



Interaction Design of Autonomous Vehicle Based on Human Mobility

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Abstract. Autonomous vehicle extends human mobility time and space dimensions under the background of intelligent transportation system big data and artificial intelligence, and drives the three flows which include logistic, financial flow and information flow to expand the new human mobility interaction paradigm. Mobility includes not only space and physics movement, but also information and time transformation, Navigation Design and wayfinding changes. Under the new social network and knowledge map human movements based on three flows (materials flow/logistic, information flow, financial flow) take place in the three time (past, present, future) and spaces (cyberspace, infosphere, noosphere). Consequently, the interaction model of human and autonomous vehicle based on human mobility has changed. In the model, the person is not only an individual, but also includes people in the sharing mode among the offline and online social networks which support the users identity duality in cyberspace, as well as the third life virtual agent or avatar driven by artificial intelligence in intelligent transportation systems. Human-Mobility Interaction (HMI) model supports the vehicles to complete the independent material flow driven by the information flow. The information structure and paradigm in the HMI transforms with the intelligent information in the digital environment and artificial intelligence algorithm in cyberspace. The information architecture has more interactive features of feedforward and feedback self-driving information. User Generated Contents (UGC), Professional Generated Contents (PGC) in autonomous vehicles, and Occupational-ly-generated Contents (OGC) under Intelligent Transportation System increase dramatically in Human-Mobility Interaction which correspondingly change interaction design, interface design, media and visual design.

Keywords: Autonomous vehicle · Human mobility · Interaction design

1 Introduction

Human Mobility indicates a regular movement of human individuals or groups in time and space [1]. Human factors in the social system implied in human mobility, include not only the rule of spatiotemporal distribution and evolution of human movement, also contains the flowing characteristics in the information space, cyberspace and noosphere synchronization of material transfer, information transformation and financial transaction or energy transit. In the process of human mobility and three flows, the human-human interaction, human-environment interaction, and the human-machine interaction

among the humans, things and the natural or digital environment have come into being. With the rapid development of autonomous vehicle, intelligent transportation system and intelligent mobile telecommunication, Human Mobility increases much more research contents about the crowds movement pattern, material information and financial flows owned by the individual moving line, block chains spaces interaction. The human movements based on three flows (materials flow/logistic, information flow, financial flow) take place in the three time (past, present, future) and three spaces (cyberspace, infosphere, noosphere). The research on Human Mobility has social and comprehensive significance for urban planning [2], traffic prediction [3], disease monitoring [4], location-based advertising [5] and location-based service system economy, social network system [6]. The existing research methods for Human Mobility focus on data acquisition methods [7–9], data analysis methods [2, 5, 10–15] and data application or influence [1, 6, 16]. As a new vehicle transportation form for human beings, autonomous vehicle can independently collect data, analyze data and apply data through sensors and AI algorithms [17], so as to expand the connotation and denotation of human mobility. Aiming at the human mobility of autonomous vehicle, this paper discusses the interaction design method in content, function and media by analyzing the three elements of interaction design.

The paper mainly use literature survey about human mobility and autonomous vehicles, the field study on potential users of the autonomous vehicle (1 worker and 1 housewife, 1 primary school pupil, 3 undergraduate students, 3 free occupation persons, 1 experts) chose four typical family members and typical users to do the field research which include 1 office worker, 1 housewife, 1 primary school pupil and 1 university student. The research directly observed, collected the video recording, and interviewed in-depth with the typical users (based on unstructured interviews) for one year. The survey on the other 6 subjects conducted in-depth interviews and scenario simulation, and a collection of recordings and interview notes as reference data. At the same time through Participatory Design, four typical users participate in the study. The interaction design results were tested by user evaluation and expert review (using Likert scale) by high fidelity prototype.

