Learning from Players

Exploring Collective Intelligence in a Cultural Heritage Board Game through Geo-Spatial and Behavior Analysis

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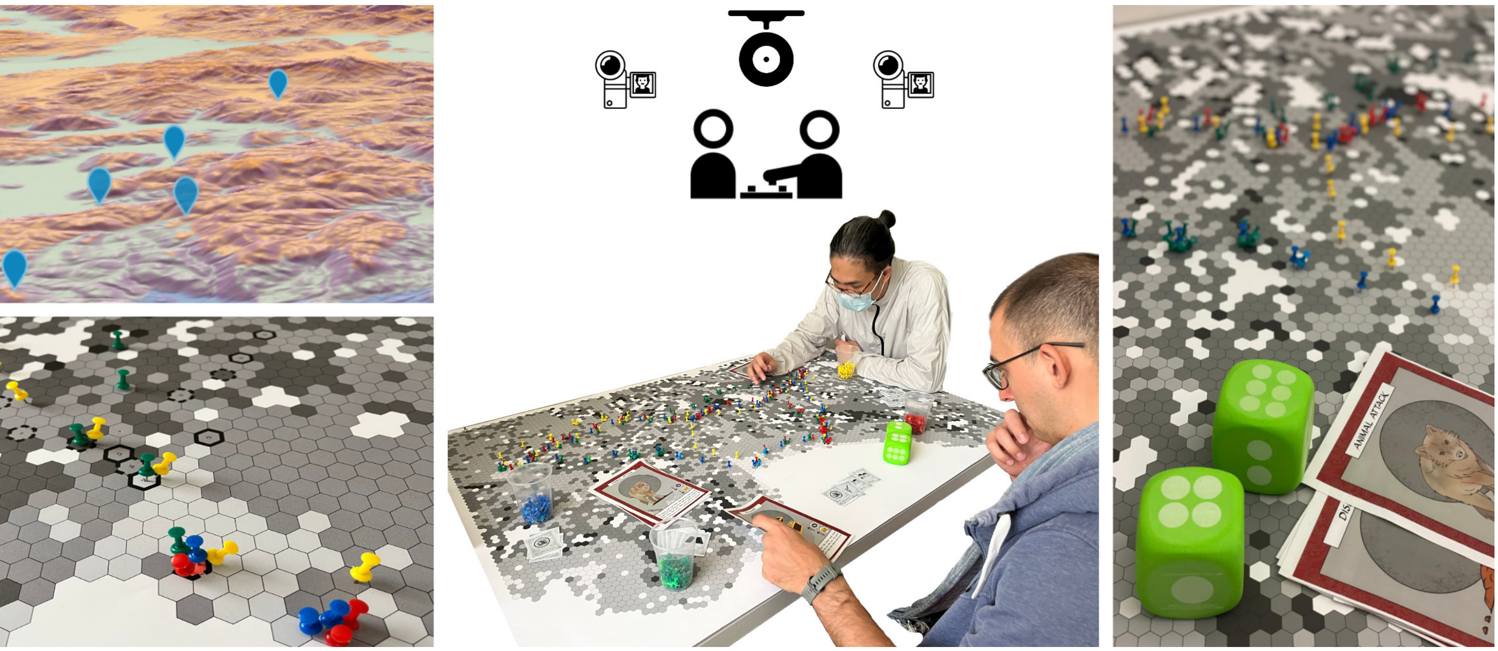

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ABSTRACT

The time spent playing games continues to increase, and educators and researchers have realized the potential of using gamification as a learning tool, and less often, using the collaborative environment of games to solve design problems. The unique contribution of this research is to employ gamers' collective intelligence to find the answers to questions of architectural history. This project is about mapping ancient trade routes, creating a credible geospatial narrative of travel and places of transported materials in the past. To uncover the intercity trade networks of the Middle Ages in Anatolia, we documented locations of an–iconic heritage building type, the caravanserai, a roadside inn used by travelers to rest during long journeys. This paper explores the unconventional decision-making environment of gamification to uncover past urban networks. To test the validity of decision making behavior of humans in the simulated topography, we designed, implemented, and tested a serious board game simulating the urban networks of the past. Using the topography, we abstracted, simplified, and represented several layers of GIS data into hexagon tiles to design a board game. The game also employs playing cards, divided into chance and trade cards, which are used to determine players' movement on the board and their scores. In the game environment, we simulate the movement of trade, while the players, as agents, explore and reveal possible intercity networks. We monitor and document the gamers' pathfinding/pathmaking decisions and use these to make comparisons with computational simulations. By tracking users' movements and behaviors, we were able to create data for spatial analysis, game statistics, and user behaviors. Based on experiments and employing gamers' stigmergy, the research provides predictions for lost urban networks of Anatolia.

