Cloudcommuting: Games, Interaction, and Learning

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ABSTRACT
This paper discusses the design, process, and results of an experimental workshop with mid-school students that introduced the theory, underlying technologies, and operational challenges of smart urban systems. Students brainstormed ideas of how to use electronics, interaction design and game theory to make bike-sharing systems that incentivize users to rebalance bikes through rewards/penalties. Furthermore they tested their ideas by collaboratively designing, prototyping, and playing an interactive board game implementing both theory and technology. Through their game students explored questions such as: how can we create coordinated behavior from self-interested players? How and when can the game reach a sustainable equilibrium? In what other systems can we apply similar concepts?

Categories and Subject Descriptors
K.3.2 [**Computers and Education**]

General Terms
Design, Experimentation, Human Factors. Management.

Author Keywords
Game Design, Game Play, Game Theory, Economics, Teamwork.

1. INTRODUCTION
Learning systemic thinking and design are essential components in contemporary children's education: the former for understanding why the world behaves the way it does while the latter for constructing the world to behave in a certain way [2]. From smart devices to smart cities we are surrounded by increasingly complex systems that blend the digital, the physical, and the political world [1]. Understanding, designing and building such systems requires integrating a multitude of disciplines including economics, game theory and communications to name few. In this paper I discuss how a game experiment turned from a research method to study intelligent transportation systems into an educational framework to teach children complex systems.

1.1 Research Context
Mobility on Demand (MOD) systems (also known as vehicle sharing systems) allow users to make point-to-point trips on demand by using shared fleets of vehicles (bikes, automobiles, etc.) and networks of parking stations. Examples include Velib in Paris, Hubway in Boston, Car2Go in Austin, and more. Despite their convenience MoD systems have significant logistical challenges as vehicles end up at stations with no pickup demand. Operators use trucks and employees to manually reposition vehicles from full to empty stations resulting in significant costs, operational complexity, and low level of service. In my research I explore the use of price incentives to motivate the users to take over the task of repositioning. The pricing scenario, titled *the Market Economy of Trips* (MET) [1], adopts a market mechanism in which trip prices depend on inventory needs of origins and destinations, causing some trips to be more expensive while others to pay back (figure 1). The development of such a mechanism of incentives is an interesting design problem: the pricing mechanism must be simple so that users can easily perceive their payoffs; prices must not over-fluctuate so that users keep using the system; and the rewards should be financed by the penalties.

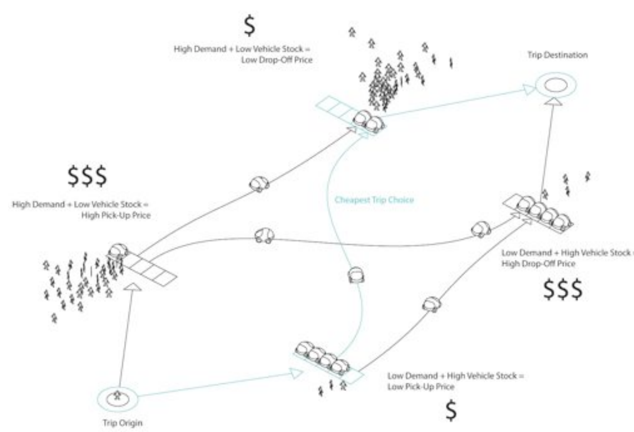

Figure 1. The Market Economy of Trips

As part of this research I designed an interactive strategic game to empirically study perception of payoffs, decision-making, and equilibrium in MET in comparison to results from computer simulation models. Although the game started as an experimental research tool, it became obvious that it can serve as an educational framework to teach others how such systems work. Recently I was invited to teach a workshop on smart cities for mid-grade and senior high school students and had the opportunity to test the effectiveness of this game as an educational tool. The rest of this paper continues as follows: first, I provide a literature review and position this work accordingly. Next, I describe the methodology and workshop process. Finally, I discuss results and future steps.

