Determining Human Dynamics through the Internet of Things

Antonio J. Jara, Yann Bocchi, Dominique Genoud
Institute of Business Information Systems
University of Applied Sciences Western Switzerland (HES-SO)
Sierre (Switzerland)
jara@ieee.org, {yann.bocchi, dominique.genoud}@hevs.ch

***Abstract*—The potential of the artificial intelligence to build solutions based on the understanding of human behaviours, and the capacity to discover patterns through their interactions with the world is being extended with the capabilities of the Internet of Things. The described potential, so-called Human Dynamics, pursues to describe in real-time the human behaviours and activities. These goals are starting to be feasible through the quantity of data provided by two of the main areas of the Internet of Things, on the one hand, the Smart cities to make more intelligent the environment and offer a smart space that sense our movements, actions, and the evolution of the ecosystem, and on the other hand, the wearable and mobile computing which allows to provide data from the humans itself, i.e., from their pockets (smart phones), wrists (smart watches), hearts (wearable sensors), and eyes (glasses). This work analyses the ecosystem defined through the triangle formed by Big Data, Smart Cities and Wearable Computing to determinate human dynamics. For this purpose, the life-cycle of human dynamics determinations in Smart Cities have been analysed in order to determinate the current status of the technology, challenges, and opportunities.**

***Index Terms*—Human Dynamics; Human Behaviours; Big Data; Internet of Things; Smart Cities; Cloud Computing.**

I. Introduction

The number and diversity of sensors and devices (smart objects) deployed is growing tremendously thanks to the capacities to offer low cost air-interfaces, extension of Internet, and reduction of size and costs for the chipsets.

A smart object, also known as an embedded device, thing, or sensor, is a physical element with the capability to be identifiable, and optionally it can be also able to communicate, sense, and interact with the environment and other smart objects.

They are considered smart, since they can act intelligently under certain conditions through an autonomous behaviour.

Smart objects are being extended to support and enable an extended range of solutions based on cellular infrastructure and wireless sensor networks. Some examples of Smart Objects in our daily life are watches, clinical devices, building automation sensors, security networks, access control systems, smart phones, tablets, smart TVs, and cars.

Their flexibility and capabilities are being extended, nowadays, with the infrastructure capacities to provide an Internet access to the cellular networks (M2M), and wireless sensors networks through technologies such as IPv6 Low Power Wireless Personal Area Networks (6LoWPAN) [1], [2].

These new Internet-based features are making them more ubiquitous in the different environments and accessible by the systems and users. Consequently, the number of sensors continues growing exponentially estimating that by 2020 between 50 to 100 billion of devices will be connecting all the things around the user, reaching so the called Internet of Things (IoT) [3].

These billions of devices are destined to improve our quality of life, security, and performance. Thanks to the potential from the interconnection of information, objects and people.

Until now, the IoT has been focused on supporting the interactions between machines, in order to send data to each other, carry out some actions under certain conditions, and make feasible that heterogeneous objects interact among themselves. For this purpose, the Web of Things and the definition of service-oriented architectures are making feasible this support to the heterogeneity [4].

Now, the challenge is to define and understand the interactions between smart objects and humans. The origin of the Internet has been a human-human type interactions, since the content was defined by humans to be consumed by other humans, but with the IoT/WoT the content is being defined by objects. Therefore, the interactions and influence over our lives is an open issue, and this needs to be understood how the IoT will play a key role in our Smart Cities and Smart environments.

In particular, this work will analyses these interactions and potential from the perspective of the *Human Dynamics*, the potential of the *Big Data* and *Smart Cities* to increase our quantitative and qualitative understanding regarding the human behaviours.

II. Internet of Things ecosystem

The IoT is defining an ecosystem, where it is not only a network to transfer data, else IoT also is interconnected with Big Data and Cloud Computing to provide intelligence, in order to be able to understand the behaviours, and even define actions according to the information captured by the smart objects that are able around the emerging smarter cities.

The Figure 1 presents the general architecture of the IoT ecosystem, where the data coming from the Smarter Cities is integrated into the Cloud Computing.

978-1-4799-2902-3/13 $31.00 © 2013 IEEE
DOI 10.1109/WI-IAT.2013.161

The presented flow is enabling the interaction between the cloud and the the humans, who are starting to be more actives (prosumers).

The cloud is taking care of the centralization of the data of each sensor and object, allowing them to interact and communicate between them through the creation of a ubiquitous network and solving the interconnection problem.

The cloud is also enabling the integration of Big Data analysis in order to reach an understanding that allow the determination of human dynamics patterns.

