User Modelling Languages for AmI: A Case Study on Road Traffic

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Abstract. Traffic is an important phenomenon in modern societies. Its complexity and the difficulties to control the actual settings where it happens have made of simulation a key tool for its study. This approach requires suitable models to capture all its relevant aspects and their mutual influences. Among these aspects, people are the key one. However, there is a limited understanding of people attitudes and behaviours and their effect on traffic. Thus, simulation has here an important component of exploration of hypotheses. Our research contributes to this line of work with a set of general and extensible agent-based models about people in traffic. These models integrate existing research from Social Sciences and simulation. The agent paradigm supports the explicit specification of processes of information management, decision-making, action execution, and interaction both with people and the environment. Such approach facilitates model reuse, and linkage between different elements relevant for the studies. The paper illustrates the application of these models with a case study that shows how to integrate in them a well-known model for drivers attitudes.

1 INTRODUCTION

Life in modern societies is highly mediated by traffic. Every day, millions of persons move on foot and by private vehicles or public transport. These flows are organized according to certain social rules, but also depend on individual attitudes and behaviours, unexpected events happening in the environment, and their mutual influences. Given the difficulties to carry out these studies with real settings, models have emerged as a key tool to study traffic.

There are several approaches to model traffic [16]. Analytical models rely on a strong abstraction of the individual components described mainly with mathematical formulas [8]. They are useful to consider phenomena with large populations, but have limitations regarding the specification of procedural and non-linear behaviors, and heterogeneous populations. As an alternative, simulation facilitates the specification of these kinds of behavior and population, but it is not usually intuitive the correspondence between the actual system and its computational representation. Agent-Based Modelling (ABM) [8] addresses this problem using agents as its core modelling primitive. Agents are intentional abstractions conceptualized in terms of elements such as knowledge, goals or capabilities. They are able to interact with other agents and their environment. These features facilitate describing people behaviour with agents. However, making realistic models still demands a high effort to integrate different theories and give the needed information.

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The work presented in this paper pursues reducing this effort by providing base models for people acting in traffic phenomena. These models are part of a wider effort to build a general framework for traffic simulation based on ABM, so they are designed looking for reusability with different theories and contexts. For this purpose, the basis of the models is a classification of people with three dimensions: their role in traffic, traits, and current state.

People role in traffic depends on their mean of transport and their relation with it People are classified in drivers, passengers of vehicles and pedestrians. All of them can be modelled at the individual level or as groups moving together.

People traits represent features of people that are permanent for the travels considered in the simulation. They include physical attributes of the body, such as age, gender or disabilities. There are also attitudes to capture personality and mental features. For instance, people can be more or less aggressive and have personal problems that increase their stress. Moreover, people get more traffic experience over time. This empowers them with additional knowledge and skills to face traffic situations through their learning.

The current state captures dynamic features that depend on the specific context and moment. For instance, they indicate if drivers attention is low because there are distracting passengers, or if traffic conditions bother the driver.

The suitability of these models is illustrated with a case study that specifies existent work on traffic simulation using the proposed primitives. It considers the simulation in [13] about drivers attitudes and their influence on group behaviour.

The rest of the paper is organized as follows. Section 2 introduces the agent modelling language used in our approach. Section 3 presents the models for people in traffic with that language, and grounds them in available research about traffic. Section 4 compares these models with those in [13] regarding the phenomenon called dominance at junctions. These results are further compared with related work in Section 5. Finally, Section 6 discusses some conclusions and future work.

2 AGENT-BASED MODELLING LANGUAGE

This work specifies their models using the modelling language of the INGENIAS methodology [14]. The key concept of INGENIAS is the agent.

An agent is an intentional entity that follows its own agenda characterized by goals. In order to achieve these goals, the agent is able to carry out certain tasks. An agent can trigger a task when it pursues an unsatisfied goal that the task is potentially able to fulfil, and all the elements required by the task are available. These elements are usually pieces of information known by the agent or events coming from the environment. As the result of the execution of the task, the agent acts on the environment and produces or modifies information.

Agents act on and perceive the environment through external applications. These are the sources of the events and tasks use their methods to affect the environment.

A final element relevant for the models presented in this paper is the AInherits relationships. This is an inheritance relationship that allows defining a type of agent as an extension or constraint of another type of agent. Thus, it highlights the common features of different types of agent and saves modelling effort.