2. RELATED WORK
Learning by game making, learning by game playing, and learning by computer simulation are popular methods in Constructionism theory: they provide meaningful yet engaging contextual frameworks for students to develop creativity, systemic thinking, problem solving, and team building skills. In [2] Kafai discusses *game designing* and *game making*, as processes in which kids learn programming, story telling, and creativity skills

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by becoming designers of fictional worlds for other participants (Logo, Scratch, etc.). For Kafai designing constitutes a self-retrospective learning experience with unique, personalized artifacts and plenty of time for self-reflection. In this work however, design is approached as a collaborative process with a single collective artifact, tight time schedule, and clear goals/deliverables. In [4] and [6] Resnick and Forrester discuss *computer simulation* methods such as agent based systems (NetLogo, StarLogo, etc.), and system dynamics (Vensim, Stella, etc.), as ways for learning systems thinking by constructing virtual ecosystems and exploring their dynamic behavior under different scenarios. Both [4] and [6] emphasize the educational importance of mapping, calibrating, and comparing a simulation model to the real physical system it resembles. In [3] Salen & Zimmerman discuss *game playing*, as a learning experience through fulfillment of missions in virtual worlds, and *role playing* as an act of practicing social, team building, and management skills by appropriating roles. In contrast to this exploratory view of playing, this work focuses on strategic interaction, ecology, and equilibrium. Strategic games –often called "serious games"– are a special category of multiplayer games in which decisions of each player depend on their expected impact on the future decisions of the opponent player(s) [5]. Examples include chess, military conquests, and market economies. "Zero-sum games" are strategic games in which the total wealth remains fixed (e.g. the gain of a player is the equivalent loss of another player). Zero-sum games find applications in many real world cases where physical resources must be carried from one location to another providing good contexts to study topics of sustainability and economics. Due to their feedback complexity strategic games are less common in Constructionism, which favors linear exploration [2].

This paper questions whether design of technologically augmented, strategic and collaborative games can provide a framework for teaching and learning complex socio-engineering systems. The main objectives of the study were: first, to assess whether teams of students with no technical or teamwork skills could collaboratively understand the components that formulate a complex socio-engineering feedback system, and resynthesize them to construct their own version of it. Second, to explore how students in teams integrate *planning* (top-down) and *bricolage* (bottom-up) methods in a complex project [2]. For example, designing the game rules is closer to bricolage, while developing the technological platform is closer to planning. Third, to assess whether kids could learn complex topics such as economics, systems thinking, game theory, and electronics in a highly structured, goal-oriented, role-playing manner, under the pressure of demonstrating results within a short time frame; in short, whether graduate-level design studios and research labs could provide learning paradigms for kids.

3. METHODOLOGY

The workshop took place at the Informatics Center (IC) of the Hellenic American Educational Foundation (HAEF) in Athens, Greece, during summer 2012, with 6 participating middle school students (ages of about 15 years). The workshop followed a design studio format with desk reviews and frequent student pinup presentations. The duration was 10 days, organized in 2 weeks, with 5 hours of work each day. The first 2 days focused on general introduction, description of the game goals, and team-building; the next 7 days focused on intense design charrettes and brainstorming sessions, quizzes, and individual team meetings; the last 2 days focused on fabrication and assembly of the prototype. Finally, on the last day teams showcased their work and made PowerPoint presentations during an open house. Each morning teams presented their progress from the previous day in relation the other teams; then, new tasks and quizzes were announced, and desk reviews followed.