Finally, as a result the human dynamics pattern will contribute to provide the tools and feedback mechanisms in order to motivate the change of the behaviors.

A. Big Data integration

From the Big Data perspective is the selection and aggregation of multiple data sources. For this purpose, Web standard specifications (e.g., URI, HTTP) and the architectural guidelines based on REST (REpresentational State Transfer), and Linked Data, are the paradigms that are making feasible the heterogeneous data integration, data representation, their semantic descriptions (e.g., Open Mobile Alliance (OMA), SensorML), and finally the data dependencies and relations.

B. Cloud Computing

The cloud storage platform provides several functional features that can be used by application developers and service providers to compose smart services on top the Smart City facility. It enables easy discovery of sensor information, effective data management and other functions that allow the development and re-use of sensing and actuation capabilities from the heterogeneous physical resources.

Cloud platforms allow to store in their database all the observations and measurements sent by the different devices, containing live and historic information. Thus, it provides facilities towards the development of services that convert raw data into useful information.

Nowadays, there are several platforms to interconnect devices. Among them there are some oriented towards business world, like the service provider: Xively (a.k.a. COSM or Pachube), Paraimpu, QuadraSpace, ThingSpeak, Sensorpedia, SenseWeb, and Fujitsu RunMyProcess.

Platforms such as Paraimpu and RunMyProcess allow to integrate several Smart Objects in one network that is capable of managing heterogeneous data, sharing it and connecting different sensors. This platform allows users to connect, create and share applications to connect objects.

III. Human Dynamics

Human dynamics basis are coming from the statistical physics and complex system research. The main goal of the human dynamics is to understand human behaviour using methods, techniques and technologies from statistical physics. We propose to extend Human dynamics with new techniques such as data mining (big data) in order to extend it and exploit the data from emerging smart cities.

The dynamics of the global population in terms of social, technological, and economic phenomena are the aggregation and consequence of billion of individual human decisions, interests, actions, and priorities.

The regularities, in terms of timing and frequency, in human dynamics for daily activities such as read emails, entertainment, sport, shopping, and work patterns were usually considered random, and consequently highly difficult to predict. In 1837, Simeon Denis Poisson discovered that several activities follows up a distribution, the denominated Poisson Distribution [5].

In 2005, the Prof. Albert-Laszlo Barasabi defined the basis about several behaviours that fit better with bursts of rapidly occupancy events separated by high times of inactivities [6].

Therefore, the traditional queuing model based on Poisson distribution was discussed, offering new evidences about the long tailed distribution of inter-event times that naturally occur in human activities. Thereby, heavily-tailed presents long periods of inactivity that appears after a burst of intensive activity, instead of a slow decreasing of the activity.

The change from intensive/burst activity to non-activity is a common behaviour in human being, who are used to follow up diets, fashion styles, sport, in a very intensive way, until that this reduces priority and is forgotten, until the next social event.

Until now, the analysis of the human dynamics has been focused on web server logs, shopping center queues, cell phone records, and even other issues such as earthquakes.

IoT and Smarter Cities are powering the access to new data sources that will enable a new generation of results in quantifying and understanding human behaviour on a global scale. Human dynamics pursues to understand through data and evidence the non-Poisson activity patterns in human collective and individual behaviours.

The society is defining new roles for the citizens such as a major interaction through social networks, interaction with the smart devices, interactions with social networks, and finally its integration into an information society, where the information is everywhere.

Specifically, in this work we will analyse the potential of the Big Data and Smart Cities for the human dynamics into three steps: First, define the new role of the citizens such as be prosumers. Second, understanding the human behaviours from the collected data. Finally, influence into their behaviours through the continuous feedback.

A. Prosumers

Prosumer concept is the result of the combination of *producer + consumer*. Prosumers are proactive consumers, who present a higher interest to stay connected, informed and participate, i.e. produce opinions, experiences, feelings and information. This voluntarily participation is motivated by being part of the co-creation of value [7].

Since, the creation of value is co-created with consumers [8], the value is no longer a single value creation from the enterprise, else that the prosumers participate in the process