3 TAXONOMY OF PEOPLE IN TRAFFIC

Traffic is the organized way of moving people using different means of transport. This people have as their main goal to arrive fast and safely to their destinations [7, 9]. They can achieve this goal through alternative sequences of actions as long as they meet some constraints. First, people use different means of transport, and can control them or be a passenger. This makes suitable only some routes and implies certain rules. Our work only considers those means sharing spaces in our cities and roads, e.g. on foot or by car. Second, the sequence also depends on the physical and mental characteristics of people and their current state. However, models cannot consider all the known people features and processes. This would be unsuitable regarding efficiency and abstraction, and even incorrect given our limited understanding of the phenomena. The taxonomy presented proposes a number of features based on literature, mainly coming from Social Sciences, widely accepted as relevant for traffic studies. Next subsections present in details all these aspects.

3.1 ROLE AND MEAN OF TRANSPORT

The behaviour of a person in traffic is first limited by his/her mean of transport. Although passengers influence traffic, e.g. distracting drivers, these models focus on people controlling their mean of transport.

The mean of transport requires certain processes to manage it, and also makes possible some processes. For instance, a person can know how to brake a car, but needs driving one to perform the action. At the same time, different means of transport obey different rules. These can be both explicit, e.g. traffic regulations, and implicit, e.g. drivers facilitating other drivers maneuvers.

The models represent this information with a hierarchy of agents (see Figure 1). The basic agent is person, which incorporates the goal of arriving to a destination following a certain route and perception of obstacles and signals. According to the mean of transport, a person is extended as a driver or a pedestrian. These agents have additional goals, information and tasks to move by car or on foot respectively. In the case of the driver, there is a related vehicle. The vehicle is represented as an external application with, for instance, methods to brake or to manage the steering wheel and events from the speed indicator.

3.2 TRAITS OF PEOPLE INVOLVED IN TRAFFIC

The way of behaving in traffic also depends on the personal traits of each person. A well-known example is the differences in accidents regarding age and gender [12]. These traits are static for each person, as they do not change during the travel, and thus in the simulation. There are three groups of traits: physical attributes, attitudes and traffic experience.

The group of physical attributes currently comprehends gender and age. The gender attribute classifies people into male or female. The age attribute uses four levels, young, adult-young, mature and elder. The age levels are different for drivers and pedestrians, as people can walk before they can drive and the required capabilities for both activities are different. These attributes mainly affect perception and reaction parameters, such as sight distance and time to maneuver.

Other group of traits is the attitudes. Models consider in it a traffic profile and relationship problems. The traffic profile is based on an extension of the selfish principle in [13], classifying drivers as aggressive, normal or moderate, and pedestrians as reckless, normal or prudent. This classification differentiates, for instance, between drivers who always drive below or at speed limits, or on the contrary usually break them. The relationship problems acknowledge this as a classical source of anxiety and distractions in traffic situations, making more likely suffering an accident or taking greater risks [18].

The last group of traits is the traffic experience. It classifies individuals regarding their traffic learning with values between 0 and 5, being 5 the maximum experience.

3.3 CURRENT STATE OF A PERSON

The traffic and personal conditions change during travels, and this affects people behaviour. For instance, drivers caught in a traffic jam can start relaxed, but their frustration and impatience will rise as they waste more time stuck, which can cause risky situations in their nearby environment. The models consider these dynamic features of behaviour with the attributes belonging to the current state of the person agent. Figure 2 shows these attributes classified in physical state and mood, depending on when they affect physical action and perception or thinking and attitudes respectively.

The physical state influences the perception of the environment. Individuals do not receive objective information from the environment, as this is really mediated by their own senses and depends on external conditions [15]. The personal conditions are represented with the values for this attribute, which are focused, drowsy, distracted and drugged. The influence of the external conditions is represented using the environment entity.

The environment entity has attributes for the weather conditions and type of environment [18]. The first one takes values between sunny, cloudy, rainy, heavy rain, windy, snowy, ice and foggy, while the second one is classified as familiar, unknown, difficult, affordable and straightforward. These attributes are linked to the physical state, pointing out that they affect its value.

