Towards a Cyberphysical Web Science: A Social Machines Perspective on Pokémon GO!

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ABSTRACT

The concept of Social Machines has become an established lens to describe the sociotechnical systems of Web Science, and has been applied to some archetypical cyberphysical systems. In this paper we apply this lens to a larger system, the location based online augmented reality game *Pokémon Go!*. The contributions are an illustrative application of the descriptive Social Machines lens to a system of this scale and type, and the use of simulation as a method for an executable description, which includes use of an ontology to represent partially the universe of the game.

CCS CONCEPTS

• **Information systems → Web applications**; *Collaborative and social computing systems and tools*; • **Human-centered computing → Collaborative and social computing theory, concepts and paradigms**; *Ubiquitous and mobile computing*;

KEYWORDS

Social Machines, Internet of Things, Cyberphysical systems, game design, Pokémon Go!

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1 INTRODUCTION

The Web Science community has studied the Web as a co-constituted 'digital world' through which humans interact. Mobile devices bring into play geographical location and movement, attaching the Web to our physical world. For example, health and fitness apps rely on movement and data gathered from health devices in order to facilitate behavioural interventions. With growing deployment of the Internet of Things we anticipate increasing numbers of connected 'smart' devices deployed around our person, home, transport and environment. Hence increasingly Web Science is becoming 'cyberphysical', with a deepening intertwining of the digital and physical worlds and the algorithms that connect them. How then shall we describe, analyse and design these systems in order to conduct Web Science?

The concept of Social Machines has become an established lens to describe the sociotechnical systems of Web Science, [8] and has already been applied to some archetypical cyberphysical systems [5]. In this paper we apply this lens to a larger system, the location based online augmented reality game *Pokémon Go!*. We see this as a poignant exemplar in our rehearsal for future systems, due to its scale, the evolving ecosystem in which it is situated, the application in massively multiplayer online gaming, the early use of augmented reality, and the rich commentary it has attracted.

The main contribution of this paper is the illustrative application of the Social Machines lens to a cyberphysical Web Science system, to inform future studies. In addition we report on a further method of description which uses a simulator, and we hope this will attract further work; this includes a preliminary Pokémon ontology.

Section 2 introduces the game of *Pokémon Go!* from the point of view of a single player. In Section 3 we extend the description to social effects, illustrating a social machine within the game. Our ecosystem approach in Section 4 shows *Pokémon Go!* in the context of interrelated social machines. We introduce a new descriptive approach through simulation in Section 5, and close with a discussion in section 6.

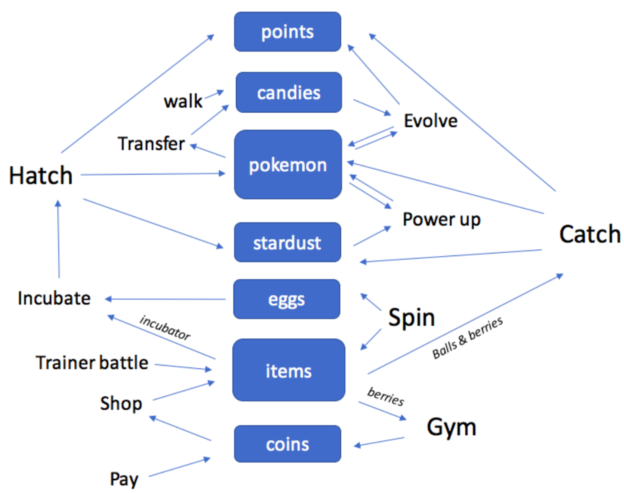

Figure 1: Diagrammatic representation of the game from the point of view of a single player and what they carry.

2 THE GAME OF *POKÉMON GO!*

Pokémon Go! is a location-based augmented reality game. Available for iOS and Android devices since 2016, the app enables the player to collect virtual creatures called Pokémon (from 'pocket monsters') by finding and capturing them as they are automatically spawned and appear virtually in real-world locations. The clear objective of the game is in its slogan: "gotta catch 'em all". To date there are around 460 different types of Pokémon which can be caught, of over 800 in the Pokémon franchise [1].

Players progress up levels (from 1–40), with successively harder goals and larger number of points needed between levels, and higher value Pokémon available to catch. Levelling up, catching Pokémon including rare and powerful types, and completing *badges*, are thus the gamification elements of the *Pokémon Go!* app.

The diagram in figure 1 provides a description of the game from the point of view of a single player whose character is carrying various game objects, and the actions that cause changes to the objects carried. Those playing the game will typically have a conceptual model equivalent to this, though they may choose to express it in different ways. Part of our methodology over several years has been to invite people to provide diagrams of social machines, and the particular diagrams in this paper come from the authors [2, 3].