1 The real-world topography in: (a) GIS; (b) the board game; (c) players during the sessions and their recording process; and (d) game elements

2 Data collection for creating: (a) distribution map; (b) abstraction of the data in GIS to create a game board; (c) gamification/design of game mechanics; (d) test plays and recording of the collective intelligence/decision making; (e) the spatial analysis, game analytics, and behavior analysis of gamers

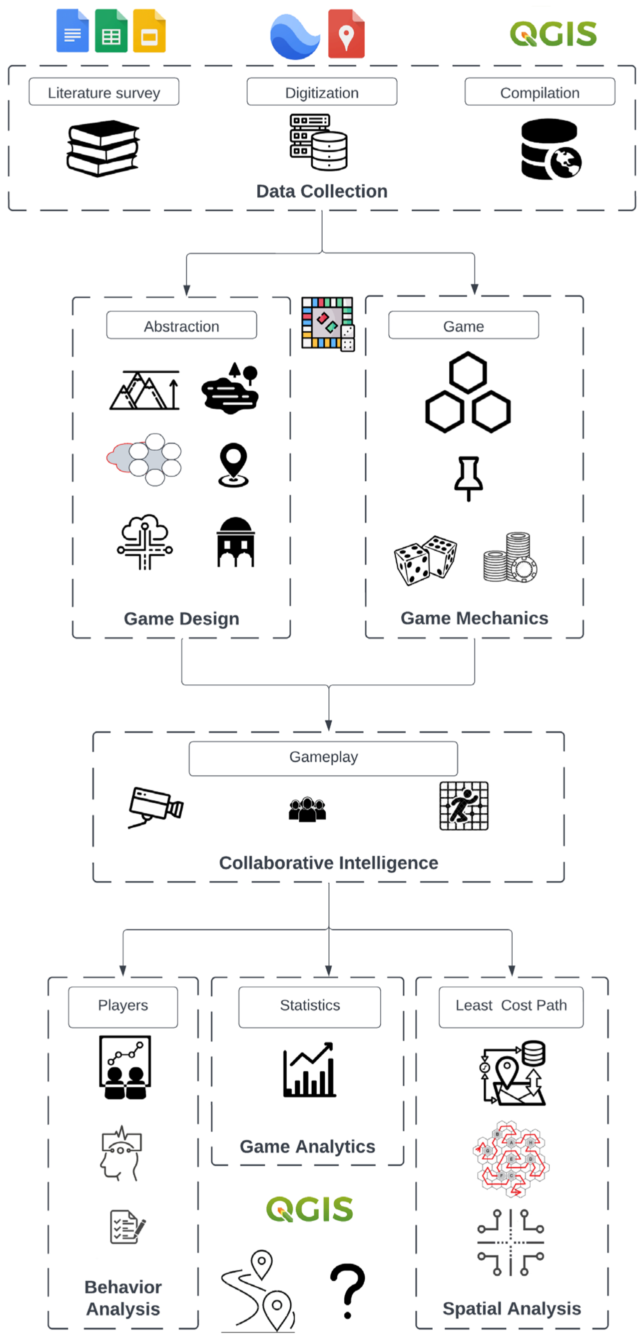
INTRODUCTION

Increasing interest in games has led educators and academicians to see their potential as a learning tool. Especially during the pandemic period, games became a tool to complement traditional teaching methods to improve the learning experience, while also teaching other skills, such as following rules, problem solving, interaction, critical thinking skills, creativity, teamwork, and decision-making. Using games as an educational tool provides opportunities for deeper learning. Games, along with certain innovations, such as VR/AR technologies, can also bring a clearer understanding of human perceptions of problems and decision-making processes in close-to-real world conditions.

Using games as participatory design tools is an approach to design that invites all stakeholders into the design process, bringing a better understanding of needs, and allowing them to be better met, and even preempted. Similarly, creating a collective intelligence is a utopian vision for collaborative knowledge culture (Levy 1999). As well as gathering, mastering, and deploying pre-existing information and concepts, members of a collective intelligence would additionally work with the collected facts and viewpoints to discover ways of thinking and coordinating. By focusing on the effect of crowdsourcing and collective intelligence in the decision-making process, especially in a game environment, we were able to explore the possibility of using games, not only as a learning tool for gamers, but as a means of learning from the gamers themselves.

To answer these questions, we designed, implemented, and tested a serious board game involving simulating the urban networks of the trade routes of the past (Figure 1). Using the actual topography, we abstracted several layers of GIS data for the game board design. In the game environment, we simulate the movement of trade, while the players as agents simulate the possible intercity networks. We recorded the traces of the players' collective movements using a ceiling-mounted video camera recording of the positions of the markers and players' behaviors. By tracking their movements and behaviors, we were able to collect user data for spatial analysis, game statistics, and user behaviors. The initial intended goal of this game was to identify possible locations of lost architectural heritage sites. The gamification of digital heritage, and using player participation in the form of the recorded observation was the research method of this study.

The central challenge of this research is the application of unconventional methods to quantify, qualify, represent, and experiment with these networks. Using this approach, the following questions are addressed: Can we reconstruct social networks of the past using gamers? Can unconventional computing help to uncover the Anatolian urban networks of the past? Does the complex system of cities and civilizations correlate with the gamers' decision-making patterns? Using the players' decision-making skills, gaming can shed new light on the field of cultural heritage.



