Towards a Gamified System to Influence Behaviour of Users in the Context of Smart Mobility

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Abstract. *One of the main concerns of modern transportation systems is the environmental impact of their operation. Such an impact is partially tied to the use customers make of the service. This paper proposes a conceptual framework to apply gamification techniques in the context of smart mobility, aiming to influence the behaviour of the users towards a more sustainable use of resources. The framework is exemplified by developing an example for a transport-sharing system. The requirements for an implementation as well as the implications thereof are analysed and discussed. Our work reflects the potential gamification has to enhance the sustainability of smart mobility solutions.*

Keywords. mobility, smart mobility, gamification, transportation, behaviour, sustainability

1 Introduction

Gamification is a broadly applicable concept of applying game design elements and mechanisms in non-game domains (Deterding et al., 2011; Huotari and Hamari, 2017), (Schell, 2019, p. 54). Some of these concepts may refer to point scoring, competition with others, rewards, and achievements, all with the ultimate goal of making the process more enjoyable. The mentioned concepts proved to bring more participation, motivation, productivity, as well as the desire for mastery (Hamari et al., 2014)(Goethe, 2019, p. 23). Furthermore, techniques of gamification can be utilised towards the goal of achieving the desired behavioural or psychological outcomes of the users (Matallaoui et al., 2017).

Some of the domains where gamification has been frequently used are education (e.g. (Kalogiannakis et al., 2021)), employee training (Iacono et al., 2020), customer engagement, etc. An application to learn a new language might be used as an example of using gamification in education (Huang and Soman, 2013). Gamification might be used in a way that, when users get to learn new words and phrases, they receive scoring points that help them level up, a good example of this is the language learning service Duolingo (Teske, 2017). The higher the level, the better they are (theoretically) in the language they learn. On a leaderboard, they can see how they stand compared to their friends.

In the domain of employee training, gamification could be used in different ways. An example could be that employees have a certain amount of literature to learn for compliance (Armstrong and Landers, 2018). After each section, they are asked questions to verify what they learned. Once they go through all the literature and quizzes, they are rewarded with a certification that acknowledges that they completed all necessary tasks for compliance.

Customer engagement is also a domain where gamification is being frequently applied. For example, after each purchase that exceeds a predefined amount, a customer might be getting loyalty scoring points (Harwood and Garry, 2015). Once the customer earns enough scoring points, they might exchange for different benefits, such as discounts, products, or similar.

There are many examples of gamification being used in the domain of medicine, with a rich collection of use cases specifically in the context of telemedicine (Schatten, Okreša Đurić, et al., 2021). Therein, gamification techniques are usually aimed at the elderly, although using gamification as a driver of engagement of the elderly telemedicine users is still a topic to be researched (de Vette et al., 2015).

Finally, gamification in the domain of transportation is a topic that has found some use cases where it is well known, yet there is room for further research and additional use cases to be developed (Okreša Đurić, 2022; Schatten, Okreša Đurić, et al., 2022), such as those presented in this paper. Although there are many contexts in the domain of transportation where some techniques of gamification are used already, most can be categorised as either referring to public transportation, or personal vehicles (Okreša Đurić, 2022).

One example beyond the two areas named above is related to installing and using personal physical-tracking devices (Greysen et al., 2021). Such applications motivate their users to choose healthier choices, promote physical activity of users, and motivate users to engage in other types of behaviour, such as social engagement or sustainable behaviour.

Ultimately, gamification in transportation is no stranger to sustainability and promoting users' behaviour towards behaving sustainably, or to motivate users to use sustainable mobility options (Zinke-Wehlmann and Friedrich, 2019).

Nowadays, there is a great concern for the environment, and transportation has a relevant impact on it, as it consumes a great amount of energy and, in some cases, generates direct carbon dioxide emissions. Current transportation research takes that into account by including in the optimisation functions a factor that aims to increase the service sustainability (Mihyeon Jeon and Amekudzi, 2005). The present research proposes integration of gamification techniques in a transportation service with the aim of influencing the behaviour of its users towards a more sustainable mobility. The popularisation of smartphone technology and the thrive of on-demand mobility applications provide the basis for the development of interactive and user-tailored mobility solutions. Taking advantage of this, our goal is to develop a framework to reproduce a transport system and implement concrete gamification techniques on it, and then test its effectiveness in terms of service sustainability.