3.1 Description of the game

The game resembles a city consisting of several interconnected station –or neighborhood– blocks, each with a limited number of parking spaces and vehicles. The game is played with two or more commuter players and one banker. Each commuter must accomplish a list of origin-destination missions while the banker controls the pricing of the stations. Commuters can move between blocks using any combination of MOD and public transit vehicles. For example a commuter that must move from block A to block D may move from A to an in-between block B with a MOD vehicle and from B to D with the public transit. Commuters use both time and money to travel however each commuter starts with a different mix of those two resources based on his/her profile (tourists, businessmen, students, etc.). Each transportation mode consumes different mix of time and money units per trip. Commuters earn points by accomplishing origin-destination missions while the banker each time a MOD vehicle is used. The more trips commuters make using MOD vehicles the more the money circulates in the game. If players and banker do not cooperate then money drains away till everyone runs out of resources. Players must use wisely their available resources to earn as many points as possible: the commuters by selecting bundles of MOD and public transit trips, while the banker by selecting prices that attract commuters. Winner is the player with the highest score at the end of the game. For the pricing we used a scenario of a two-sided market competing station-traders: commuters buy vehicles from origin stations and resell them to destination stations paying the difference of those two transactions which can thus be positive, zero, or negative (rewarding).

3.2 Teams, roles & process

Teams were organized according to the tasks of the game's feedback loop: measure inventory changes at the stations; send messages from stations to a server; receive messages from stations and store them in a database; convert inventory information into price information; communicate price information back to the players; determine how price information affects players decision. Finally, simulate the above feedback loop in a computer.

3.2.1 Electronics team

The task of the electronics team (1 male student) was to develop the electronic infrastructure of the stations and the communication network that would read data from vehicles and user ID cards, and send event messages to an IP address of a remote server computer. The protocol and content of these messages was to be agreed with the rest of the teams. Stations were implemented using Arduino microcontroller boards. Students used RFID tags/sensors (figure 2, left) to track vehicles and players and Ethernet shields for communication. The electronics team started on day 3 by exploring the basic functionality of the Arduino microcontroller and familiarizing themselves with the RFID technology. On day 4, they learned how to program the microcontroller to read two buttons incrementing/decrementing an LED bar chart. On day 5 they programmed the board to read an RFID tag and display the ID on screen. On day 7 they learned how to send a message from their Arduino boards to an IP address via the Arduino Ethernet shield and library. On day 8 they connected the station boards to an Internet switch and send individual messages to the IP address. Finally on day 9 they implemented their prototype to the game.

Figure 2. Electronics team programming RFID sensors (left); the game design team (center); AB model of simulation team (right)

3.2.2 Data visualization team

The task of the data visualization team (1 male student) was to program the server to receive messages from the stations, archive them in a database, and visualize them back to the players. To visually communicate price information to the players, a color-based scheme was used that associates price levels to color tones: for example moving from dark-red to light-red stations could be expensive while moving the other opposite way could be rewarding. The team developed the server program using Processing, an open-source Java-based programming language. The data visualization team started on day 3 by learning how to visualize real time data from bike sharing systems using JSON data feeds. On day 4, they learned how to make two desktop computers exchange messages using the User Datagram Protocol (UDP) library in Processing. On day 5, they determined a message format with the first team and they programed the server computer to parse the message, split its tokens, and create a simple database. On day 6, they implemented the pricing method of the game design team and generate prices (the pricing method could be as simple as "divide current inventory by maximum inventory"). On day 7, they developed and implemented a color-coded scheme for the prices that would be projected on the physical surface of the board game through a mounted projector from the ceiling (figure 3, left). On day 8 they setup the projector and worked with the electronics and game design team on prototyping the board and mounting the Arduinos and sensors on it.

3.2.3 Game design team

The task of the game design team (3 female students) was to design the rules, gameplay, layout, and fabrication of the game ensuring that the underlying virtual economic system would be fair (e.g. if all players played equally well there would be equilibrium). Furthermore they had to ensure that players have clear goals, it is possible to win or lose, and that the game is interesting, meaningful, and engaging. The team worked mostly with sketches, quick mockups with paper/carton and colored pencils, and discussions with the instructor(s) (figure 2, center). After experimenting with different network topologies the team selected a ring layout consisting of 3 stations indicated by red circles. The game design team started on day 3 by deciding the physical layout of the game as well as the number of stations, players, vehicles, pawns, network topology, etc. On day 4 they developed the monetary system, representing time and money with white and red chips respectively, and coordinated with the other teams about the design of the stations. On day 5 they focused on the monetary system, scoring, designing the economy, and first play of the game. On day 6 they finalized the board layout, ordered materials, worked on fairness of game and equilibrium conditions. On day 7 they designed and printed the profile and mission cards. On day 8 they fabricated pawns and painted/prepared the board for the microcontrollers. On day 9 they focused on finalizing the prototype and playing the game.