2 Human Machine Interaction and Human Mobility Interaction

HMI (Human Machine Interaction) is essentially about developing easy, effective, and pleasing interactive products [18]. The three elements of interaction are closely related to the design of human communication and interactive space [19]. With the popularity of Internet of Things(IoT) and intelligent mobile communication devices, the subject and object of interaction have changed. The main body can interact with information and do not need entities. The behavior of judgement, decision-making and execution of objects is changed from passivity to initiative. Human mobility is integrated into the transfer of information based on information density and information exchange on the basis of physical migration, meanwhile, Human Machine Interaction transforms into Human Mobility Interaction. The new Human Mobility Interaction can be divided into different representations of the subject as presence, telepresence and co-presence. The

entity user driver controls the car in the presence style Human Mobility Interaction, and the virtual user driver controls the autonomous vehicle in the telepresence style Human Mobility Interaction (see Fig. 1). In the co-presence style Human Mobility Interaction, the users have the duality identity, normally the real user driver who is driven by human intelligence and the virtual user driver who is driven by artificial intelligence third life joint control the autonomous vehicle. In the HMI interaction, the relationships among the materials, information and financial energy synchronously change with the new paradigm of Human Mobility. In 2018, for example, Beijing city took out the issuance of traffic decrees including “Beijing Road Vehicle Automated Driving Ability Evaluation Test Content and Method (Trial)” and “Beijing autonomous vehicle closed test site technical requirements (Trial)” two documents which was issued by The Beijing Municipal Traffic Commission Joint Municipal Public Security Traffic Management Bureau and Economic Information Commission [20]. Beijing Evaluation of road test ability content is divided into five aspects: cognition and ability to comply with traffic regulations evaluation and execution capability assessment, emergency disposal and artificial intervention ability evaluation, driving ability assessment, internet e-driving ability assessment. In these capabilities, cognition and execution the traffic regulations evaluate HMI presence and telepresence performance. Emergent information processing and human intervention, comprehensive driving ability and internet e-driving abilities require the HMI co-presence performance.

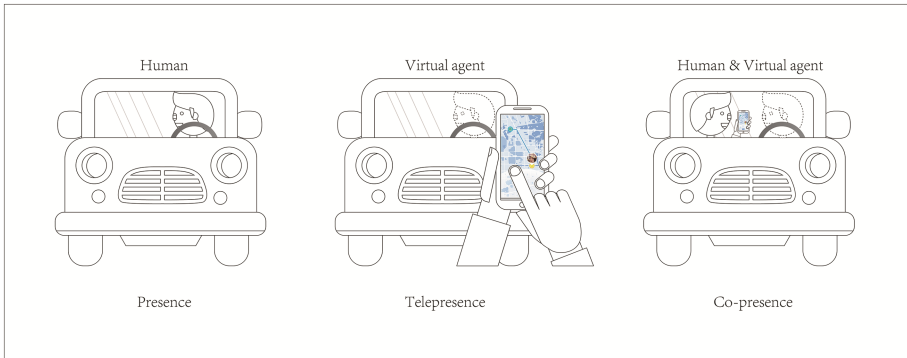


Fig. 1. Three kinds of presence based on human mobility of autonomous vehicle.

2.1 Presence in Human-Mobility Interaction

In the presence style Human-Mobility Interaction, the subject (user) needs to interact with the object in the state of the entity. The identity of the subject is single in the physical space, the driver and passengers, the information disseminator such as information communication users have no ability to identity multiple roles. The interactive behavior occurs mainly between the real person and the entity of the vehicles. As seen the scene 1 of presence (see Fig. 1), mobility refers to the real person or object motion based on physical spatiotemporal movement, the moving path is effected and determined by individual driving concept, life style wisdom, user experience, preferences, environmental

factors, material flow, information flow and financial flow by the real time and physical space constraints. Real people produce the driving behavior through physical operation, the main distribution in human cognition lies in the driving behavior in human-computer interaction. And the interactive contents focus on-the-spot handling information. The driver and the passengers have interactive tasks independently, and their identity and function of operation cannot be parallel superimposed. The media of interaction is the vehicle and physical interface as the main information carrier.