Here we describe the game loop and structure, with social aspects discussed in Section 3, and then in Section 4 we consider the co-evolution of social machines in the broader ecosystem in which this is situated. This sequence of sections, with textual and diagrammatic descriptions, illustrates what we are describing methodologically as a social machines lens, as we zoom out from individual to crowd.

In game, players are known as *trainers* and carry Pokémon *storage* and a *backpack* of game items. Caught Pokémon are kept in the storage, and every time a new type is captured this is recorded in the player's *Pokédex*, a form of catalogue which enables the trainer to see the completeness of their collection. The backpack contains *Poké Balls*, *Incubators*, *Berries*, *Revives*, *Potions* and other game items. The player also carries a number of *Pokécoins*, *Stardust* and numbers of *Candies* associated with particular Pokémon types, and none of these variables occupies storage. Trainers accumulate experience points (XP), which dictate their level between 1 and 40. Other variables associated with individual trainers include distance walked and badges awarded.

In the spirit of "gotta catch 'em all", trainers walk around and encounter geolocated Pokémon which are spawned automatically for a period of time (minutes). The frequency of particular Pokémon spawning is influenced by geographical features, a link between the physical and digital. Trainers can catch a Pokémon by throwing Poké Balls at it repeatedly until the capture succeeds (effectively virtual dice are rolled each time). Different types of Poké Ball have different levels of effectiveness, and capture is made easier by feeding the Pokémon different types of *Berry*. Poké Balls and Berries are obtained when the trainer encounters and spins a PokéStop or Gym. Multiple players will see the same Pokémon in the same location and can all capture it, obtaining independent instances which are only associated by their provenance. Although creation of copies is a familiar affordance of the digital, this cloning is perhaps dissonant from the physical world that is overlaid; however, this cloning encourages cooperation, rather than competition, in social engagement between players.

Trainers can *evolve* Pokémon according to a scheme of evolutionary relationships which is defined in the *Pokémon Go!* universe. This uses up *Candies* for that Pokémon type and generates XP. They can also power them up by using *Stardust*, bringing the Pokémon up through levels as per the player. Collecting Pokémon and hatching eggs generate Candies, XP and Stardust, so the whole game is fuelled by the 'grind' of walking, catching and hatching. Evolving and powering up enables trainers to improve their collections.

Pokémon Go! can be seen as an 'exergame' with walking incentivised by the need to capture Pokémon and also to visit and spin PokéStops, which replenish game items in the backpack again randomly. Spinning may also provide an egg if the trainer has space: up to nine eggs can be carried in Pokémon storage, and can hatch Pokémon by placing them in up to nine *Incubators* and walking 2, 5, 7 or 10km. Additionally covering a distance with a 'buddy' Pokémon generates candies, and there are rewards for the player walking distances (e.g. 50km) in a week.

3 SOCIAL EFFECTS

The second major game incentive is to train Pokémon in Gyms. A Gym belongs to whichever of the three teams has captured it, and a player can choose a team to join on reaching Level 5. Multiple trainers can come together to capture a Gym, and a Gym belonging to one team might be attacked simultaneously by trainers from other teams. An incentive for battles is that the longer the Pokémon stay in the captured Gym, the more Pokécoins the trainer gets when the Pokémon leaves the Gym, up to a maximum of 50 coins per day. The other way to gain coins is by buying them with real-world money. Hence Gyms are where players come together, and illustrate how Pokémon has real-world social effects. Gyms may be attacked in an *ad hoc* manner by nearby solo players, or else players may

[1] https://en.wikipedia.org/wiki/List_of_Pokemon

form small groups of the same Pokémon team, and proactively take over a Gym or a series of Gyms.

Real-world social effects also occur when players gather to win a Gym *raid*, sometimes in large numbers. A raid is where a Pokémon spontaneously becomes the *Gym boss* for a limited time period; defeating the Gym boss gives each trainer involved in the *battle* a bonus opportunity to capture another instance of that type of Pokémon. Raids are beneficial for both combat and capture: they are the mechanism for capturing 'legendary' Pokémon, which do not appear through hatching or in the wild, and which can subsequently be used to attack (though not defend) Gyms.

There are other social features. Each trainer can have friends of various degrees of closeness, and can send them gifts (which contain randomly selected game items). They can also trade Pokémon when physically colocated, subject to various constraints, and hold 'person versus person' battles with friends and with other players encountered in real life.

