The Gaia System: A Tabletop Projection Mapping System for Raising Environmental Awareness in Islands and Coastal Areas

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ABSTRACT

Islands and coastal areas, including those in the Nordic region, are considered highly vulnerable to the impacts of climate change. Raising environmental awareness is a crucial first step towards protecting the ecosystem and preventing environmental deterioration. In this work-in-progress paper, the first version of the Gaia System is presented, and its use for raising environmental awareness is described. The Gaia System is a tabletop projection mapping system installed at the Sortland Museum in the Vesterålen district, Norway. The system creates a digital twin of the area and enables the user to interact with and explore time (i.e. navigate to the past, the present and the future of the visualised area). The Gaia System targets residents, tourists and stakeholders of the Vesterålen district as its users, aiming to contribute to the sustainable development of the local community through establishing new behaviour patterns among users and/or being used in decision-making processes. The Gaia System prototype was informally evaluated during a demonstration event, when positive feedback was received. However, several adjustments and additions will be made in the next version.

CCS CONCEPTS

• **Human-centered computing** → **Visualization systems and tools**; • **Applied computing** → *Media arts*; • **Software and its engineering** → *Software implementation planning*.

KEYWORDS

augmented reality, environment, projection mapping, sustainability, visualisation

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1 INTRODUCTION

Islands and coastal environments have long been favoured for human settlement, providing access to resources, transportation, trade and defensible locations [4]. Nowadays, island territories and coastal areas are considered highly vulnerable to the impacts of climate change, with sea level rise being one of the most significant issues that has already been recognised and is expected to further exacerbate in the future [5, 15].

The Nordic region contains thousands of islands, and future climate change is expected to have an environmental impact on them by altering the frequency and magnitude of certain types of weather events in the region [3]. The most recent Intergovernmental Panel on Climate Change (IPCC) assessment of extreme events [20] reported high confidence in climate projections for the wider northern European region based on multiple model-based sources. These projections indicate a highly likely increase in the frequency of high temperature extremes and a decline in the frequency of low temperature extremes during the 21st century. Increases in the frequency of heat waves and heavy precipitation are also likely. In addition, it is likely that there has been a poleward shift in mid-latitude, extra-tropical storm tracks during the last 50 years, with medium confidence that this shift will continue due to future anthropogenic forcings [3, 20].

The Vesterålen district is part of the Nordic region, as it lies to the north of Lofoten and is geographically part of the larger archipelago. However, it is considered a distinct region, with a population of approximately 30 000 living in six municipalities, distributed among five large islands, Langøya, Andøya, Hadseløya, the western part of Hinnøya, the northern part of Austvågøya and several smaller islands [2, 10]. Fisheries dominate the commercial sector in Vesterålen, since it is a focal point and base for a substantial part of the cod fisheries in Northern Norway. Nature-based tourism and small-scale agriculture also play their parts in the local economy [10]. Based on a recent study [10], Vesterålen residents have identified climate change as a 'somewhat negative influence' on future development and, even though the negative influence of climate change is recognised, its significance seems to be underestimated. Another study [17] that included tourism and hospitality business representatives in the northern Norwegian areas of Senja and Vesterålen revealed a gap was revealed between the actual impacts of weather and climate change on the businesses and the representative's perceptions of the impacts. Therefore, it seems that there is a need for the region – and the many regions like it around the world – to have the effects of climate change and environmental deterioration better communicated to target environmental protection more effectively, both at an individual and a community level.

Raising environmental awareness is a crucial first step towards protecting the ecosystem and preventing environmental deterioration [14, 23]. The main reason for raising environmental awareness is to change how humans conceive the idea of nature and to create

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a sense of responsibility towards the causes of climate change. One widely used approach for raising environmental awareness uses information systems and technology platforms, which are important tools for environmental decision-making, enhancing the awareness and drawing the attention of various organisations with regard to environmental matters [8, 21].

In this work-in-progress paper, the first version of the Gaia System is presented and its use for raising environmental awareness is described. The Gaia System is a tabletop projection mapping system, installed at the Sortland Museum, in the Vesterålen district, Norway, which is currently at the prototype stage. By visualising sets of environmental and historical data on the physical scale model, the system creates a digital twin of the coastal region and enables the user to interact and explore time (i.e. navigate to the past, the present, and the future of the visualised area). The Gaia System targets residents, tourists and stakeholders of the Vesterålen district as its users, aiming to contribute to the sustainable development of the local community through establishing new behaviour patterns among users and/or being used in decision-making processes. Researchers and practitioners in the field can benefit from this work by focusing on: i) the description of the Gaia System and, specifically, its visualisation and interaction elements as a source of inspiration; ii) the work's approach to targeting environmental impacts on islands and coastal areas by utilising the museum as a 'gateway' to the local community and visitors; and iii) the use of projection mapping to create a digital twin of an area for visualising historical data, data from monitoring tools and/or forecasting data for decision-making purposes.