The rest of the paper is structured as follows. Section 2 comments on relevant works and technologies within the topic at hand. Then, Sec. 3 describes the conceptual framework, tailoring it to a transportation application. Section 4 presents the issues that implementing the framework would involve. The implications of gamifying mobility are discussed in Sec. 5. Finally, Sec. 6 concludes the work and outlines future research.

2 Related Work

This section briefly presents previous work developed in the areas of transportation, multi-agent simulation and gamification. In addition, SimFleet is presented, a simulation tool we aim to integrate in our framework to test and evaluate gamification techniques over realistic smart mobility scenarios.

The basis of transportation is to provide displacement services to those who require it. From a general perspective, a transportation problem involves optimising the use of resources to complete the displacement in the best possible way, according to a specific optimisation function. These resources combine the vehicles that provide the service as well as all the infrastructure the vehicles employ, such as road networks or power stations. The optimisation of the transportation service usually combines two perspectives (Vansteenwegen et al., 2022). On the one hand, the transportation provider aims to reduce operation costs. Furthermore, the users wish for a fast and reliable transportation. In general, transportation solutions offer a compromise between both perspectives, ensuring the economic viability of the service as well as guaranteeing a minimum service quality.

Because of the complex nature of transportation, multi-agent simulation is adequate to reproduce mobility services in virtual environments (Horni et al., 2016). In this work we depart from and adapt SimFleet (Palanca, Terrasa, et al., 2019), an agent-based transportation simulator that focuses on providing an environment for running and testing complex coordination and negotiation services in the domain of people and goods mobility. Additionally, SimFleet provides wide applicability, which is a welcome feature for this research. Vehicle fleets, which among others could be courier companies or taxi services, require high-quality coordination, in order to preserve efficiency, on-time, and economically sustainable services. Oftentimes it is very challenging to achieve the perfect balance of all three previously listed characteristics, making different negotiation strategies very useful.

In this research, fleet refers to a larger number of vehicles that have a goal to deliver a service. The proposed simulation tool involves three types of actors: customer agent, transporter agent, and fleet-manager agent. The behaviour of each of these agents can be fully coded by the simulator user. Thanks to that, the simulator allows for the representation of many different mobility schemes with various degrees of freedom for each actor. Moreover, the predefined communication flow can also be altered by the user, giving place to a highly configurable simulator that fits the requirements of the present research.

Research described in (Okreša Đurić, 2022) investigates what domains of smart and sustainable mobility are adequate candidates for the application of gamification concepts. The explored domains therein are: eco-driving, driving safety, marketing, vehicle user interfaces training, increasing social awareness, and increasing trust in autonomous driving. Mastering vehicle user interfaces shall greatly increase overall driver safety, as it would indicate that a driver is familiar with all functionalities of the vehicle, hence they can use them in an appropriate manner when needed. The aspect of social awareness could use gamification elements in a way that the driver gets recognised and appreciated when being respectful towards other drivers. Similarly, gamification could help promote more economical and ecological transportation habits, by rewarding the driver for using more eco-friendly vehicles, or by not engaging in mobility during rush hours.

Research presented in (Schatten, Okreša Đurić, et al., 2022) explores how cognitive agents could help in the domain of smart mobility. The authors provide conceptual solutions on how cognitive agents may enhance public transport, vehicle sharing, parking experience, crossroads safety, electronic toll systems, and variable information panels. In public transport, a cognitive agent might help with purchasing tickets, providing information about possible routes, checking on the arrival time, etc. Parking experience might be extended with a cognitive agent which would navigate a driver to a free parking spot. Similarly, at crossroads, a cognitive agent could help people with sight disabilities to inform whether they shall pass the street or not.

3 Conceptual Framework

The foundational part of the system conceptually described in this paper is the system providing transportation services, such as transportation sharing, public transportation, or private transportation. SimFleet simulator is used here as a specific system building on the idea of, and allowing for the simulation of, a transportation sharing system. Other concepts which form the basis of this framework include the users, vehicles, the environment, and the crucial addition: gamification techniques.