The mood considers that external factors influence people mental state [7]. This state affects aspects such as decision making or level of attention to the environment. The specification of this attribute is further decomposed into the attributes impatience and self-confidence. The impatience represents the frustration of the person, perhaps because she/he is in a hurry or the traffic conditions are adverse. The self-confidence represents the assurance of individuals on their own knowledge, capabilities and skills. Both attributes take values between 0 and 5. Depending on the value, they can have a positive or negative effect on the person processes. For instance, a person with self-confidence 5 can make risky decisions that are inadequate for the perceived situation. In the case of pedestrians, the self-confidence also indicates how crowds influence individual trajectories [9].

As it happened with the physical state, the value of the self-confidence is affected by other attributes. A familiar type of environment and good weather conditions increase the self-confidence. Moreover, people frequently move in groups, and this companion al-

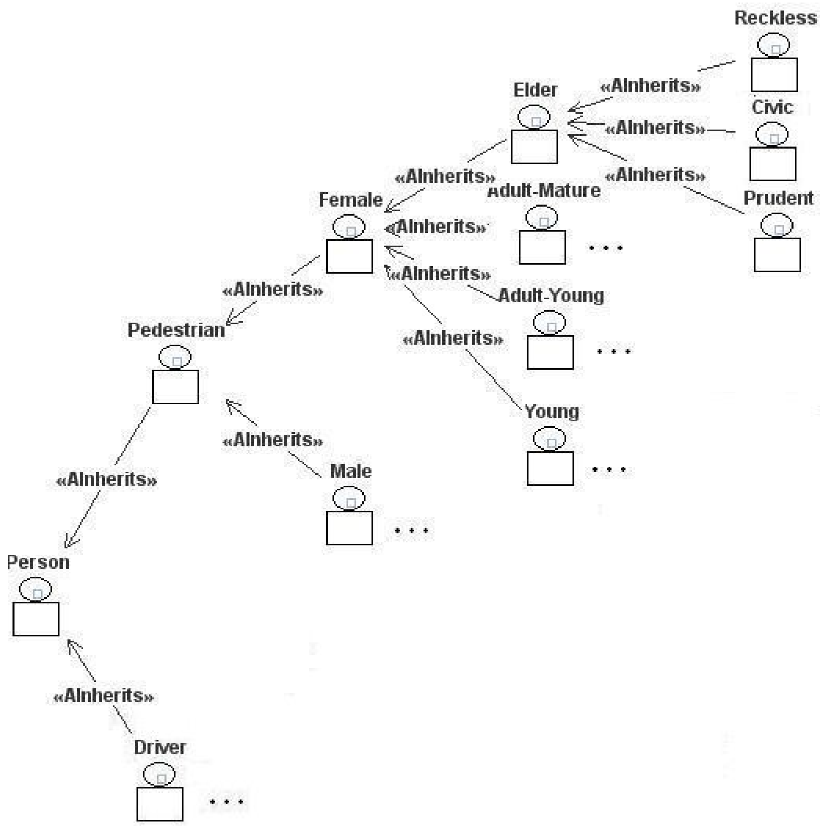

Figure 1. Inheritance of driver and pedestrian agents.