The rest of this paper is organised as follows. Section 2 provides brief details about the projection mapping technology. Section 3 describes the Gaia System in detail. Finally, Section 4 concludes the paper and describes future directions.

2 PROJECTION MAPPING

Over the last few years, projection mapping, also called spatial augmented reality, has become widespread worldwide. The goal is to seamlessly merge physical and virtual worlds by super-imposing computer-generated graphics onto real surfaces, such as large buildings, cars, shoes and furniture [7]. One of the biggest differentiators compared to other augmentation techniques is the capability of projection mapping to let many users directly experience the augmentation without wearing glasses or other devices [7].

Projection mapping has found several applications in public spaces, targeting crowd engagement in various ways. The technology (also characterised as 'guerrilla projections' and 'digital graffiti') has been used to project graphics and animations onto the facades of buildings for i) raising environmental awareness using the surface of popular monuments [16], ii) gamifying buildings [24], iii) creating impressive, dynamic public art exhibitions on buildings through animations [13], iv) making political statements and v) educating users, such as in augmented reality sandboxes [13].

In more controlled environments, projection mapping has been extensively used for cultural applications in museum settings, usually displaying the history of a place or tradition. These projections can be displayed on the walls [6, 9, 12, 13], actual exhibits [11] and physical scale models of a site of interest [1, 19]. These physical scale models are usually installed on tabletop surfaces, with the projector(s) being placed on the ceiling, hence the term 'tabletop projection mapping' [7, 18].

A common theme running through most of the aforementioned project mapping installations is that they focus on producing artistic value and/or targeting public engagement by triggering a 'wow' effect. At the same time, from an interaction perspective, some of these installations do not offer interaction capabilities to the audience, essentially inviting them to be viewers of the projected content. In cases where the projection allows for interaction, this is some kind of single-user interaction (i.e. one user acts as administrator of the projected content).

3 THE GAIA SYSTEM

In this section, the Gaia System prototype is presented (Fig. 1). This version of the system was developed to evaluate the system's feasibility, to become familiar with the projection mapping technology and to plan/design the future system attributes. An iterative design process will take place, based on the informal feedback collected from the system's demonstration and the system requirements as defined in its conceptual design, with higher-fidelity prototypes to come.

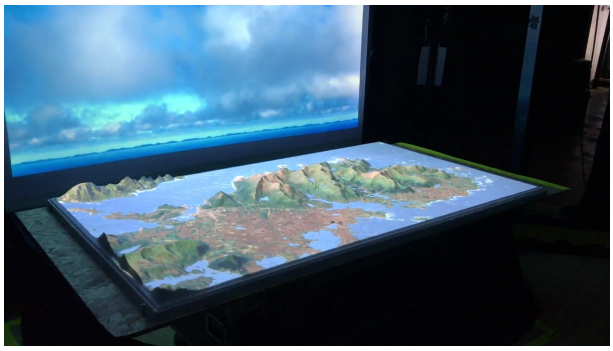

Figure 1: Gaia System prototype. Demonstration videos are available at: https://boletsis.net/gaia/prototype1/

3.1 Concept

The Gaia System's overall purpose is to inform users about the history of the area and to demonstrate how the environment has changed over the years and how it may change in the future. To do so, certain high-level requirements (R) were set:

- (R1) The system content should cover environmental data (including temperature, sea level, etc.), as well as other socio-economic data for topics that are related to the environment, such as infrastructure, roads, urban settlements, population density, waste management, tourism, fishery, etc.
- (R2) Where applicable, the system data/content should be indexed in time order using time series. This is needed to display the history of the place, the current situation and forecasts for the future, thus enabling the user to witness changes in the landscape and become informed in a constructivist way. Essentially, the projection mapping in the Gaia System will cover four dimensions (4D).

(R3) The system should support multi-user interaction. There can be a single-user/super administrator functionality; however, the system should enable interaction with as many museum visitors as possible simultaneously.
(R4) The system's physical scale model should cover many of the Vesterålen islands. Fig. 2 presents a conceptual sketch of the Gaia System's final version, as installed in the museum space.
(R5) The system should be aesthetically pleasing and trigger a 'wow' factor, so that it provides initial engagement for users and then moves on from there.