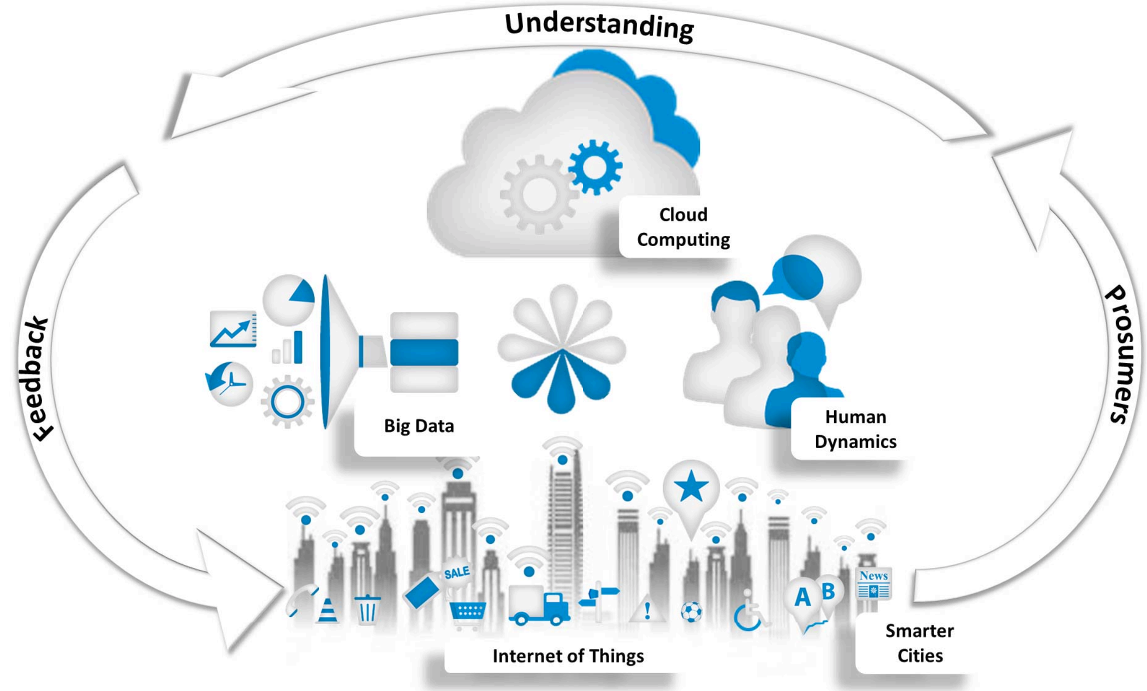

Fig. 1. A general architecture of the Internet of Things ecosystem.

of creating value through interaction with other customers and the enterprise. The motivation to participate in a prosumer seems utopian and utterly opposed to the natural motivation. For example, a previous study carried out about the role of the prosumers in the marketing [9]. For the marketing, the main motivation is to earn profits through increased demand, and that is why companies invest in it. But from the consumer side there is a direct benefit quantitative, but in fact, the power to overcome the barriers of consumers to participate by a stranger to the quantitative motivation is something that the world of values, the Internet world [10], and the social world [11].

Several consumers of Internet are characterized by participation, altruism, collaboration, contribution and participation without the higher interest of helping, we can see this in non-governmental organizations, and volunteer groups. Internet users create content online without interest. It can be found several courses, tips, and video tutorials in the network of non-profit users. It can be also found the power of collaboration between multiple users for creating even greater resources. For example, the world's largest encyclopedia, Wikipedia, with high quality and virtually no centralized control, developed only through altruistic and selfless contribution. The Wikipedia has accomplished what no publisher would ever achieved, and this is possibly the best example to date of the potential of collaborative intelligence and voluntary participation.

Following the principles of Thomas W. Malone, director of the MIT Collective Intelligence, *you can understand the potential of these social skills to build great things like Wikipedia, or all the videos and tutorials out there today on platforms like Youtube and see as it can be used to gain competitive advantage of these capabilities* [12].

Therefore, Big Data for prosumers and their behaviour persues to analyses how is the activity from indivual users to create a solution such as Wikipedia, in terms of participating, providing expertise for the company.

B. Understanding behaviours

The understanding of behaviours is being carried out through the human dynamics for limited data source, such as logs from email servers, and web browsers. The source and quantity of the data is changing drastically with the appearance of the social networks. But, this continues increasing through the the smart cities, where the data about the behaviour of the citizens and prosumers is also available from the real-life. Specifically, this data is coming with extended environments such as Smart Cities. For example, the European Union Project SmartSantander [13] has defined the service of participatory sensing, called *The pace of the city*.

The participatory sensing solution from SmartSantander aims the use of citizens smartphones to make people become active in observations and data contribution. This platform offers details from the Santander City Council, public transport information, cultural agenda, sensor values, and a local newspaper. The users can read news, but they can also report, share and be notified of events happening in the city. An example of this platform experiences is a user walking in the city centre who finds a hole in the pavement can take a picture, write a text and finally share this incidence with other users of the application. A similar use case and experience is found in the project FixMyStreet from United Kingdom [14].