3.2.4 Simulation team

The task of the simulation team (1 male student) was to develop a model to explore how demand patterns affect service rate of the vehicle sharing system. While system dynamics (SD) is often used for addressing such questions, its abstract top-down modeling approach through stocks, flows, and feedback loops, requires significant modeling experience. Furthermore, SD modeling requires solving the equilibrium condition of the system to be studied. The bottom-up Agent Based (AB) modeling approach is more suitable when the micro-behavior of the agents is known, and the macro-behavior of the system is asked. AB systems are more intuitive (and fun) tools for kids due to their immediate association to the real world (kids can literally observe agents moving and interacting). For these reasons we chose to work with NetLogo, a free agent-based software that is easy to learn and well documented. The simulation team started on day 3 by downloading and familiarizing with NetLogo using an example from the library that would serve as the basis upon which to build the model. On day 4 the team developed a simple conceptual model, simulating flow of vehicles between two groups of stations with decreasing and increasing inventories (see in figure 2, right, stations in blue and red circles respectively). On day 5 the team decided how many breeds of agents it would use (vehicles, stations, users), and thought of the conditions that would allow a vehicle to depart (e.g. both a waiting user and an available vehicle at an origin) or prevent it to arrive at a station. On days 6 and 7 the team worked on making agents (e.g. users and vehicles) move to targets using simple conditional statements. On day 8 the team defined the types of output graphs it would produce. Day 9 was spent on refining and completing the model for the open house.

3.3 Open house and final product

During an open house all teams demonstrated and explained their work in public. Visitors interacted with the prototype and asked questions to the students. The final product implemented most of the technology that contemporary vehicle sharing systems use. The game consisted of a white horizontal surface under which there were 3 ID12 RFID sensors mounted. Each sensor connected to an Arduino board (representing a MOD station). The three Arduinos connected to a network switch/hub through Ethernet shields and from there to an Ethernet socket on a wall. Once the Arduinos read an RFID tag they sent a message to a remote IP address.

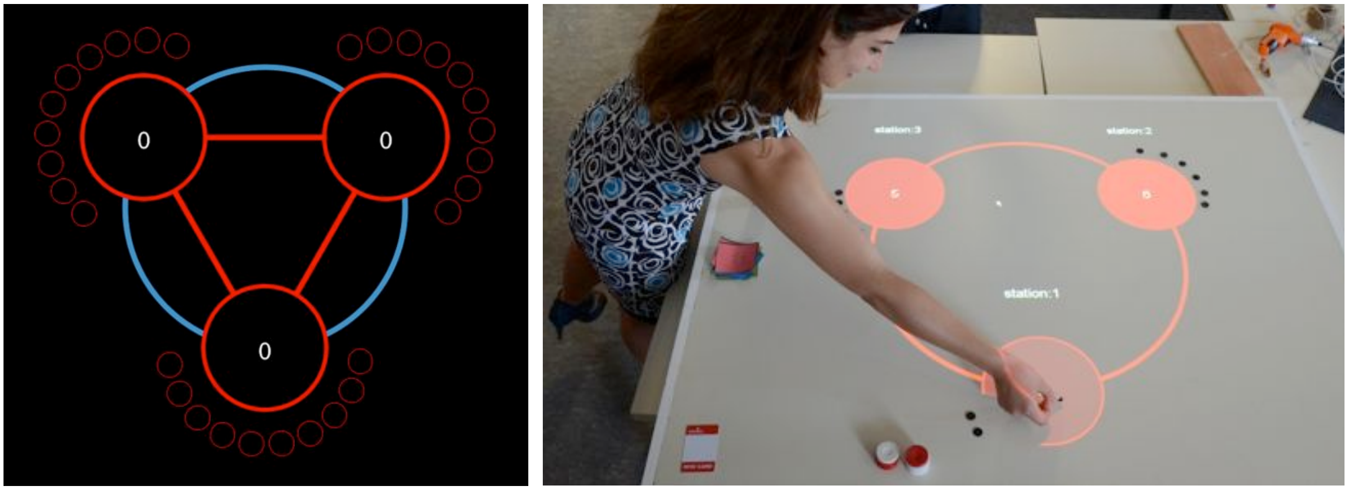

Figure 3. The design scheme of the visualization team (left); the end prototype during open house (right)