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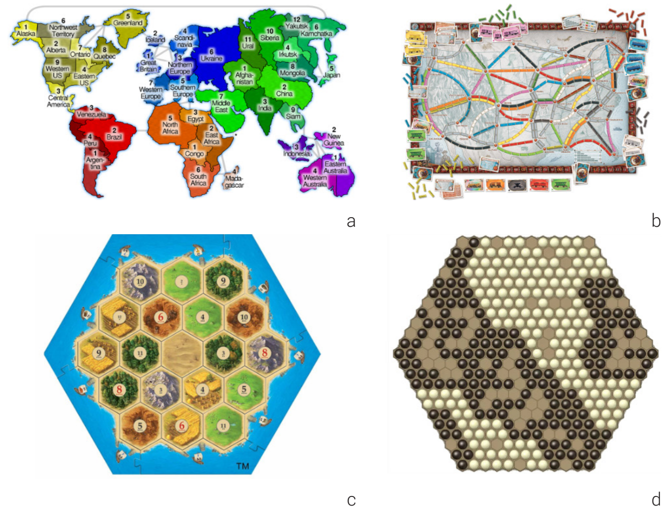
This research employs the collective intelligence of gamers to imitate the development of these ancient networks (Figure 1). As a case study in GIS, we collect and compile data from the ancient Silk Road routes, more specifically, the architectural evidence of these routes, namely, caravanserai, a roadside inn of ancient times. Based on the caravanserais' geographical coordinates, we used the GIS to overlay the following five layers: (1) base map from OpenStreetMap; (2) hexagon tiles on the board, in which all cells are equidistant; (3) terrain displaying the difference between flat valley floors, steep mountain climbs, and water elements; (4) today's traffic networks, referring to both the current route network and the density of the urban population, and finally (5) the location of caravanserais. The caravanserais, as nodes for safe-stay, are represented by solid hexagons. By allowing gamers to progress towards these, we aim to reveal the distribution networks of roads, paths, and traces. We monitored and documented gamers' pathfinding/pathmaking for comparison with computational simulations. Thus, the experiments and gamers' stigmergy provided predictions for lost urban networks of Anatolia.



3 Levels of abstraction in games: (a) Risk, (b) Ticket to Ride, (c) CATAN, and (d) Stigmergy

STATE OF THE ART

At the core of this paper is an interdisciplinary approach at the intersection of collective learning, gamification, and computational tools.

Game as Stigmergy and Collective Intelligence

Stigmergy is a form of indirect communication and coordination in which agents modify the environment to pass information to their peers. Stigmergic interactions can occur variously in social species, robotics, web communities, and human societies (Heylighen 2016). This emerging phenomenon is highly relevant to the understanding of modern human society. Another concept, that of collective intelligence, similarly emerges from many individuals' collaboration, collective efforts, and competition, and is seen in consensus decision-making. Rather than simply gathering, mastering, and deploying preexisting information and concepts, members of collective intelligence work with the collected facts and viewpoints to discover new ways of thinking and coordinating.

Collaboration is an important aspect of architectural design. Kalay and Jeong (2003) make the connection between traditional project-based learning methodology based on individual design decisions, and the potential of collaborative design through multi-player games. Through their redesign of popular board games such as Scrabble and Monopoly, they were able to use gamification in collaborative design. Another example, Play the Koepel, is a multi-stakeholder game for developing collective scenarios as part of a city consultation process (Play the City 2020). Multiple stakeholders are invited to the game, designed specifically to promote interaction to bring together different ways of thinking for a possible interpretation of the city complex. Santacruz (2019) designed ScarCity Game, a board game and a pedagogical tool to involve architecture students in a series of experimental design sessions aimed at understanding the design process of scarcity, and the true relation between craft and the digital. Game environments provide students with the medium to challenge conventional methods of teaching and learning in design.

Game design involves planning various aspects of the game, such as mechanics and dynamics. A game should be a challenging abstraction of reality and should involve following specific rules to achieve a goal. In the examples above, the game format was not only considered as a teaching aspect, but also aimed at providing an innovative and unconventional environment in which to solve scientific or design problems. An example of design problem-solving gamification is Ahlqvist and colleagues' game on resource management. This real geography component inspired Ahlqvist et al. (2011) to develop tools that others could use to create location-based learning games, making geography and GIS a fundamental component for game players. Efforts were made to integrate GIS to Massive Multiplayer Online Gaming (MMOG) to support the integrated modeling of human-environment resource management and decision-making (Ahlqvist et al. 2012). Games are also used to test specific innovations in close-to-real world conditions (Piette et al. 2021). Since the advent of Artificial Intelligence (AI), games have become testbeds not only because of their simplicity and popularity, but also due to their capacity to allow a clearer understanding of human perceptions of problems and decision-making processes, in comparison with those of machines.

Many games, in essence, are simulations of real world scenarios. Most well-known historical games use maps at various abstract levels; for example strategy games, such as chess or checkers using black/white board, or, in the case of backgammon, the board allows for a combination of strategy and luck. At the abstract level, Risk, a strategy board game, depicts the political map of the world, divided into six continents and 42 territories, where players occupy territories to eliminate others (Figure 3a). A well-known pathfinding game is Ticket to Ride, a cross-country train adventure in which the players build routes in between the cities, with more points scored for longer routes (Figure 3b). CATAN is a strategy game in which the aim is to trade, build, and settle an imaginary island, where players control their own civilizations and aim to spread across a modular hex board in competition for victory points (Figure 3c). At a higher level of abstraction, the game called Stigmergy is a borderless territory game for two, played on cells of hexagons, similar to Go, in which each player aims to gain possession of a certain number of positions, occupying these with stones of their color (Figure 3d).