In addition, this allows to share social-related events, and finally, this also samples the values sensed by the smartphones in terms of GPS location, lighting level, acceleration, magnetic field, etc. At the same way, our previous works developed for the IoT6 EU Project in [15], where the prosumer is also able to interact with QR codes, RFID tags (integrated with the Electronic Product Code Information Systems), discover 6LoWPAN devices through the digcovery architecture [16], and interact with them through CoAP WebServices.

All this new ways to interact with the smart cities, provide opinions, contribute with sensing data, events (e.g., problems in the street), traffic analysis based on smartphone tracing, etc..., are a huge area to apply human dynamics.

C. Changing behaviours

People harm or damage themselves, their environment, and others. For example, hey smoke, make poor dietary/exercise, and waste natural resources through excessive consumption. This is a consequence of the lack of awareness, but several time even when they are aware of the negative impact of their actions, they are not really aware about the impact of an individual action in the aggregated result.

The challenge to encourage and motivate behaviour changes has been addressed by psychology for issues such as smoking cessation [17], increase exercise levels [18], drugs adherence [19], and reduce energy consumption [20].

Fogg in [21] described how the computers can persuade citizens. Therefore, following the Figure 2 the challenge from the IoT is to provide just-in-time feedback that contains the relevant contextualized data to make aware to the citizen. Thereby, it can be influenced in order to improve their behaviours.

This motivation feedback can be provided in form of messages, avatars, or metaphors such as a garden of flowers, or animals. For example, in our product for drug adherence found in [22] is used a growing flower.

The motivation of the people is the major outcome that can be reached from the Internet, in order to break all the frontiers of the smart cities and social networks. Thereby, reaching an Internet of People (IoP) [23], where all the potential of the Internet of Things, Smart Cities and Big Data is focused on improving our quality of life, and provide us the tools for understanding the consequences of our actions, role in the world, and the opportunity to improve.

Fig. 2. The awareness loop.

IV. Conclusions and ongoing work

This work has presented the potential of the data, from the Internet of Things in smart environments such as smart cities, for determining human behaviours through Big Data analysis. This has described the Internet of Things ecosystem, and defined the data flow around them.

This flow is composed of three phases. An initial phase of enabling to the citizens with mechanisms to be connected, and motivate them to participate in order to be prosumers. For this purpose, several solutions from our previous works such as smartphone applications (mobile digcovery, drugs adherence, marketing, etc.) and other existing solutions for participatory sensing. These participatory applications are presenting the initial steps to promote the digital inclusion and interaction of the citizens with the emerging smart cities.

Once, the data is being provided directly from the users a huge range of new applications, patterns and understanding can be reached. The understanding from this new data is not going to be limited to external analysis about web servers usage, traffic frequency, or queues length, else the integration of the citizens like prosumers will allow to reach a higher and more accurate quantity of data from the people, at the same time. that allows to build not only general models, else also personalize and analyze behaviours from individuals.

Then, the challenge from the understanding and continuous awareness is to offer a feedback to the users that offers them the opportunity to improve their behaviours. These behaviours will address issues such as diets exercise, drugs adherence, and energy consumption.

Therefore, new challenges are arising for empowering users in order to enable them to provide data with new gadgets such as glasses, watches, and bracelets. These gadgets will extend the potential from the current smart phones. Another emerging challenges are arising to analyze the huge amounts of data, in order to understand and discover the new models that describe the human dynamics, and finally to define the proper and non-invasive mechanism, such as avatars, messages, and metaphor mechanisms, to offer the feedback.

Our ongoing work is addressing different topics, first, we will analyze new wearable technologies such as smart watches. Second, we will continue analyzing the data from our existing solutions and mobile applications, in conjunction with the data from Smart Cities, in particular the data from the SmartSantander EU Project. Third, the potential of the cloud computing as an orchestor among heterogenous resources will be analyzed over the Fujitsu RunMyProcess and Paraimpu. Finally, we will evaluate how this continuous monitoring can be applied and impact for applied areas such as healthcare and energy management, through the mentioned wearable devices such as bracelets and smart watches.

Acknowledgment

The authors would like to thank to the HES-SO and the Institute of Information Systems funding and support, and the European Project "Universal Integration of the Internet of Things through an IPv6-based Service Oriented Architecture enabling heterogeneous components interoperability (IoT6)" from the FP7 with the grant agreement no: 288445.

References

[1] J. Hui, P. Thubert. *Compression Format for IPv6 Datagrams over IEEE 802.15.4-Based Networks*, RFC6282, 2011.

[2] Jara, A. J., Zamora, M. A., Skarmeta, A. *Glowbal IP: An adaptive and transparent IPv6 integration in the Internet of Things*. Mobile Information Systems, 8(3), 177-197, 2012.