The message consisted of a timestamp, the ID number of the Arduino that sends the message, and the ID code of the RFID tag, and the type of event. A server computer, running a Processing application, received messages from the Arduino stations, determined whether they were pickup or dropoff events, and it appended these events to a text log file that recorded the history of the system. Furthermore, it updated a color-coded visualization that is then projected back to the surface to inform the players of the game about the payoffs of each origin-destination movement (figure 3, right). Students used plastic red and white chips to represent money and time units and wooden pawns to represent vehicles and commuters. Mission and user profile cards were printed and cut out of paper. Student presentations addressed the following questions: *What did I make? Why is it important? How does it work? How did I make it? What did I learn? How can I make the world better with what I learned?*

4. RESULTS & DISCUSSION

The work presented here illustrated that designing, making, and playing of technologically augmented strategic games may facilitate learning of complex systems thinking in mid- and high-school kids. The workshop is normally designed for graduate level students at the MIT Media Lab and it was the first time that was offered in secondary level education. Several observations are worth mentioning. First of all, students did not design a representation of an ecosystem; instead they created the ecosystem itself and its interaction with the human world. Even though there was not enough time to play the game, the perspective of showcasing a prototype and the awareness of dealing with big unresolved real world problems motivated students in their tasks *("I can use the information that I learned in order to create car and motorcycle sharing systems so that the world will have not only bike sharing systems but all of the other vehicles,"* student quote). Secondly, due to task interdependence none of the teams could work without the feedback of the others. For example, game design depended on the technology of the technical teams while their decisions depended in turn on the concept of the game design. Furthermore gameplay decisions had to be simple enough so that the simulation team could model them and so forth. Thirdly, students became designers, electronic technicians, visualizers, simulators, and most of all, negotiators, engaging in discussions of what works and what doesn't with the other team "experts" (*"When we work in pairs and we split the tasks of the workshop, the whole project can be done faster and more efficient,"* student quote). Finally, students managed to articulate not only how the system worked technically (*"A number of Arduinos equal to the stations the project has, is under a table…These Arduinos have been combined with RFID sensors and when you tap a RFID card there the information is sent to the computer and the system 'understands' the change,"* student quote), but also its underlying economic principles *("…the customer may choose different routes, depending on the amount of price and time,"* student quote). Future iterations of the workshop will include a sufficient timeframe for the students to play the game and analyze the results; an increase in scale of the prototype covering a building or even a school campus; finally, pricing controlled by the station microcontrollers.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Papanikolaou, D. 2011. *The Market Economy of Trips.* MSc. Thesis. Massachusetts Institute of Technology.

[2] Kafai, Y. B. and Resnick, M. 1996. *Constructionism in Practice: Designing, Thinking, and Learning in a Digital World.* Psychology Press.

[3] Salen, K. and Zimmerman, E. 2003. *Rules of Play: Game Design Fundamentals*. The MIT Press, MA.

[4] Resnick, M. Turtles, Termites, and Traffic Jams: Explorations in Massively Parallel Microworlds. (A Bradford Book, 1997).

[5] Dixit, A. K., Reiley D. H. Jr, and Skeath, S. 2009. *Games of Strategy*. Third Edition. W. W. Norton & Company.

[6] Forrester, J. W. 1992. System Dynamics and Learner-Centered-Learning in Kindergarten through 12th Grade Education. In *Introduction to System Dynamics Packet.* Creative Learning Exchange.