How do we describe these social features and effects? This is where we call on the notion of *Social Machines*, a term introduced by Tim Berners-Lee in 1999 [1]. Today we see them as networks of people and devices at scale, their behaviour co-created by human participants and technological components. They harness the power of the crowd, with everyone able to contribute—to document situations, cooperate on tasks, exchange information, or to play. Through social machines, existing social processes may be scaled up, and new processes enabled, to solve problems, augment reality, create new sources of value, and disrupt existing practice. [8]

Raids are a classic social machine: they cause humans to come together to solve a problem. While the numbers involved in an individual raid may be 10s, *Pokémon Go!* operates at massive scale. There have been "Global Catch Challenges" where the global extent of activity (e.g. 3 billion Pokémon captured globally in 7 days) triggers predetermined rewards to players, such as increased points and stardust.

We have made use of a notation called a *sociogram*, which was developed as a successful workshopping tool, has also been used in teaching, and was developed further as a specification language [7]. A full sociogram schematic for *Pokémon Go!* would be extensive and complex, but we illustrate it in figure 2 which describes a Raid.

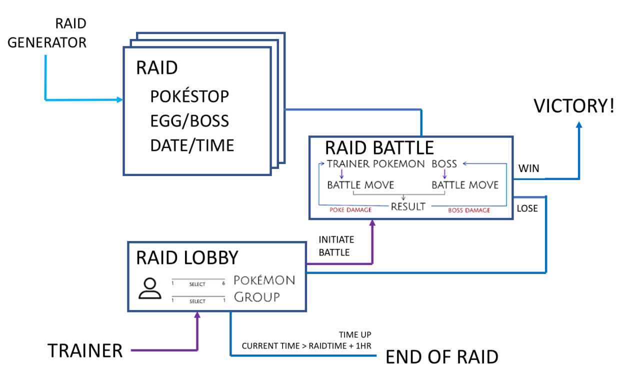

Figure 2: A Raid, described in a notation inspired by sociograms.

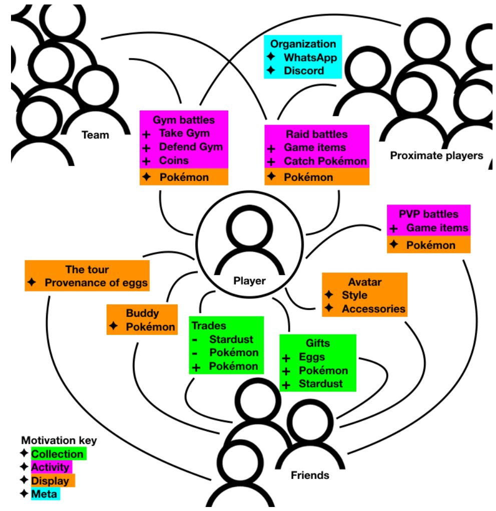

Figure 3: A description which includes other players.

4 THE POKÉMON GO! SOCIAL MACHINES ECOSYSTEM

The diagrams in figure 1 and 2 are from the perspective of a single player who is experiencing the game with increasing social features. Figure 3 focuses on the social, with teams, friends, and proximate players. Importantly, as indicated at the top of the diagram, *Pokémon Go!* does not operate in isolation of established social machines and in turn it has given rise to new ones. It is coupled by its human players into the social machines ecosystem, with players interacting with multiple social machines during play. For example, without in-game communication mechanisms between players, the use of other social platforms to support *Pokémon Go!* is an important aspect of the social characteristic of the game: very often the need for people to act simultaneously in Gym and raid battles requires coordination out of game through social media apps such as Facebook, the gamer network 'Discord', WhatsApp and Reddit channels.

Pokémon Go! is in fact based on an earlier social machine. *Ingress* is the forerunner of *Pokémon Go!* and feeds directly into it by providing the locations of PokéStops and Gyms. Also a location-based, augmented-reality exergame, *Ingress* was released by Niantic in 2012 for Android and 2014 for iOS. In *Ingress* there are two teams, as opposed to the three of *Pokémon Go!*, and they aim to capture geolocated portals and link them to control geographical regions. In the backstory, the earth has been seeded with 'exotic matter' (XM) by an alien race regarded by the 'Enlightened' faction as benevolent, while the 'Resistance' faction fight to protect humanity. Players gain XM by walking. Emergent social behaviours during gameplay include establishing neutral zones, as well as training and creating rules of engagement.