2.2 Telepresence in Human-Mobility Interaction

In the telepresence mode of Human-Mobility Interaction, the subject (user) interacts with the objects (autonomous vehicle) through the virtual agent. In the autonomous vehicle, users can achieve the goal of picking up passengers on the autonomous vehicles without staying in the vehicle. The subject (user) takes information as a carrier to control the driverless vehicle through virtual agents or avatars, which enriches the form and contents of human mobility. As seen the scene 2 presents the telepresence mode for interaction (see Fig. 1). The user communicates through mobiles application to remote control the autonomous vehicle. Telepresence means the substance moving in the different spatiotemporal physical environment though the information flow in the info-sphere and forms the new human mobility. The real humans use the intelligent telecommunication devices to interact with the virtual agents such as program, applications and operation systems. The contents for interaction are generated by remote control intelligent information. The autonomous vehicle has the multiple functions as the transportation tool and the communication media being the virtual agent which is controlled by the real humans remotely. In these scenarios, the autonomous vehicle can pick up the passengers summoned by the users without drivers in the vehicle, move from one spot to another spot. The interaction media include intelligent mobile communication devices, telematics, intelligent transportation system, internet of things and even the autonomous vehicles themselves are the media for Human-Mobility Interaction.

2.3 Co-presence

The subject (user) in the real substance form and in the virtual state interacts with the object (autonomous vehicle) in the same space (autonomous vehicle) and time. The virtual agent or avatar subject include the real user at the present time and in the past time, also include the individual user's human intelligence and artificial intelligence from citizen crowds wisdom. The virtual subject includes the dual users and the virtual agent for the real user, as well as the avatar formed by the third life driven by artificial intelligence. The choices for the OD moving path are determined by the joint decision of human intelligence and artificial intelligence. As seen the scene 3 shows the co-presence mode scenario (see Fig. 1). Human mobility has developed together with human intelligence and artificial intelligence. In the autonomous vehicle, the identity of the users transform from the driver to passengers in the most scenarios. The interaction behaviors take the emphasis on the travel experience rather than driving experience, while the interaction contents take the non-driving behavior as the main target tasks in

the process of the human mobility. The leading function transform from the driving to mobile entertainment, mobile dating and casual mobile learning. The autonomous vehicle has become the leading media and the main carrier interface of the three flows in human-mobility interaction.

2.4 Three Core Flows for Human-Mobility Interaction

Human mobility include material flow logistics, information flow and financial flow. Information flow as the core movement drives the logistics and financial flow. In the autonomous vehicle, information flow embraces the non-digital information from the real vehicle, also stores digital information from the autonomous vehicle and the intelligent transportation system. The way of obtaining information includes not only the digital information of people, vehicles and environment detected by sensors, but also the digital information in intelligent transportation system, as well as the self-quantified information obtained by the driverless car. Autonomous vehicles can be used as the carrier of information to achieve the fusion flows of material and information in the presence, telepresence and co-presence human mobility.

In the information flow, the affiliation between people and information has changed. The social network formed by the inherent information of users, that is, the birth identity information, the conversion transformation information and emergent impromptu information have formed a new knowledge map. In the material flow, the subordinate relationship between man and autonomous vehicle has changed. Independent human and autonomous vehicle are associated with information flow. In the scenarios of self-driving, autonomous vehicle dominates human mobility and also is controlled by the crowds wisdom based on Artificial Intelligence. Autonomous vehicle with autonomous vehicle or vehicles interaction is also driven by information flow. Even if there is no one in autonomous vehicle, the material flow also forms between autonomous vehicle and autonomous vehicle. The relationship between the autonomous vehicle and humans is equal and self-forming system. The paradigm of human mobility changes from centralization to flat networks concern with individual and group data contents service design. In the capital flow, it reflects the human-vehicle and human-mobility interaction between autonomous vehicle and the online & offline flows environment from IaaS (Infrastructure as a Service), PaaS (Platform-as-a-Service), SaaS (Software as a Service) to DaaS (Data as a Service), AaaS (Algorithm as a Service) and AIaaS (Artificial Intelligence as a Service). The self-driving environment includes not only the natural non-digital environment but also the intelligent transportation system form a mixed environment of human mobility.