Analysis Tools

Recent developments in emerging technologies have allowed the establishment of the phenomenon of digital heritage. These developments grew out of conventional computing, and the use of GIS in archaeological studies from the early 1990s, which represented progress towards a more fully macro-scale analysis of human societies and their environment. This approach included the representation of data in layers, the integration of statistical and spatial programs, and most importantly, the ability to work on 3D terrains. Thus, GIS has evolved as an invaluable aid for the heritage sector, allowing the incorporation of historic map data, physical details of the landscape, and known information about the past inhabitants. A significant example is the web application entitled The Stanford Geospatial Network Model of Roman World (ORBIS) (see ORBIS n.d.), simulating movement along principal routes of Roman road networks. This project enables the reconstruction of the time needed and the expenses associated with a wide range of different types of travel in antiquity.

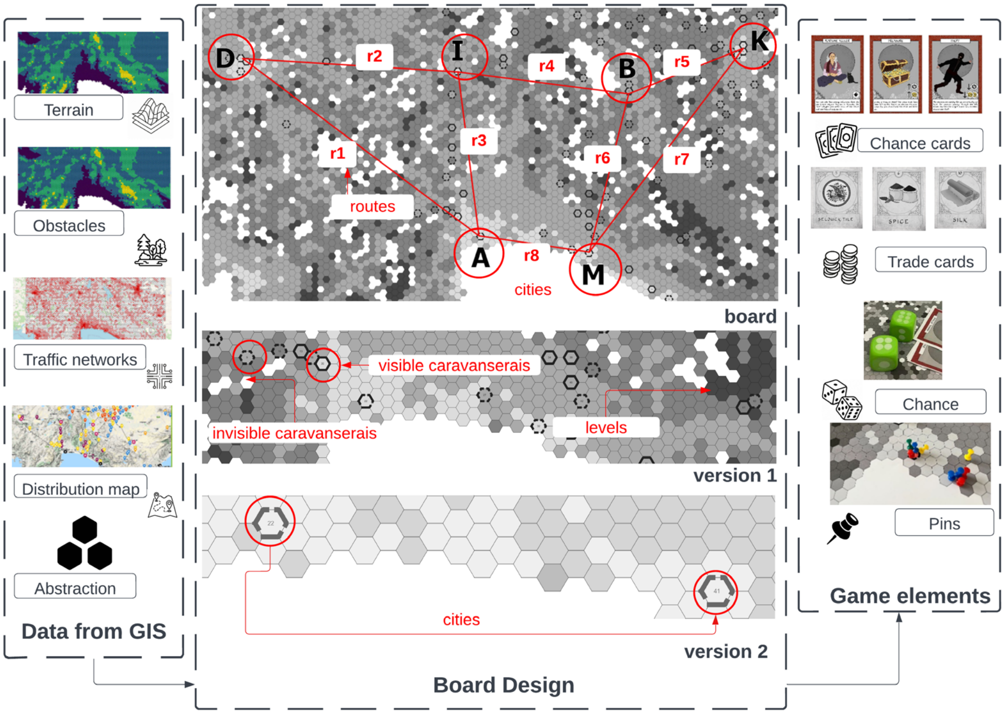
Spatial analysis deals with the use of space. Network spatial analysis, as opposed to traditional planar spatial analysis, concerns events strongly constrained by their networks e.g. the locations of car crashes and fast-food shops on streets (Okabe and Sugihara 2012). Urban network analysis, although developed for the analysis of urban streets and networks, is also suited to railway networks, highway networks, or utility networks (Sevstuk and Mekonnen 2012). In the heritage context, network spatial analysis in GIS involves finding patterns of distribution of archeological finds, features, sites and monuments (Hodder and Orton 1976). The distribution map, able to show the totality of information, is one of the main instruments of archaeological research and exposition.

GIS facilitates agent-based simulation, which is an approach to modeling systems composed of individual, autonomous, interacting agents. There are a variety of simulation tools in GIS for analyzing the distribution of archaeological heritage along the network. Our focus is the "least cost path," allowing the determination of the most cost-effective route between a source and destination. Thus, least cost path analysis shows the optimal path between a source and destination in terms of cost function. Some of the previous works in the book *The Least Cost Analysis of Social Landscapes* (White and Surface-Evans 2014) focus on contexts such as hunter-gatherer zones, water transport trails, and prehistoric trail networks. Another prominent study takes the approach of juxtaposing GIS and archaeologically mapped ancient road routes for a region of ancient Italy, and reveals the map differences (Hodza and Butler 2022). Similarly, in these games, there are tools that can be used for analysis, such as the heatmap, density/location-based aggregated visualization of the users' movement, and GIS (Drachen and Canossa 2019).

Emerging technologies allow the better analysis of the user experience of space through systematic data collection via path tracking, bioinformatics, sonic analysis, and visual recording. However, computer vision provides another opportunity for behavior analysis and gesture tracking to recognize patterns. Moments in Time at MIT CSAIL (2019), is a research project dedicated to building a very large-scale dataset to help machine learning systems recognize and understand actions and events in videos (Monfort et al. 2019). In addition, specialized equipment such as a wearable electroencephalography (EEG) headset can present a framework for classifying the game player's expertise level.