[3] Emmerson, B. *M2M: the Internet of 50 billion devices*. WinWin Magazine, 19-22, 2010.

[4] Guinard, Dominique, et al. *Towards physical mashups in the web of things.* Networked Sensing Systems (INSS), 2009 Sixth International Conference on. IEEE, 2009.

[5] Haight, F. A., *Handbook of the Poisson distribution.*, 1967.

[6] Barabasi, A. L. *The origin of bursts and heavy tails in human dynamics*. Nature, 435(7039), 207-211, 2005.

[7] Ritzer, G., Jurgenson. N., *production, Consumption, Prosumption: The nature of capitalism in the age of the digital prosumers*, Journal of Consumer Culture. Marzo 2010 10: 13-36, doi:10.1177/1469540509354673, 2010.

[8] Prahalad, C.K. Ramaswamy, V., *co-creating unique value with customers*, Emerald, 32, doi: 10.1108/10878570410699249, 2004.

[9] Jara, A. J., Parra, M. C., Skarmeta, A. F. *Participative marketing: extending social media marketing through the identification and interaction capabilities from the Internet of things*. Personal and Ubiquitous Computing, 1-15, doi: 10.1007/s00779-013-0714-7, 2013.

[10] Hong-Youl Ha, Helen Perks, *effects of consumer perceptions of brand experience on the web: brand familiarity, satisfaction and brand trust*. Journal of Consumer Behaviour, 4(6), 438-452. Publisher John Wiley and Sons, Ltd., ISSN: 1479-1838, 2005.

[11] Singh, Vivek Kumar, *collective Intelligence: Concepts, Analytics and Implications*. 5th Conferencia; INDIACom-2011. Computing For Nation Development, Bharati Vidyapeeth. Institute of Computer Applications and Management, New Delhi. ISBN 978-93-80544-00-7, 2011.

[12] Kraut, Robert. *Building Successful Online Communities: EvidenceBased Social Design*. MIT Press, 2012.

[13] Sanchez, Luis, et al. *SmartSantander: The meeting point between Future Internet research and experimentation and the smart cities.* Future Network and Mobile Summit (FutureNetw), IEEE, 2011.

[14] Walravens, N., *Validating a Business Model Framework for Smart City Services: The Case of FixMyStreet,* Advanced Information Networking and Applications Workshops (WAINA), 2013 27th International Conference on, pp.1355,1360, doi: 10.1109/WAINA.2013.11, 25-28 March 2013

[15] Jara, A. J., Lopez, P., Fernandez, D., Castillo, J. F., Zamora, M. A., Skarmeta, A. F. *Mobile digcovery: discovering and interacting with the world through the Internet of things*. Personal and Ubiquitous Computing, 1617-4909, 1-16, doi: 10.1007/s00779-013-0648-0, 2013.

[16] IoT6 EU Project, *D3.1 Look up and discovery, context-awareness and resource repository report.*, http://www.iot6.eu/images/stories/deliverables/IoT6 - D3.1.pdf, 2012.

[17] Scholl, P.M., van Laerhoven, K., *A Feasibility Study of Wrist-Worn Accelerometer Based Detection of Smoking Habits,* Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 2012 Sixth International Conference on, pp.886,891, 4-6 July, doi: 10.1109/IMIS.2012.96, 2012.

[18] Consolvo, S., Klasnja, P., Mcdonald, D. W., Avrahami, D., Froehlich, J., Legrand, L., Libby, R., et al. *Flowers or a Robot Army? Encouraging Awareness and Activity with Personal, Mobile Displays*. Ubicomp 2008, 54-63, 2008.

[19] Jara, A. J., Zamora, M. A., Skarmeta, A. F. *Drug identification and interaction checker based on IoT to minimize adverse drug reactions and improve drug compliance*. Personal and Ubiquitous Computing, doi: 10.1007/s00779-012-0622-2, 1-13, 2012.

[20] Abrahamse, W., Steg, L., Vlek, C., Rothengatter, T. *A review of intervention studies aimed at household energy conservation*. Journal of Environmental Psychology, 25(3), 273291, 2005.

[21] Fogg, B. J. *Persuasive Technology: Using Computers to Change What We Think and Do*. Morgan Kaufmann: San Francisco, 2003.

[22] Skarmeta, A.F., Zamora, M.A., Jara, A.J., et al. *HIGEA: System, device and method for detection of encapsulated objects*, Patent, P201230267, 2012.

[23] Kranenburg, Rob Van. *Internet of People*, http://www.theinternetofpeople.eu/, 2012.