The main contribution of the framework described in this paper, shown in Fig. 1, is introduction of gamification techniques into the context of public and private transportation, especially when transportation sharing is considered. Gamification techniques have been proven to be able to influence behaviour of its users in various domains, e.g. (Kalogiannakis et al., 2021; Martinho et al., 2020; Tomičić and Schatten, 2020). Gamification is presented here as a sort of an added value concept over a working transportation-concentrated system, providing the benefits of influencing the users' behaviour.

The constituent parts of the system can be abstracted as agents (people or simulated agents), shown as solid circles in Fig. 1, in the context comprising vehicles and the surrounding environment (shown as squares in Fig. 1). The agents can be represented as pertaining to the belief-desire-intentions (BDI) paradigm. Such agents contain certain beliefs about the world surrounding them (knowledge about the context and other agents), desires that they strive to achieve, i.e. goals, and intentions that describe how the agent is planning to fulfil the defined desires, based on their beliefs. This approach allows for greater autonomy and decision-making capabilities in artificial intelligence systems by allowing agents to reason about their actions and make decisions based on their current state and goals. BDI agents have been used successfully in various fields such as robotics (Palanca, Rincon, et al., 2023), game theory (Ambroszkiewicz and Komar, 1999), and various expert systems.

In essence, BDI agents rely on their beliefs to construct their understanding of their surroundings, i.e. of the context. These perceptions are constructed under the influence of agent's perceptors, but they may be shaped by the application of a gamified interface, i.e. application of various gamification techniques, leading to altered desires that subsequently shape the behaviour of the agent. This interplay highlights one of the benefits of incorporating gamification into intelligent systems - specifically, enabling effective task execution through adaptive desire modification. In other words, even though the context might not actually change, applied gamification techniques are expected to induce change in agents' knowledge (their belief), and subsequently modify their desires, or their intentions of reaching an already set desire, towards a more sustainable behaviour.

Gamification techniques or mechanics that are here seen as convenient, suitable, and applicable include, but are not limited to, the following, described in detail below: (a) quests, (b) scoring points, (c) scoreboard, (d) avatar customisation, (e) in-app currency, (f) roles.

Quests provide the agent with an option they can use and utilise towards fulfilling some of their desires. A single quest may consist of multiple tasks. As agents engage with quests, they receive immediate feedback on their performance, which enables the agent to update its internal representation of the status of the system, and adjust its future behaviours accordingly.

Scoring system is a gamification technique that can be understood from the agent's point of view as earning rewards for achieving certain objectives, tasks, or simply behaving in a specific way. Thereafter, the interacting individuals acquire new information regarding their abilities to perform specific actions, e.g. the value thereof, within the simulated system. This acquired knowledge updates the agent's beliefs about their own capabilities and preferences related to shared mobility practices, steering future choices and promoting the desired behaviours associated with sustainable, efficient, and ecologically sound transport options.

Scoreboards can contribute to modifying an individual's belief structure via competition and comparison mechanisms. Agents viewing their rankings relative to others' performances can stimulate cognitive dissonance and the need for self-validation, leading to changes in beliefs surrounding their abilities and values toward sustainability-oriented mobility habits.

Avatar customisation can potentially transform agent's beliefs about its roles in promoting sustainable or green mobility. Through the process of personalising virtual representations depicted on the app's digital landscape, individuals are provided the opportunity to experiment with different identities and personas, exploring alternative perspectives relating to their relationship with the wider community and natural environments.

In-app currency could provide primarily people with the means of achieving tangible or sensed real-