CONTENT AND SCOPE

As humans traveled and traded with neighbors, exchanging goods, skills, and ideas, Eurasia became covered with intersecting routes, known today as the Silk Road. The Silk Road's inland routes were marked at intervals with caravanserais and guesthouses that provided accommodation for traveling merchant caravans. Extending along the Silk Road from China to Turkey, connecting east to west, these buildings not only provided a safe resting place, but also served to promote the exchange of cultures, languages and ideas, allowing the spread of news, but also, unfortunately, diseases. Caravanserais were carefully positioned a day's journey apart, which means every 30-40 km in well-traveled areas, approximately 6 (+/-2) hours' journey time. The diversity of paths, tracks, and roads changed not only in the long-term, but also seasonally, as weather conditions made river crossings and mountain passes impassable, forcing travelers to take different routes, often across wide valleys and steppes. We adopted the approach of identifying major nodes (large cities) along the Silk Road routes; identifying caravanserais as waypoints between these, and, rather than identifying



4 Data layers in (left) GIS; (center) board design, and (right) game elements

5 V.1 of the board, four main colors show players' paths, while black line shows the (a) optimal path; V.2 of the board, white line shows the (b) optimal path; (c) heatmap; and (d) modern intercity road networks and caravanserais plotted on the game board

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potential specific roads, broadening out these routes between the nodes to represent the corridors of movement and impact. Selected as a case study, Antalya was a prominent ancient city on these roads, representing a secure transit point for goods, its harbors providing access to the maritime trade routes of the period. Another advantage was its proximity to networks of caravanserais. Studies in modern-day Antalya/Manavgat revealed that the city is at the intersection of eight caravan roads.

METHODS

Data Collection

To address the lack of a holistic approach in geospatial inventory of caravanserais of Anatolian Seljuk, we digitized and created a compilation of all the major cataloging studies. We created a structured database using maps, web inventories of travelers, books, a list of individual researchers, and a list of caravanserais. Subsequently, we reorganized this data, with each building being categorized according to the nearest cities, and made this information accessible in the Google Earth platform cloud service, allowing the team to work remotely on a common database. In the later stages, we exported the online database to Google My Maps, for public dissemination, and distributed it through social networks for travelers' guidance. This was a very early effort to crowdsource the data collection methodology.

Game Design

The game board granularity (size of the hexagon and number of elevation shades) has a considerable impact on the players' traversal. First, we designed the board, in which the various terrain differences were simplified, and represented by hexagon tiles of four shades of gray. We used GIS to overlay the multiple layers: base map from OpenStreetMap, hexagon tiles representing 5 km span, the terrain representing flat valley floors, steep mountain climbs and water elements, modern traffic networks referring to both the current route network and the geographical coordinates of caravanserais (Figure 4, left). The 5 km distance between two cells gives enough granularity to provide a reasonable level of topographic detail. Each player's movement is limited to six hexagons at the same level, represented by the shade of gray and one less movement per each level change. The six hexagon-move corresponds to 30-40 km in real world travel.

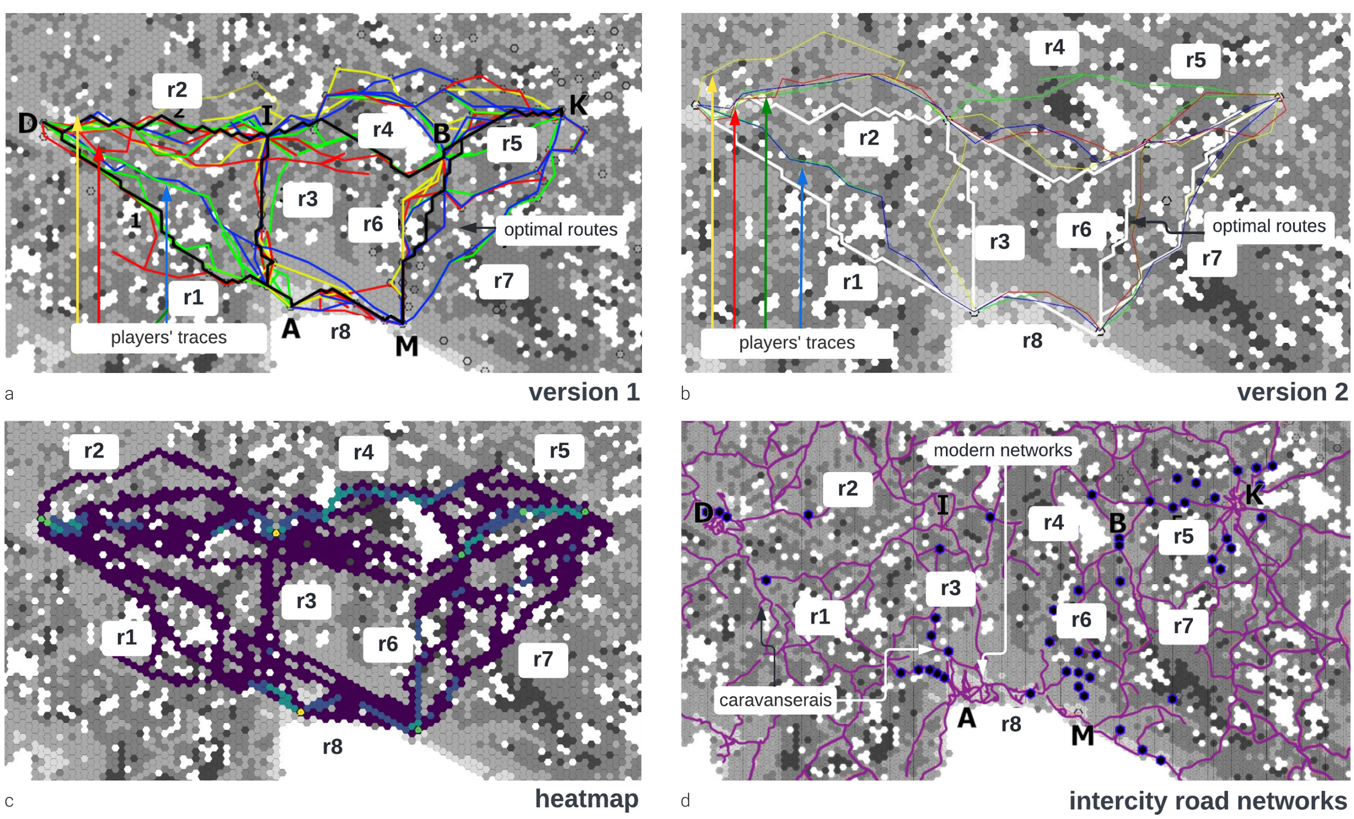
There are two versions of the board: V.1 refers to the board showing both visible and invisible caravanserais. Visible caravanserais refer to located and identified buildings in varying stages of preservation, while invisible caravanserais refer to an approximate location only, for example, those whose existence is implied in settlements whose name includes the word "han." V.2 refers to the board design with cities but without any caravanserais locations (Figure 4, center).