The portals of *Ingress* are located at landmarks which have historical or cultural significance. These include public and historical buildings, tourist and recreational spaces, and public art. These locations are crowdsourced, with millions of submissions received by Niantic, and the portals subsequently provided the locations of PokéStops. Hence the social machine of *Ingress* portals has fed directly into the social machine of *Pokémon Go!*

The *Silph Road*[2] is a research-focused grassroots network of *Pokémon Go!* players on Reddit, conducting research projects to help understand game mechanics and features, as well as providing community support for *Pokémon Go!* enthusiasts. With emergent rules for conducting the research projects, and proactive moderation to ensure constructive discussion in line with the objectives, the Silph Road can be seen as a social machine which in turn is constructed within the Reddit social machine.

As an example, some of the research projects have explored the distribution of apparently random outcomes to see what factors may actually influence them. The moveset (attacks) that a Pokémon has after evolution appears random, as if by dice roll. In a study of moveset factors the Silph Road community gathered data from over 10,000 evolutions and tested against 11 factors, with a null hypothesis that a Pokémon's moves are selected in a uniformly random fashion from the moves available. No evidence of correlation was found, and the distribution was found to be uniform.

IV calculators also result from reverse-engineering the programming of the game. Internally to an instance of a Pokémon are three variables known as the *Individual Values* (IVs), representing Attack, Defence, and Stamina with an integer between 0 and 15. The IVs determine how powerful a Pokémon will be when it is fully powered up, in addition to the species-specific *base stats*. The user interface keeps these variables hidden, but provides derived *Combat Power* and *Hit Points* values as well as the amount of stardust needed to power up the Pokémon. Additionally an *appraise* mechanism provides an automated textual appraisal of the Pokémon, which further constrains the possible IVs. This is sufficient information to be able to infer the IVs, or at the least sets of possible values. The result is that the equations used to derive the visible values have been reverse engineered by the community, and many online IV calculators have been provided.

Other social machines have come about to assist *Pokémon Go!* players. There are crowdsourced maps showing locations of PokéStops and Gyms, and multiple efforts to crowdsource the location of Pokémon. Established social machines have also modified their behaviour to couple with the *Pokémon Go!* social machine, for example Yelp included a feature to enable users to report the proximity of PokéStops to listed businesses [4].

5 THE SIMULATOR AND ONTOLOGY

In order to explore our understanding of the game, and investigate the prospect of simulation as part of social machine design methodology, we have built a simulator for a subset of the *Pokémon Go!* game structure and metagame. A secondary goal was to experiment in describing player behaviour in pseudocode—by asking players to write down the rules they are using in play, and implementing these in the simulator, we begin to establish a domain specific language to represent behaviour. The simulator enables us to explore the relationship between the 'micro' and the 'macro' effects. [6]

The simulation is built using NetLogo, which is an open source programmable modelling environment designed for modelling a complex system consisting of hundreds of independent "agents", as it develops over time. The programmer defines the micro-level behaviour of agents, using an extension of the Logo programming language, and runs the simulation in order to investigate the macro-level behaviours that emerge. Typical examples of NetLogo simulations are drawn from biology, medicine, physics, chemistry, mathematics, computer science, economics and social psychology.

[2]https://thesilphroad.com

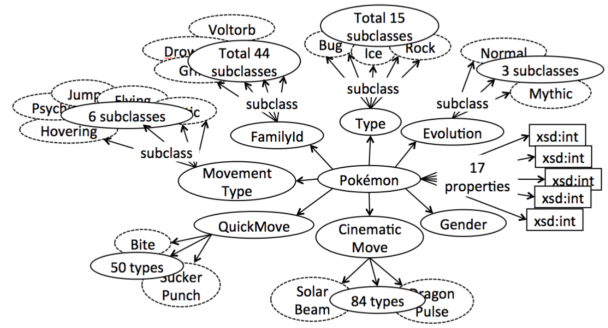

Figure 4: Visualization of the Pokéontology

The *Pokémon Go!* simulator has agents which represent the geolocated Pokémon, PokéStops and Gyms. These do not move, and the Pokémon are spawned only for a period of time. Other agents represent the trainers belonging to one of the three teams, and move around to visit the PokéStops and Gyms and to capture Pokémon. Simulation parameters include numbers of Pokémon, PokéStops, Gyms, players, and the maximum number of Pokémon a player can keep. A plot keeps track of the number of uncaptured and captured Pokémon, and the number of Poké Balls.

The simulator makes it possible to encode different player behaviours and see the consequences over time. In particular, making small changes to individual player behaviour may have consequences in terms of mobility and also interactions with other players. Apart from this ability to conduct 'what-if' experiments, the principal benefit of these exercises is in finding ways to describe the individual behaviours. For the initial simulator, we wrote pseudocode which attempts to describe the decision-making by one player in the field. As experience grows in this process, we are essentially creating a domain-specific language in which players can describe their behaviour. We suggest that this exercise could be replicated for other social machines, and tells us something about the primitives of human behaviour in the machine.