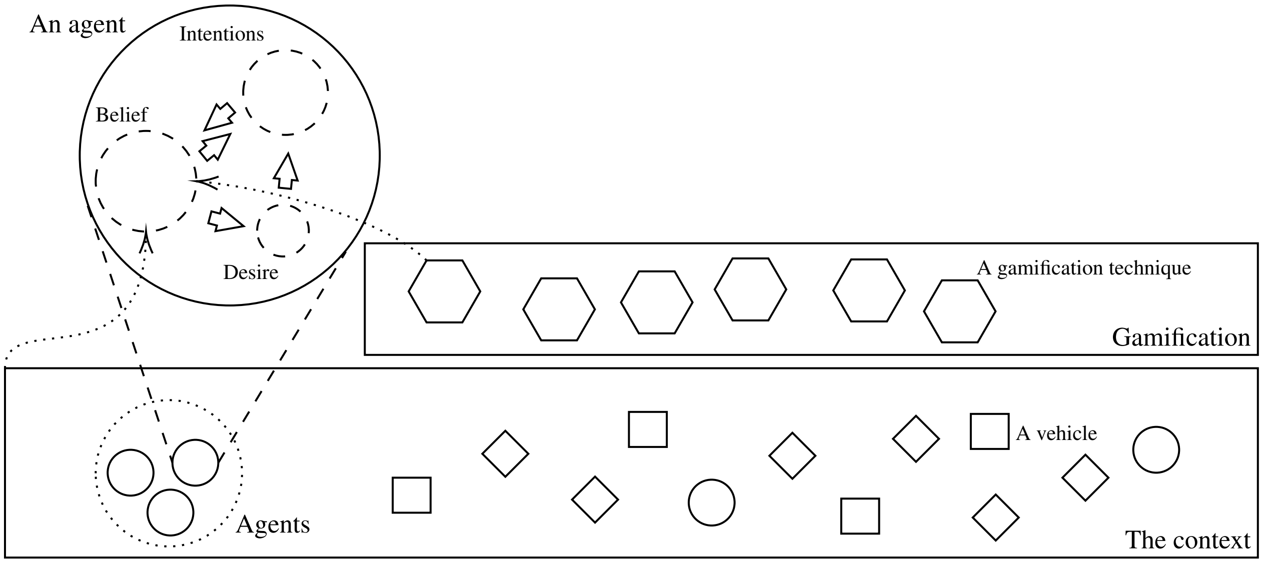

Figure 1: Visualised conceptual framework, showing the relationship of agents, the context, and gamification

life outcomes of their participation in the gamified system. Currency, in this aspect, can be considered as a specific case, or an outcome, of the scoring system. This mechanism is the most complex one to implement, as it would demand cooperation with real-life entities and organisations, which would recognise the currency and give it certain value, e.g. after accruing a certain number of points, the user is given a certain amount of currency, and can exchange a part of that currency at the local hair dresser's.

Roles can be used to further profile users based on their historical performance, i.e. on how they behaved in the past. Roles can be assigned automatically, or made available to the user, so they can activate, for example, at most one role at any given time. Some roles may grant users priority in choosing a vehicle to share, increase privacy in a shared vehicle by reducing the number of possible other travellers, or automatically choose pedestrian paths for them over e.g. cycling options. Roles may be though of as tightly integrated with avatar customisation.

The described framework is made to be general-purpose, wherefore the more detailed specific transport-sharing example is provided below.

3.1 Transport-Sharing Services

The aforementioned general-purpose framework is thought to be tailored to various transportation services. This, of course, requires the development of specific gamification techniques that fit the transportation mode. To exemplify a specification of the framework, a carsharing system has been chosen. Following, we describe the operation of such a system to later formulate the gamification proposals. Keep in mind that the term "car" may be substituted by variety of vehicles, for instance motorbikes or bicycles; the described operation can thus be applied to other types of transportation-sharing services.

In a carsharing service the transportation provider has a series of vehicles available for usage. Vehicles are located either in stations (bicycles) or parked anywhere inside a predefined area (motorbikes, cars). Users of the service are able to see the location of every available (not booked) vehicle and issue a booking to make use of one. The user is asked to leave the vehicle either in a station or correctly parked within a specified area. In general, the user pays either a monthly fee for the service or an amount per trip, computed from the total time and/or travelled distance.

The main costs of a carsharing operation come from vehicle relocation and energy consumption. Relocation is the displacement of a vehicle from its current station or location to a different one, aiming to improve the service by having the available vehicles well distributed. Energy consumption represents the cost of recharging/refueling the vehicles. These sources of costs are, in addition, closely related to the sustainability of the service, as the more relocations and energy consumption, the more impact does the service have on the environment. It is therefore in the best interest of both the transportation provider and society as a whole to influence the users of the service to make a better use of it.