The game also employs playing cards, divided into chance and trade cards, which are used to determine players' movement on the board and their score (Figure 4, right). The visual and textual information on the cards is inspired by the architectural heritage of this period, utilizing contemporary symbols, instruments, characters, tales, food, clothes, artifacts, animals, etc. Subsequently, these elements were displayed in 2D graphics designed to visualize the daily life associated with the particular cultural heritage. The trade cards define the overall earned score, defined by the roll of dice, which determines how much money is won or lost. The trade cards are not related to the movement of the players. The chance cards may lead to a positive or negative outcome, leading the player either to proceed forward on the board and gain money, expressed as trade cards in the game, or to lose properties and move backward. Card dynamics add an element of flow, without disturbing players' path making decisions.

The game involves pathfinding through visiting caravanserais (waypoints) to reach the main cities (nodes). The aim is to score as many points as possible and return to the starting point as quickly as possible. The players are allowed one move at a time (six hex at the same level or one less movement per level change). When reaching a caravanserai, they stop, roll dice, and pick a trade card. If the caravanserai is invisible, they stop, but do not take a trade card. If they decide not to rest at a caravanserai, they pick a chance card, but this might bring negative outcomes, and should, if possible, be avoided. Players have to visit all cities. The winner is the first player to arrive back at Antalya, the starting point, and who has collected the most trade cards. The rules of the game motivate players to visit as many caravanserai as possible, and reach all of the cities in the fewest turns, while avoiding staying out in the open (cells without caravanserais). These rules provide the motivation for players to follow the actual historical trade routes.

Spatial Analysis

To test the historical hypothesis of the potential locations of trade routes, we collected the traces of gamers' movements in GIS. These traces show players' responses to the conditions reflecting the trading mechanics of the era, providing data for locating lost connections along the routes. The game is played six times to record the players' decision making under different conditions. The first four instances are played with all the caravanserais on the board, the fifth instance, with only visible caravanserais, and the final instance, with only cities visible. The aim of playing with different levels of information on the game board is to compare the deviation of paths from the optimal least-cost path. We conducted six game sessions of 24 participants, each session lasting approximately 90 to 120 minutes. After being instructed on the purpose of the game, a group of four players traced paths in between the cities. The first four sessions targeted the gameplay and game testing, on a board that includes the both visible and invisible caravanserais (V.1). In the first version of the board, four main colors show players' paths, while black lines show the optimal path (Figure 5a). The fifth



and sixth sessions were played on different board designs with no caravanserai data (V.2). In the second version of the board, four main colors show players' paths, while white line shows the optimal path (Figure 5b). A heatmap of all the traces of players' movements was created to show the cumulative paths (Figure 5c). Finally, modern roads, the location of caravanserais and the gamers' routes were plotted together, showing the relation between these (Figure 5d). Intercity road networks were obtained from OpenStreetMap (OSM) street networks of Turkey. We selected the roads with the type "highway," "primary," "secondary," and "trunk."

To compare the players' movements with the optimal topographic conditions, we used "least-cost path analysis" from the grids, which involved calculating optimal paths between cities using QGIS shortest path function. In the hexagon tiles, each cell has its own gray shade which also indicates its level. To calculate the least-cost path between two points, the movement cost of every cell along the route should be added (Figure 6). The granularity of the board selected for this project means that the spatial analysis is limited to topographical optimal path analysis.

Behavior Analysis

The students, as players, take on the role of agents simulating traders' behavior. Following the participatory design/co-design perspectives, the game was used as a research method rather than as a product. It is important to note that we additionally evaluated the users' behavior to assess the game design (Figure 7).