Nevertheless, being aware of environmental problems is not enough. Only when changes in practice are observed can environmental problems be solved [22]. To that end, and in addition to the Gaia System, an 'environmental contract' (i.e. an action plan with clearly defined environmental goals and actions at individual, corporate and organisational levels) will be co-produced with actors in the local community. The goal is for the contract to lead to concrete changes in a more environmentally and climate-friendly direction for those who sign. Specifically, the contract may address goals of changed behaviour related to sustainability goals, such as energy consumption, waste management and ecological footprint.

3.2 Target users

The Gaia System targets tourists and local residents of the Vesterålen district. Many of the Sortland area tourists come from the Hurtigruten cruise ship, which sails along Norway's rugged coastline and makes a short stop. To that end, the Gaia System is designed to support both casual and extended use, so that it accommodates people with different time constraints. The engagement of local residents is also very important. Thus, the system targets – among all other residents – students of all ages and representatives of local companies and organisations who can be informed on environmental issues, be motivated to take action and, ultimately, establish new behaviour and/or action patterns for themselves or other people.

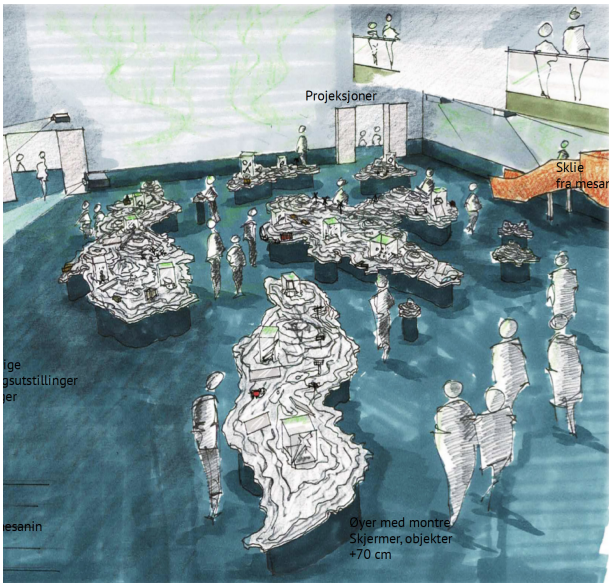

Figure 2: Conceptual sketch of the final version of the Gaia System positioned in the museum room, featuring multiple projections of the Vesterålen islands.

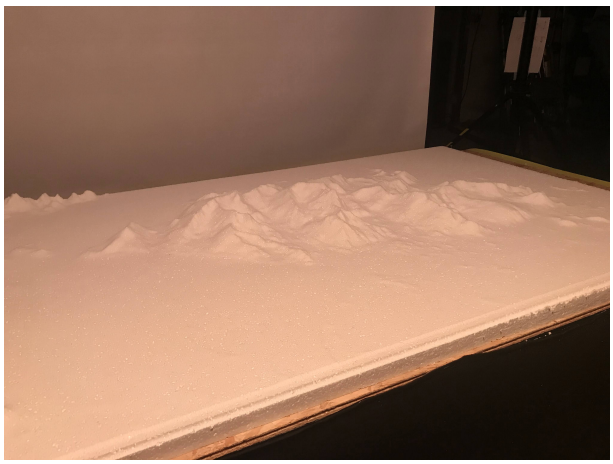

Figure 3: Physical scale model of the Gaia System.

3.3 Installation

To approach its target group, the Gaia System is installed in a museum (Sortland Museum) as an exhibit. Moreover, the Gaia System holds the necessary aesthetic qualities to act as an exhibit, which is facilitated by the visually impressive augmented reality attributes of the projection mapping technology. At the same time, its installation elevates the museum's societal role from an exhibitor and curator of culture to an active contributor to significant universal issues, such as climate change.

3.4 Apparatus

The physical scale model represents part of the Øksnes area. It was printed out using styrofoam at dimensions of 112 x 200 cm (Fig. 3). The projection technology was implemented through a 4K Optoma UHZ65LV projector installed in the ceiling of a room of 4m height. A regular HD projector was also used to project information and animations on the wall behind the main projection (Fig. 4). The projected content was developed using the Madmapper software[1], an application for video and projection mapping and laser shows.