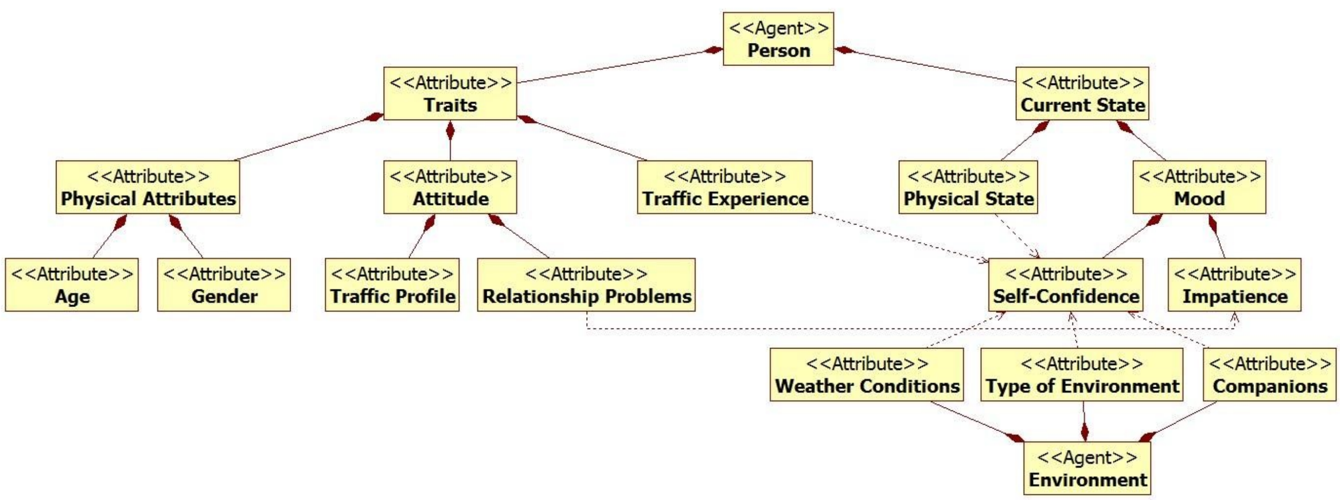

Figure 2. Relationships between the elements of the taxonomy. Dotted lines represent that an attribute affects the calculation of other.

ters the self-confidence with comments or actions. The companions attribute gathers this information. It considers the attitude of the companions with values in silence, little chatty, chatty and fun-loving, and the number of individuals.

Note that this presentation has pointed out several mutual relationships between attributes. For instance, a bad physical state worsens the perception of the road, reducing the self-confidence. In the models, tasks managing the internal state of agents implement these mutual influences.

4 CASE STUDY

The attribute traffic profile presented in this paper is based on the classification of drivers in [13]. This classification uses the selfish principle, which assumes that any driver has a certain level of selfishness when pursuing his or her goals. This level classifies drivers in moderate, normal and aggressive, determining their speed or proneness to make risky decisions. The main limitation of that work is that two drivers of the same group do not differ in their behaviour, which is not a realistic approach. This case study considers how the models proposed in our work cover the previous classification and facilitate its extension.

As previously mentioned, the traffic profile trivially supports the classification in [13]. Its effect over driving depends on the implementation of the tasks of the different agents. Note that since this is an attribute of the person agent, which is the base type of all our agents, all the agents in our models include that attribute.

The heterogeneity of behaviour for agents with the same traffic profile is achieved with several attributes. The impatience is particularly relevant in this context, as it captures the anxiety produced by the current traffic situation.

The original work in [13] also discusses the phenomenon appearing at junctions known as dominance. It happens when a driver or a group of them who are in a lane of a junction push their way, followed by other cars, and get to block the other lanes. This lane of cars will be the only one able to move forward as long as they do not free the junction. If drivers of two or more lanes of a junction exhibit this behaviour at the same time, they can produce a deadlock where nobody will go forward.

With the presented models, this kind of behavior can be the consequence of the traffic profile and certain attributes present in the current state of the person. An aggressive driver is more dominant at a junction than a moderate or normal one, and therefore the former tries to cross the junction with greater determination. When drivers have the same traffic profile, their current state is also crucial for the dominance. The attributes of current state more directly involved in this behavior are impatience and self-confidence. A high impatience makes the driver prone to make quick decisions, not always enough meditated. With a high self-confidence, the driver dares to perform maneuvers that in other circumstance she/he would not carry out. On the contrary, a low self-confidence leads the driver to doubt about maneuvers in complex settings (e.g. many cars around), causing that other more determined drivers cross before her/him. Furthermore, drivers that are more impatient push others, which increase the frustration of the later. This causes a widespread anxious mood in the junction [11], which makes it more hazardous.

The update of the impatience level requires that agents know their position and that of their neighbors. The own position can be included as a new attribute position of the driver agent. The positions of the other drivers are known through interactions of the driver with an external application that mediates its perception. Direct communication between driver agents is not suitable, as drivers are in their own vehicles. The perceived agents could depend on new physical attributes related to sight.

This approach enables that the effects of the driver attitude in the simulation can dynamically change. Such effects are modulated by attributes of the current state, which are influenced by traffic conditions, e.g. surrounding vehicles, speed or time waiting. Therefore, studies using these models provide behavior that is more realistic.