We recorded the players' behaviors and movements across the board game by using markers through video recordings. A camera focused on the game board recorded the players' movements. Each player used a distinctive pin marking their movement on the game board (Figure 7a). The locations of these were registered in the recordings using Python OpenCV libraries, converted into lines, and stored in QGIS. In addition, another camera was used to record the players' gestures (Figure 7b).

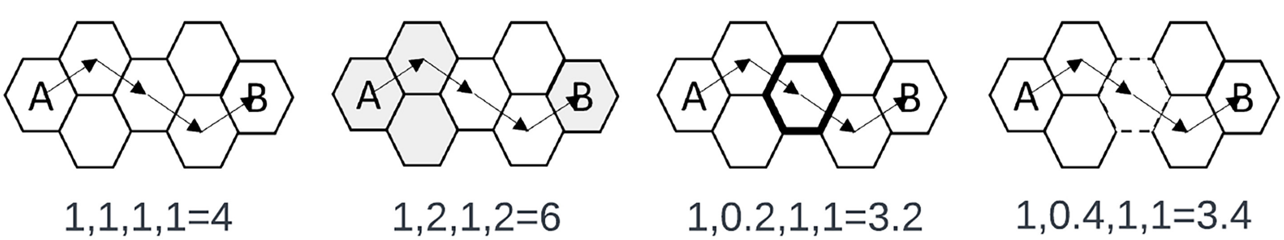
Moments in Time, co-developed by MIT and IBM, is a large-scale dataset for recognizing and understanding motion in videos (MIT CSAIL 2019). It was used to analyze players' behavior while playing the game. We compared the frequency of spoken communication in each session, detecting some frequent behaviors, such as "combing," "shrugging," etc. Figure 7b shows an example of action recognition of a three second video clip, and the prediction result showed some potential. The error in detecting the behavior was caused by the usage of facemasks, and could be enhanced by removing this visual obstruction.

RESULTS AND DISCUSSION

The game was designed to help the researchers to build heritage information. The initial results of the study based on gameplay, and also the statistics showed a need to divide the routes into eight fragments. Depending on the changes on topography, and the availability of modern traffic networks, each segment of the network (routes 1-8) displayed a variety of results. In this part, each segments' results are presented and discussed in relation to the gamers' decisions and optimal routes on both versions of the game.

The V.1 game results showed that along the routes with a major obstacle, a small majority of players chose the optimal route, especially in relatively uniform landscapes, but in segments with small obstacles of minor variations, a clear majority tended to choose the optimal routes. Exceptions were routes 6 and 7, where most diverted away from the optimal paths. These routes had the most frequent changes in topography and greatest uncertainty in the location of the caravanserais. These exceptions might indicate inconsistency in the method of abstraction of topography while designing the board. The 5 km distance of hexagons might have missed some natural features, as the average (overall height domain/4 levels of gray) cannot represent the scale of historical travel or human biodynamics with great accuracy. The V.2 game results proved that without any caravanserais information, players tend to follow paths further from the optimal routes, with an exception of routes 7 and 8, which have the fewest major obstructions.

Optimal routes partly coincide with players' decisions, but more completely coincide with existing modern traffic networks, with the exception of route 6, for which some



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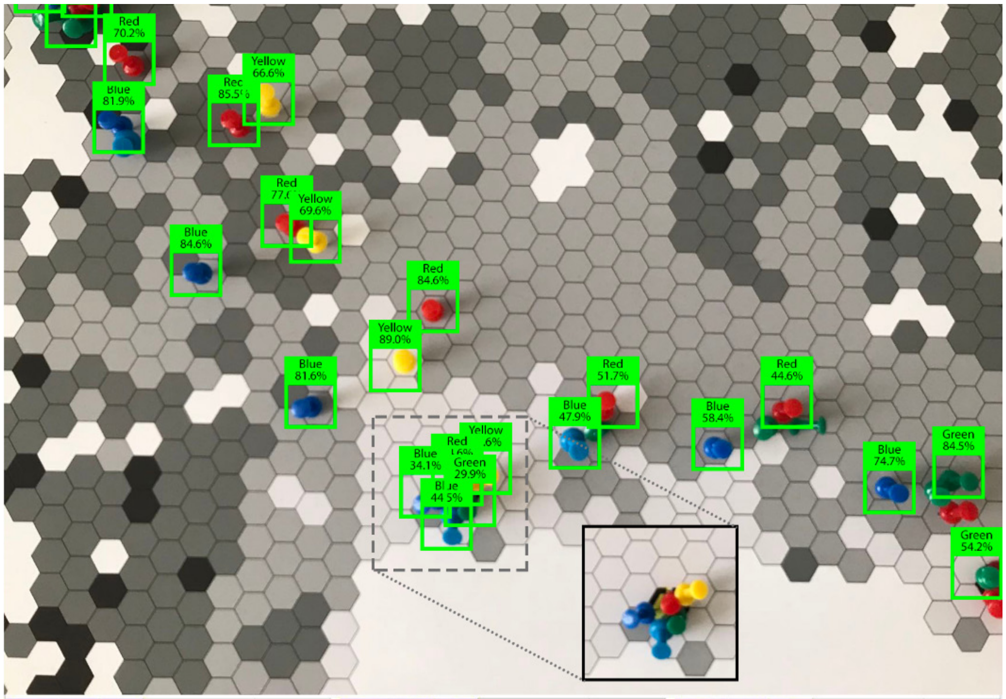