Coding the simulation also necessitated some clarity about the Pokémon ontology. The term 'Pokémon' is used ambiguously: it can refer to a specific instance, to a multitude, to a type, to a series of types. Pokémon can change type, while retaining some characteristics, on 'evolution' (which might better be thought of as metamorphosis, given that it occurs at speed and to an individual Pokémon).

The *Pokéontology* was designed to capture several different aspects of the Pokémon, both at a generic (overview) level of types and the separate stages of the biography of a specific individual. It was complicated by the lack of narrative continuity between different instances of the Pokémon universe across the franchise. For example, Pokémon can be traded in earlier games, whereas this feature was only recently introduced in *Pokémon Go!* in June 2018. The process of ontology development was complicated by the changes the Pokémon universe had undergone in different stages of the franchise's growth. Individual Pokémon level up, acquire new skills, and evolve or metamorphosize. The number of species has also dramatically increased from 151 in the first generation, resulting in more complex arrangements of phenotypes, morphologies and categories. Later generations introduced new species which are polymorphic, and can break the category boundaries of earlier species (such as the third generation Pokémon Wurmple, which can evolve into a Silcoon and then a Beautifly, or into a Cascoon and then a Dustox), so the ontology was designed to represent the entirety of the biodiversity of the Pokémon universe, rather than be built up sequentially representing the development of that universe.

As Pokémon evolve or metamorphosize from one subspecies to another, they improve in skill and increase in power. Representing this progression in an ontological structure necessitates the capture of diachronic change (occurring to one specific individual). These features were added to the ontological structure which also included characteristics such as details of the non-playable attributes of the phenotype (colour and size).

Underlying the ontological structure is the hypothesis that each instance of a Pokémon is an abstract concept prior to capture. Once captured, it becomes a unique specimen of a specific (sub)species (an instance of a type) and it is awarded a unique ID.

6 DISCUSSION AND FUTURE WORK

Our methodology for this work has been for the authors to describe social machines through different diagrams, text, and through pseudocode. We hope the examples here help convey the social machines 'lens'. A broader range of descriptive approaches, including a wider range of diagrams, can be found in the social machines literature [8].

Reflecting on the work, we see a clear resonance between social machines and games, and this suggests that practice in games design could be usefully applicable to social machines. Ethical issues in games design also translate to social machines, and hence to Web Science. For example, *Pokémon Go!* can be seen as an 'open ethical game' in which the players' values are used in developing a relation with the game world, and the game world accepts and encourages this player-driven ethical affordance [9].

One apparent difference might be the 'fantasy' backstory in games, but our social machines are not without associated narratives and universes too. Looking through the lens the other way, it seems entirely possible to view social machines as games. We have virtual persona on social platforms and it is not a great stretch to see Facebook and Twitter as about role-playing. Consider a comparison of Linked-In and *Pokémon Go!*–both involve collecting, competing, improving.

We have also found the notion of the *metagame* useful. In the ecosystem perspective on social machines, we do not so much design and deploy a machine as make an intervention in the ecosystem. The clear attention to metagame design as 'engaging with life', versus the in-game structure, is something we believe should be just as explicit in social machine design. Gamers frequently speak of 'the meta' and we feel there is still much understanding to be gained in 'the meta' of social machines.

Finally, the simulator has proved to be a useful tool, as much in programming it as in using it. We are not aware of previous work on agent-based models of social machines *per se*, and in we fact might be cautious about a methodology that risks being deterministic—more machine than social. However the simulator enabled us to capture behaviours, to test our understanding, and to try 'what-if' scenarios that could not be achieved 'in the wild'. There is further work to be done on describing player behaviour and the 'primitives' of the social machine. We recommend the use of simulation as part of social machines design in the future.

We expect Web Science to be increasingly situated in the physical world, thanks to smart devices and the broadening deployment of the Internet of Things. The fact that *Pokémon Go!* is location-based makes it an exemplar in this respect also. There is still much to be explored about situated social machines going forward, including the dimensions of ethics and responsible innovation, and the incorporation of the emerging techniques of artificial intelligence.

Our presentation of *Pokémon Go!* has been from a social machines perspective, presenting the game design, social effects and context in the social machines ecosystem. We hope that this serves to illustrate social machines thinking, and that this paper has set the scene for future work at the intersection of games and social machines, particularly with respect to design.

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