3.2 Gamifying a Carsharing Service

Upon submitting desired trips through our application interface, sustainable alternatives are displayed that may prove to be slightly slower to complete, but incorporate increased pedestrian travel distances, reduced traffic exposure, and circumvention of urban centres. Various points are assigned to these environmentally conscious choices, with the aim of engaging and motivating users in adopting greener transportation methods. Additional, if any, walking requirements resulting from these decisions are calculated, subsequently offering corresponding bonuses.

The system offers users alternative stations or areas where they can pick up or park their vehicle, thus incentivising users to accept and accomplish quests entailing redistribution journeys between regions with varying concentration ratios. The alternative location may incur a longer trip and or more walking distance to the user. They shall be rewarded accordingly.

We create a competitive atmosphere by providing unique customisation attributes based on accumulated scores; targeted challenges throughout holidays or other significant events can galvanize responsible conduct and inspire community interactions. By addressing several aspects of ride-sharing behaviour, we aspire to develop a more sustainable urban framework.

Scoreboards and customisation opportunities create a sense of community among the users and a bit of healthy competition. Therefore, a positive competitive atmosphere is created by providing unique customisation attributes based on accumulated scores; targeted challenges throughout holidays or other significant events can galvanize responsible behaviour and inspire community interactions. Score-based systems is expected to be an outcome of a list of challenges that should be obeyed if full points are expected. Finally, points may be exchanged for rewards, e.g. simple customisation options. By introducing challenges that promote certain kinds of behaviour, it might be possible to motivate users to adopt a more sustainable usage during specific time periods (e.g. holiday season).

4 On Implementing the Described Model

This section provides the authors' view on the data that would support the framework described in Sec. 3, and the simulation that would illustrate the framework's working.

4.1 Data Gathering

The gamification techniques described in Sec. 3 require various types of data as input to compute quests and tailor them to the user's usage of the transportation service. Moreover, additional user data may be shared both with the application and other users of the service, to access the customisation and scoreboard features.

The obvious prerequisites to a successful application of the described framework is a working transport-sharing system that features, at least, a demand prediction system, and a user behaviour learning system. Both of these require specific sets of data, yet both of these systems can provide output data that can be used as input for the various gamification mechanics, such as quests.

A demand prediction system is a crucial element in forecasting future areas of high demand and in motivating users to make trips that reduce energy consumption and empty vehicle movement (e.g. relocations). Based on the results of such a system, specific areas can be identified as more or less relevant, thus making them interesting in the context of devising quests, and pointing other gamification techniques towards them. On the other hand, a user behaviour learning system is identified as a fundamental input for creating user-tailored quests or rewards, based on the learnt trends of each user, their behaviour, and their interaction with the system.

4.2 Simulation

The described framework allows for the setup and execution of simulations that evaluate the effect of the proposed gamification techniques. To characterise the many actors of the transportation system, agent-based modelling (ABM) is employed. ABM allows for the definition of each actor as a rational entity. Specifically, we make use of BDI agents, designed to model human-like reasoning and decision-making processes.

The BDI agents are deployed in SimFleet. The key feature of the simulator is that it offers a flexible implementation of agent strategic behaviour. Each type of agent executes its own strategic behaviour, in which different types of users could be defined, studying the behaviour evolution according to their susceptibility to the gamification techniques. In addition, the simulations can be configured to collect all necessary data for us to evaluate and adjust the system.

As for the implementation of strategic behaviours, finite state machines (FSM) are chosen. An FSM defines a behaviour split in states. According to each specific state, the agent will be awaiting different inputs and may act in various manners. In general, an agent will begin its execution in an initial setup state and transition to a new one whenever a specific input is received. The agent's FSM may be cyclic, executing the same behaviour periodically; or one-shot, being executed until a goal is achieved. Finally, it is worth mentioning that SimFleet agents are able to execute, in parallel, more than one behaviour, thus allowing the programmer to split the processing of distinct types of input in distinct behaviours.

5 Discussion

The authors find it necessary to argue here in the direction of security and privacy, but also some other topics, such as ethics.

5.1 Gamification and User Trust

The first point of discussion is derived from the title of the paper, and is focused on influencing people and their behaviour, and the morals of such an approach. Although the science of influencing behaviour is not new, and this research is not the first to delve into the topic of influencing behaviour of people using a specific technique, it is beneficial to argue here that users should be made aware of the goals of using the system conceptually described in this paper, and that the ultimate purpose of it is to motivate a more sustainable and ecological transportation behaviour.