Logistics. The principal and subordinate relationship between the human and the vehicles has been changed. As seen the scene 3 (see Fig. 1), the autonomous vehicle is controlled by the virtual agent when the users stay in the vehicle. The autonomous vehicle has the dominant human mobility. When user stays out of the autonomous vehicle, human-machine interaction is made up of the human-vehicle interaction, vehicle-vehicle interaction and vehicle-environment interaction. Humans and vehicles separately interact with the human mobility through information flow. The paradigm of

human mobility becomes more and more flat agile networks. Autonomous vehicles and humans can be separated (each of them are materials), emphasizing independence (autonomy), and autonomous vehicles can move independently as we-media itself.

Information Flow. The principal and subordinate relationship between the human and information has been changed. As seen the scene 2 and scene 3 (see Fig. 1), information generates from self-quantified, user-generated contents from the cognitive redundancy, artificial intelligence analyzes the big data for the human-mobility interaction and transforms the non-intelligent information into intelligent information for the autonomous vehicle. Information exists in the virtual agent or avatar independently or flows embedded in the humans in the autonomous vehicle. The identity information, impromptu information and the transformation information construct the new social network system among human-vehicle interaction and human-mobility interaction. The information develops with the big data as the knowledge graph for autonomous vehicle and expands the human mobility which include the individual and crowds service design. Non-digital information and digital information contribute to the data contents service for human mobility. In the scenario of driverless car, users' cognitive focus is liberated from driving behavior. The cognitive redundancy and self-quantified constitute a new information flow, and stimulate the birth and flow of social capital flow through data exchange.

Financial Flow. In the intelligent transportation system big data and self-quantified autonomous vehicle small data exchange process, algorithm and data form the new service [21]. Users and autonomous vehicles receive the crowds wisdom service through data sharing and artificial intelligence. Data as a service and AI algorithm as a service ignite the economic value of data oil. The information flow drives the financial flow from offline to online service system and big data platform. Human-Machine Interaction transforms into Human-Mobility Interaction through IaaS (Infrastructure as a Service) to PaaS (Platform-as-a-Service) and SaaS (Software as a Service).

3 Human Mobility and Three Elements of Interaction Design

3.1 Data Collection Method and Interaction Design Content

The data collection method for Human Mobility corresponds to Interaction Design content-level design. Human Mobility usually considers three aspects: geographic context, distance attenuation, individual spatial behavior characteristics, population density in the region, spatial distribution, individual differences (commuting activities), the factors that influence the forecast are age, population density, number of visiting information towers, external parameters, etc. [8] Previous Human Mobility data acquisition mainly relied on bank notes dispersion and GPS, and later CDR (Call Detail Record) enabled us to capture the dynamic information of individual movement and social interaction, thus predicting what new link will be developed in The Social Network, we can get its regularity on Spatiotemporal by investigating the frequency and duration of contact between users, but CDR has two biggest limitations: sparse time and

rough space [9]. With the widespread use of smart mobile phones, our expanded use of Human Mobility data through the widespread use of cellular and GPS [7], and to ensure continuous connectivity, PSNs (Pocket Switched Networks) leverage human mobility and local/global connectivity to transfer data between mobile users' devices, exploiting human mobility to provide occasional Communication opportunities [22]. Disruption-Tolerant Networks (DTNs) can store the data they are transmitting or forwarding while disconnected from the network until a contact is made that can be relayed when needed, thus sending the message end to end [23]. Autonomous Vehicle obtains data about the user's personal movement path and the surrounding context of the user during movement through sensors such as LIDAR, Ultrasonic sensor, camera and GPS (Global Position System) [17]. With autonomous Vehicle, we can make up for the problems of low value of human data acquisition, single user information, lack of continuous path data in the individual space and low accuracy (see Fig. 2). With Autonomous Vehicle, we can not only get third-person GPS data, but also first-person viewers' data. Flattening data sources enables interactive content to support Mass Customization's data content services. Autonomous Vehicle enables self-quantified approaches from "Around Me" information through wearable smart devices [24], extends to "Include Me" information in Autonomous Vehicle, Quantified the individual's small data to make it more comprehensive and includes the inherent identity information, impromptu information and transformation information, enable Interaction Design's content design to provide mass customization (MC) data services to individuals, mass computing of big data under mass-based individual data, and mass data usage as a public resource for mass, It is necessary to pay attention to the scope of application of data and the ethical and moral issues of design. Data and design should be people-oriented and can't harm people

