, new challenges: Indigenous spiritual perceptions of landscapes and forest management. Soc. Nat. Resour. 18, 907–920.

Lienzo, n.d. URL https://www.lienzo.mx (accessed 3.28.24).

Little, S., 2020. Whose heritage? What inheritance?: Conceptualising family language identities. Int. J. Biling. Educ. Biling. 23, 198–212.

Liu, J., Snodgrass, S., Khalifa, A., Risi, S., Yannakakis, G.N., Togelius, J., 2021. Deep learning for procedural content generation. Neural Comput. Appl. 33, 19–37.

Liu, W., Zhou, P., Zhao, Z., Wang, Z., Ju, Q., Deng, H., Wang, P., 2020. K-bert: Enabling language representation with knowledge graph, in: Proceedings of the AAAI Conference on Artificial Intelligence. pp. 2901–2908.

McNeill, L.S., n.d. Digital Folklore Project [WWW Document]. Digit. Folk. Proj. URL https://chass.usu.edu/english/opportunities/digital-folklore-project (accessed 4.17.23).

Meighan, P.J., 2022. Indigenous language revitalization using TEK-nology: how can traditional ecological knowledge (TEK) and technology support intergenerational language transmission? J. Multiling. Multicult. Dev. 1–19.

Michalopoulos, S., Xue, M.M., 2019. Folklore (Working Paper No. 25430), Working Paper Series. National Bureau of Economic Research. https://doi.org/10.3386/w25430

Mural [WWW Document], n.d. URL https://www.mural.co/use-case/mind-map (accessed 5.30.23).

Never Alone - Homepage [WWW Document], n.d. . Never Alone. URL http://neveralonegame.com/ (accessed 3.28.24).

Never Alone - The Story of Kunuuksaayuka (Part One) [WWW Document], 2014. . Never Alone. URL http://neveralonegame.com/kunuuksaayuka/ (accessed 3.28.24).

Obsidian [WWW Document], n.d. URL https://obsidian.md/ (accessed 5.30.23).

Parkinson, H.J., 2014. Alaska's indigenous game Never Alone teaches co-operation through stories. The Guardian.

Pastor-Sánchez, J., Kontopoulos, E., Saorín, T., Bebis, T., Darányi, S., 2021. Greek mythology as a knowledge graph: from chaos to zeus and beyond. Seman Web J Rev.

Peterson, S.S., Manitowabi, Y., Manitowabi, J., 2021. The Niichii Project: Revitalizing Indigenous Language in Northern Canada. TESOL Context 30, 85–104.

Pop, A., Nandra, C., Mocan, C.M., Gorgan, D., n.d. Procedural Generation of landmasses and terrain.

Raistrick, A., Lipson, L., Ma, Z., Mei, L., Wang, M., Zuo, Y., Kayan, K., Wen, H., Han, B., Wang, Y., others, 2023. Infinite photorealistic worlds using procedural generation, in: Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition. pp. 12630–12641.

Report: 83% of mobile games fail in the three years after launch | LinkedIn [WWW Document], 2023. URL https://www.linkedin.com/pulse/report-83-mobile-games-fail-three-years-after-launch-lvqsf/ (accessed 3.28.24).

Shi, D., Wang, T., Xing, H., Xu, H., 2020. A learning path recommendation model based on a multidimensional knowledge graph framework for e-learning. Knowl.-Based Syst. 195, 105618.

Smith, G., Gan, E., Othenin-Girard, A., Whitehead, J., 2011. PCG-based game design: enabling new play experiences through procedural content generation, in: Proceedings of the 2nd International Workshop on Procedural Content Generation in Games. pp. 1–4.

Tergan, S.-O., 2005. Digital concept maps for managing knowledge and information. Knowl. Inf. Vis. Search. Synerg. 185–204.

Tinderbox: The Tool For Notes [WWW Document], n.d. URL https://www.eastgate.com/Tinderbox/ (accessed 5.30.23).

Unity Addressable Asset System | Package Manager UI website [WWW Document], n.d. URL https://docs.unity3d.com/Packages/com.unity.addressables@0.8/manual/index.html (accessed 3.29.24).

Wang, S., Sonmez Unal, D., Walker, E., 2019. MindDot: Supporting effective cognitive behaviors in concept map-based learning environments, in: Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems. pp. 1–14.

Xiao, G., Ding, L., Cogrel, B., Calvanese, D., 2019. Virtual knowledge graphs: An overview of systems and use cases. Data Intell. 1, 201–223.

Yannakakis, G.N., Togelius, J., 2011. Experience-driven procedural content generation. IEEE Trans. Affect. Comput. 2, 147–161.

Yeh, J.H., Lin, S., Lai, S., Huang, Y., Yi-Fong, C., Lee, Y., Berkes, F., 2021. Taiwanese indigenous cultural heritage and revitalization: Community practices and local development. Sustainability 13, 1799.

Zhang, Y., Sheng, M., Zhou, R., Wang, Y., Han, G., Zhang, H., Xing, C., Dong, J., 2020. HKGB: an inclusive, extensible, intelligent, semi-auto-constructed knowledge graph framework for healthcare with clinicians' expertise incorporated. Inf. Process. Manag. 57, 102324.

Zuo, Z., Cheng, J., Guo, H., Li, Y., 2021. Knowledge mapping of research on strategic mineral resource security: A visual analysis using CiteSpace. Resour. Policy 74, 102372.