5 RELATED WORK

The current research must be framed within two main lines of work: studies on people and their behaviour regarding traffic, and traffic simulations. Both of them are sources of information to develop our models and validate them.

Studies on actual people provide information on the relevant attributes regarding traffic and the actual processes involved in it. These studies typically focus on obtaining data, statistics and relationships among some factors under scrutiny. For instance, they try to identify aggressive behaviour and the reasons of their appearance [17]. Some commonly considered attributes in these studies are gender and age, as in [4, 12], presence of passengers in a vehicle, the weekday and the most troubled hours [4], the driving experience of drivers [10], the physical state [18], and the mood [10]. There are also behavioral studies more focused on the driving processes. These studies monitor, for instance, physiological signals, gestures or speech to identify and/or predict decision-making, low-level maneuvers or drivers mood [19]. These studies propose attributes and processes that could be considered for simulation, but have some limitations for this purpose. They are difficult to use to validate simulation models or check the influence of new elements, as this would imply researchers to carry out new studies.

The previous knowledge has been used in a variety of simulations with different goals. Regarding the level of abstraction at which traffic phenomena are considered, these simulations can be classified in: macroscopic, mesoscopic and microscopic simulations. The first ones attempt to capture the general principles governing the system instead of individuals, in a way similarly to analytical models. They are typically used to represent large areas of terrain with large quantities of vehicles and traffic infrastructure conflicts [3, 16]. On the contrary, microscopic simulations present individual elements with higher complexity. Most of ABM in traffic belongs to this category [5]. The related computational costs make them suitable only to represent small areas of terrain with few individuals. Moreover, it is difficult to embed general rules of behaviour in them, as rules usually appear on each agent. Mesoscopic simulations are hybrid between the previous types. They try to solve their limitations locating each information or behavior at the most suitable level, either individuals or groups [2]. Our work belongs to this category. As it is based on INGENIAS [14], it supports modelling both individual agents and groups (not shown in this paper), as well as inheritance hierarchies involving those abstractions.

As a distinctive feature of our research, it works with simulations at the level of models. As shown in [6], this facilitates the automated generation of simulations for different target platforms from the specifications using model-driven techniques. Other works have this information embedded in their programming tools [1], reducing the possibilities of studying and reusing that knowledge.

6 CONCLUSION

This work has presented the models of a taxonomy of people regarding their participation in traffic phenomena. These models are intended to provide the basis for an extensible specification able to integrate available research and applicable to develop simulations.

The taxonomy is organized around three main dimensions: the mean of transport used by people, their traits and current state. The mean of transport currently only distinguishes between pedestrians and people travelling using some motor vehicle, and among the later between drivers and passengers. Traits provide information about static features of people, both physical (e.g. gender and age), attitudinal (i.e. traffic profile) and based on experience (i.e. traffic experience). The current state considers several dynamic attributes that depend on the current environment and traffic state, such as self-confidence and impatience. Among all these attributes, the discussions have been focused on the traffic profile, which distinguishes moderate, normal and aggressive people, and self-confidence and impatience as dynamic modifiers of that profile. The relationships between these attributes illustrate how people behavior can be linked to specific situations and combinations of attributes.

The case study has shown how to use the proposed models to specify the simulation in [13]. The drivers attitude from [13] is the traffic profile of our models, but our modes additionally fix some of the limitations pointed out in that work. In particular, they offer a simple way to introduce heterogeneity in the behavior of drivers in each attitudinal group using the current state. At the same time, the specifications in the case study were able to replicate other phenomena appearing in [13] such as dominance.

Working at the level of models facilitates comparing approaches and reusing information between different studies. It also reduces the costs of migration between different simulation platforms, as the relevant information is available at a higher level of abstraction than that of code. Moreover, it promotes the design of domain specific modeling languages for different needs in traffic studies.

The current models are part of an ongoing effort to build a general simulation platform for traffic. The current prototype integrates the previous information in multi-agent systems based on the A-Globe platform and using geographical information from Google . The development process is evolving to a fully model-driven approach in order to explore the actual benefits of these approaches for simulation. Regarding the models, those presented here still does not consider several relevant aspects of traffic. Some of those to be included are vehicles, companion agents or public transport. There is also need to consider extensions of the modelling language to facilitate the specification of, for instance, relationships between attributes and the influence of these on the execution of certain actions.

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