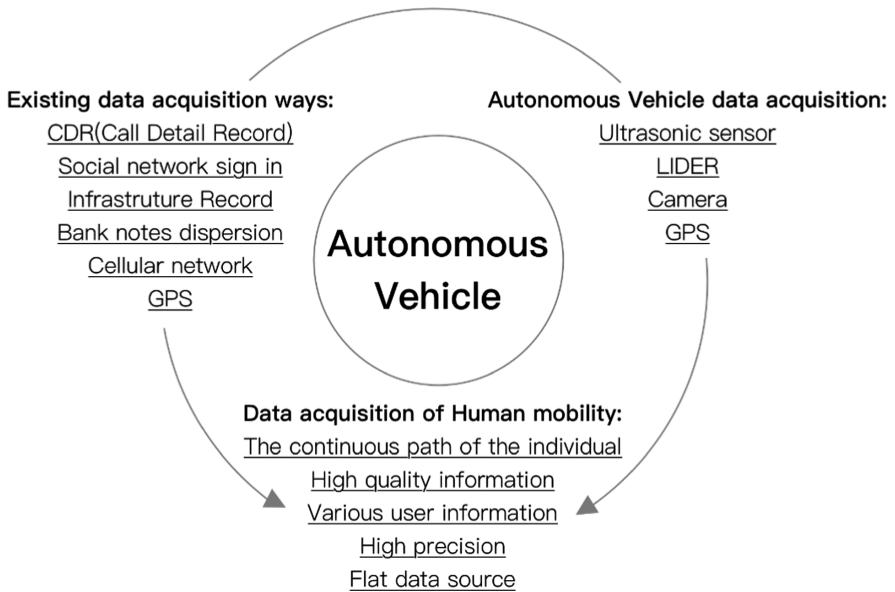


Fig. 2. Autonomous vehicle expanding of human mobility data collection method.

themselves. On the basis of this, the laws, cultures, contexts and social contracts of the applied area should be respected. Therefore, in Autonomous Vehicle interactive content design, users and Autonomous Vehicles require a service agreement and social contract, users accept the premise of data services is the need to share their own data, Autonomous Vehicle also requires the user's authorization to the user's personal data applied to the mass service. Authorization to the user's personal data applied to the mass in service is dramatically. Autonomous Vehicle interactive content needs to be based on hosting logistics, information flow as a driving force to transform and promote logistics and financial flows, supporting Mass Customization's data content services under self-Quantified.

3.2 Data Analysis Method and Interaction Design Function

Human Mobility data analysis method corresponds to Interaction Design functional level design. Through intervening opportunities model [2], Lévy flight model [10], radiation model [11], d-EPR model [12], deep learning models (the deep belief network (DBN) and deep neural network (DNN)) [13], Exploration and Preferential Return (EPR) model [14], gravity model [15], a hybrid Markov-based prediction model [5], triangulation [25] and other model analysis. Human Mobility pays more and more attention to the analysis of an individual's laws of movement in time and space and thus predicts the individual user's movement path, The Social Network, preferences, and the like. For example, E Mucceli et al. Classify PI (people and points of interest) into nine categories by analyzing the frequency and duration of user visits: arts & entertainment (aquariums, casinos, etc.), education (schools, universities, etc.), Food (coffee, restaurant lamp), religion (church, mosque, etc.), outdoor & sports (gymnasium, stadium etc.), nightlife (bars, nightclubs etc.), shopping, Service (self-service teller, dentist, doctor, etc.) [9]. Through the improvement of Human Mobility data analysis method, we can better grasp the movement rule of individual or mass and apply the law to the development of Autonomous Vehicle interaction function. For example, users with overlapping paths are more likely to form new social relationships [6]. Autonomous Vehicles provide similar services to users with overlapping paths. Autonomous Vehicle, as an intelligent carrier that wraps the human movement, can calculate the passenger's PI based on the contextual awareness in a timely manner, achieving the result of being there. So in the design of Autonomous Vehicle interaction function, we need to pay attention to the elements of speed (computing speed, feedback speed, etc.) Human Mobility data collection in the past is dominated by people, need to be analyzed after the completion of the movement, autonomous Vehicles now move with people, data collection and analysis can be carried out simultaneously, through instant mobile context-awareness computing and mobile computing, to achieve where the resulting interactive features.