3.5 Content

In this version of the Gaia System, the content included topics such as cars, fishing boats, roads, population density, cultural landmarks and hiking routes (Fig. 5). To test out the interaction with time series through a slider, sea level was chosen, where a projection of a future 4m sea level rise was visualised to show the environmental impact of the phenomenon on the coastal areas. Each topic was activated individually and visualised as a layer appearing on top of other topics' layers, if any. Users could choose between 'day' and 'night' brightness settings for the mapped area. In the background, a wall

[1] https://madmapper.com

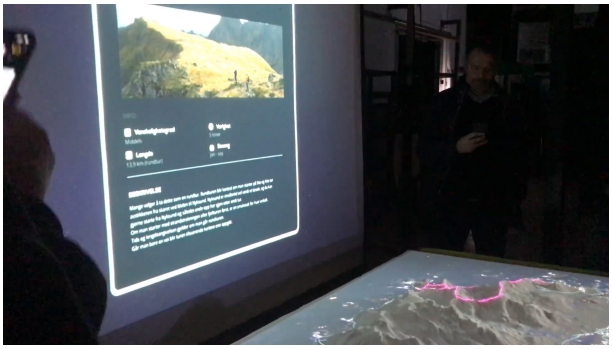

Figure 4: Wall-projected information in the background of the tabletop projection mapping system.

projection with related landscape animations or textual information about the visualised topics was taking place.

The projected content was developed to try out different ways of visualisation, and only parts of the available datasets about specific topics were used in this prototype. The full datasets contain historical data going back centuries (past), recent sensor data (present) and forecasting data (future). In the future, content will be offered in a narrative-driven structure, as described in Section 4.

3.6 Interaction

A single user/administrator interacts with the projected content through a tablet device with a simple button-based user interface. So far, time series data (sea level) are handled by a slider, but this will be revisited – along with the whole user interface – in future versions of the Gaia System (Fig. 6).

During this work-in-progress, multi-user interaction was not implemented or tested, since the focus of this prototype was on technical feasibility and visualisation. Nevertheless, multi-user interaction will be addressed in future versions of the system (see Section 4).

3.7 Demonstration

A two-day demonstration on November 2021 took place at Sortland Museum. There, the Gaia Vesterålen project's consortium partners and their guests experienced the Gaia System prototype. The users

Figure 5: Projected content of the Gaia System.

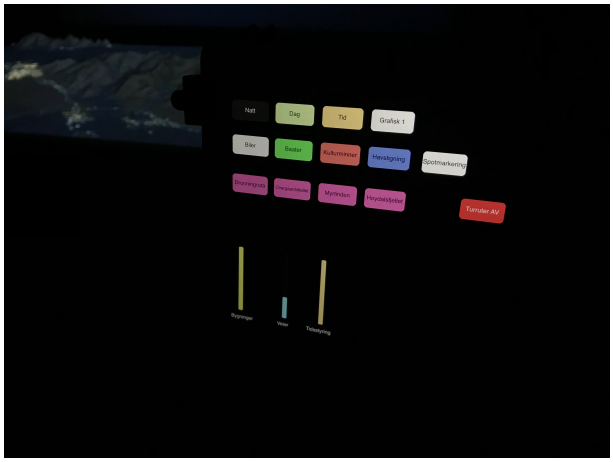

Figure 6: User interface for interacting with the projected content and activating/deactivating layers of information.

provided very positive feedback regarding the potential of the projection mapping technology, its suitability for presenting content in an attractive way and its visual fitness for museum settings, thus addressing the R5 requirement (Section 3.1). At the same time, feedback was received regarding the display resolution of the projection, which came from one 4K projector (Section 3.4). This was characterised as satisfactory. However, it would be advisable to improve this in future high-fidelity versions of the system. The users also provided ideas and design recommendations regarding the concept of the Gaia System, as well as additional characteristics and technologies that could be included in future versions.

4 CONCLUSION

In this work-in-progress, the prototype version of the Gaia System is presented. The system utilises projection mapping technology to visualise content about the past, present and future of the Vesterålen coastal area. It is installed in the Sortland Museum so that it reaches the local community, as well as tourists. The first reactions towards the developed system have been positive, yet several additions and adjustments need to be made.

Future work includes:

- expanding the projected area by creating more and larger physical scale models, covering many islands of the Vesterålen district, as per the concept description (Fig. 2 and R4 in Section 3.1);
- implementing multi-user interaction, as per the set requirements (R3 in Section 3.1), even in a simplistic form, such as multiple projections covering spatially large physical scale models and multiple administrators, or even with the introduction of physical objects that are linked to how the projected content unfolds;
- formulating the content as several narratives. Narratives will present several of the area's environmental and socio-economic issues and characteristics (R1 in Section 3.1), unfolding over time and addressing several time periods (R2 in

Section 3.1), depending on the topic. The narratives' development will be coordinated by partners in the project who are experts in museum curation and storytelling;
- implementing a multi-projector setup to achieve higher display resolution/better visualisation quality; and
- conducting empirical studies about the Gaia System with museum visitors, utilising the metrics of usability and user experience.

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