Building on the latter point, the system must be built, and communicated to users, in such a way that would ensure transparency and build awareness about the collected data and the possibility to deny the collection. Denying access to data would pose a substantial risk of reducing the initially promised set of features. Benefits of using the system, and allowing access to the necessary data, should therefore be communicated in a clear and user-friendly fashion. Building trust of users might be enhanced by open-sourcing the implementation.

The third point that is discussed here is related to the growing concern about explainability in the context of artificial intelligence and related models. Lack of explainability can lead to mistrust, lack of accountability, and difficulties in debugging misbehaving systems. It raises ethical concerns over transparency, fairness, and the impact of automated decision making on society. Ultimately, addressing this challenge requires concerted effort towards developing techniques and metrics to assess AI interpretability, ensuring alignment with human values and societal expectations, and fostering collaboration across disciplines to achieve explainable AI.

In order to give the users a piece of mind, and build trust, the feature of activating and deactivating specific features such as individual gamification techniques or user-tailored techniques, should be considered. Some users might be fine with participating in a scoring system, and being awarded points based on their performance, but they might not be willing to share their success with the general public. Therefore, giving them the option to deactivate specific gamification techniques, such as leaderboards in this particular example, might provide those users with a more fulfilling experience of using the provided system.

5.2 Social Awareness Potential

In addition to already described features of the selected gamification mechanisms, quest mechanics often introduce elements of social interaction and cooperation, further motivating agents to adopt more sustainable travel patterns (e.g. transportation-sharing services) and positively impacting their overall attitudes towards mobility. Implementing scoring points as part of a BDI agent design may prove advantageous in fostering the adoption of sustainable mobility habits among both individual users and society as a whole.

Presenting score as a scoreboard, with the results visible not only privately, additional effect are achieved. As participants strive to improve their standings, they may recognise the benefits of adopting efficient and low-carbon transport modes, gradually revising their belief structures and translating such modifications into actionable intentions to promote environmental friendliness across daily life activities involving mobility.

Avatar customisation is geared more towards people than software agents. The introspective journey provided by the possibility of customising their appearance towards others provides users with the ability to present themselves to other users in the desired fashion. Furthermore, it might instil a sense of environmental responsibility within individuals, ultimately contributing to revised belief frameworks around shared transportation practices and encouraging the adoption of pro-social attitudes favouring collective progress toward sustainability objectives.

5.3 Gamifying Transportation

With regards to the specific application field, the introduction of dynamic features to a transportation service must be carefully studied to avoid the distrust of its users. Traditional mobility services are generally expectable, basing their operation in restricted timetables. The more dynamic a mobility system is, the more it can be tailored to its users; however, dynamicity also incurs more demands towards the user, such as the explicit introduction of the desired trip, or the definition of desired travelling times, for instance. A balancing of dynamic and predictable features must be achieved in order to give the impression of a reliable yet adaptable service.

Finally, the introduction of gamification techniques, as commented throughout the paper, does not modify the reality but influences the user's perception and behaviour. The introduced mechanisms must take this into account to avoid negative user perceptions. On the one hand, the user should feel motivated but never forced to follow quests; similarly, they should have positive feelings towards their own score, but the fact of having a lower score with respect to other users should not bring up negative feelings on the user. Gamification is meant to complement but not dominate the mobility service, and it never should affect its quality. Too aggressive gamification features may end up frustrating the users and deteriorating the image they have of the transport service. This, in turn, would have a great negative impact on the service's economic sustainability.

6 Conclusion & Future Reasearch

The conceptual framework for a gamified system in the context of smart mobility is provided in this paper. The main goal of such a system is to influence behaviour of users towards a more sustainable and energy-efficient behaviour.

The framework described in Sec. 3 is exemplified in the subsequent sections, thus being shown in a more understanding manner on a specific case of transportation-sharing services, i.e. as an abstraction applicable to a gamified carsharing service. This example is intended to show the reader how the framework, which is designed with abstraction in mind, can be used in the context of smart sustainable mobility.

The framework is expected to be researched and developed in more detail in the future, as well as expanded and described using richer and more detailed examples that could be used for providing further arguments for and against the framework presented herein.

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