3.3 Data Application and Impact and Interaction Design Media

Human Mobility data application and impact study corresponds to the design of the Interaction Design media level. Urban planning, traffic forecasting, disease surveillance [1], commercial promotion, and the construction of The Social Network System [6, 16]

can be better achieved through the mastery of the human trajectories in human mobility [1, 9]. Autonomous Vehicle as a medium, itself, can take on Human Mobility data applications. It is divided into weapons and containers. The former can exist as a medium carrying single functions, such as work tools and vehicles in dangerous places. The latter may exist as inclusive and adaptable containers, such as mobile self-media, shared space for economic mobility, and the like. Autonomous Vehicle as a carrier of information, the inherent identify information, impromptu information and transformation information of people and vehicles constitute a new The Social Network, Affected by a typology of mechanisms of change in social networks (relational mechanisms, Dynamics of Reciprocity, Dynamics of Repetition, Dynamics of Clustering and Closure, Dynamics of Degree) under Human Mobility [26]. In the design of Autonomous Vehicle interactive media, we need to consider how to make the new The Social Network become one-way relationship from one-way interdependence, how to maintain stability, reciprocity, trust and good relations.

4 Autonomous Vehicle Interaction Model and Information Architecture

The Interaction model for the Human Mobility based on Autonomous Vehicle has changed. Users in the model include real physical humans, virtual agent information, individual, mass, users in the online social network and offline social network system, cyberspace identity duality role multiplicity of people, and people who make Collective Intelligence decisions based on the Intelligent Transportation System. The objects in the model also changed. Autonomous Vehicle has independent integrity. It can independently control the flow of logistics driven by information flow. The context in the model also changed. Non-intelligent traffic and intelligent traffic systems formed a hybrid Human Mobility context. In the present study, the Interaction model is modeled after the Flickr User Model (see Fig. 3). There are three key elements in the autonomous Vehicle Interaction model: users, mobile devices, autonomous vehicle. There are three kinds of relationships in mobility: active mobility, passive mobility, and follow-up mobility. Each of the three types of relationships is related to the mobile terminal. Users map to the autonomous vehicle through strong associations with the mobile terminal, and are categorized as three major functions: call, send, share. Three major features have enabled autonomous vehicle to promote the three major streams of “taking you moving”: information flow, material flow, extension of financial flow, Three streams in the context of the realization of the function, the sharing of location, the birth of the data, the provision of services to individuals and their families, friends, people in the vicinity linked together to achieve the promotion of activities and financial returns, the exchange, transaction and mutual transit of the three major streams enable the system to achieve a coordinated and continuous operation in the continuous updating and agile development. Artificial Intelligence and Human Intelligence work together in this system.

the interaction of the new Human Mobility can be divided into presence, telepresence and co-presence mode under different subject representations. In the three major flow streams for Human-Mobility Interaction, people and vehicles are independent and make use of information flow to create the interaction among humans, vehicles and intelligent transportation system. The paradigm of Human Mobility is more flat and diversified. Information can be generated by Self-Quantified initiatives, exist independently in the form of virtual proxy or co-exist in the Autonomous Vehicle, digital information and non-digital information form the data content services design of Human Mobility, which stimulate the birth and flow of financial flows through the use of algorithms and data services.

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