Prediction	Acc.
shrugging	0.613
standing	0.032
speaking	0.028
raising	0.027
lifting	0.026

Prediction	Acc.
flipping	0.633
throwing	0.073
flicking	0.047
laughing	0.019
speaking	0.014

Prediction	Acc.
combing	0.109
brushing	0.075
speaking	0.073
shaving	0.068
laughing	0.027

7

6 Movement costs for different cell configurations: The cost of movement along the same level grid cells is one for each cell from A to B, the cost of movement is 4 (a). If there is a change in the level of the grid cell, the cost of movement increases by one to reflect the need to climb up or down the slope in the topography, therefore the cost of movement from A to B is 6 (b). If there are caravanserais (bold cells) the cost of movement for that cell is 0.2, as a result the cost of movement from A to B is 3.2 (c). If there are hidden caravanserais (dashed cells), the cost of movement for that cell is 0.4, so the cost of movement from A to B is 3.4 (d).

7 Tracking players' pins (top) and their gestures (bottom)

caravanserais do not coincide with the modern roads. This suggests the possibility of another city or political center around route 6, which is already distinguished by its location next to steep mountains. This seems to justify the need for a higher resolution abstraction method in locations with greater topography changes.

CONCLUSION

Keeping in mind the rhetorical question of human rational and irrational decision-making processes, the study explored the potential of the game environment as an analysis tool. In addition to the use of gamers as agents to discover trade routes, the research also presents a novel perspective on the analysis of the past, to predict the actual and future development of cities and city networks. In other words, the aim was to understand the urban dynamics in the current era, which is characterized by constant change in city networks, due to climate change, immigration, and the recent pandemic period. The use of gamification allows understanding of the behavior of crowds in a visual and collaborative manner. A similar effort is the CityScope, a project conducted at the MIT Media Lab City Science group (2021), including tangible and digital platforms dedicated to solve spatial design and urban challenges. Another potential outcome of the project is to allow the integration of immersive aspects, and develop it into an AR game.

The game was designed and implemented as a board, around which the users can physically sit and interact, avoiding the need for an interface between individual players, the game environment and co-players, allowing them to collectively discuss, and agree or disagree with each others' moves. The competitiveness of the game required thinking about other players' moves and improving them to find the best strategy. The collaborative and competitive nature of the game helped reveal optimal paths in the topography. The removal of the caravanserais in V.2 showed that, in this case, players diverged farther from the optimal routes, which would provide evidence contradicting the players' own pathfinding ability. However, this result should be treated with caution. The sample set is limited to six games and 24 players, and warrants a more targeted summary, and therefore, it is likely that the determination of what is optimal, and thus efficacy of the game schema, needs further exploration.

The behavior of the users was analyzed through computer vision, to identify key moments in thinking and deciding. As our current focus is on the game rather than the student learning, no background information about the users was presented. However, for the next stages, gamer analysis could be improved by collecting more background information (age, gender, nationality).

In conclusion, this proof-of-concept project explored how games can be used to simulate ancient trade routes and how the players of the game can be used as a data source for research. Further studies could explore the benefits of transferring this game to a virtual platform, allowing automation of data collection from the users. In this virtual version, the targeted data set would be larger, leading to greater accuracy in determining the users' pathmaking. This large data set would allow us to use reinforcement learning methods, with humans as agents revealing emergent patterns.

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Session Introduction

Advanced Production Methods II: Knitted Architecture

Tsz Yan Ng, Chair

CNC knitting has become a robust area of research in academia in the last ten years. So much so that this year's ACADIA conference includes a dedicated session: "Advanced Production Methods II: Knitted Architecture." The four papers in this session represent distinct applications and research approaches to CNC knitting, but they all harness a combination of three characteristics unique to knitting. The first is the customizability of the textile, that a single surface does not have to be homogenously structured. Through specification of yarn type (material) and knit structure (looping construction), a knitted textile could have varied behavior across a seamlessly knitted surface. This aspect of knits defies our normal conception of material logic, that across a single material, one can have localized behavior that contributes to and at the same time unique from the global behavior. In this respect, no researcher could escape the intrinsic nature to working with knits, where one must toggle between calibrating at the stitch level against the overall behavior of the entire surface. The second aspect unique to knits, and perhaps because of the customizability, is the ability to tune the knit's performance toward targeted goals. As demonstrated by Zilka and Underwood and Sinke et al., performance is integrated via computational methods/simulation. Through the calibration of parameters, the knitted textile is an engineered system, controlling for elasticity, formal geometries, and tensile strength. Such control enables applications at diverse scales, from the sleeve of a space suit by Tessmer et al. to ribs of a self-supported structure by the Newcastle research team. The third characteristic to knits is the capacity to embed and integrate other systems into the material with ease. This includes sensing systems knitted into the material as shown by Tessmer et al. for monitoring performance, or in the case of the Newcastle team, to allow mycelium to stiffen the softness of the knitted textile so that the textile could be leveraged for architectural applications. The papers herein highlight the keen awareness that knits, with its unparallel design capacity, is a material system that will have wide impact in the future for architectural production.