EveryAware

Enhancing environmental awareness through social information technologies

White Paper

ISI, UCL, LUH, VITO, PHYS-SAPIENZA
`http://www.everyaware.eu`

> *"A revolution doesn't happen when a society adopts new tools. It happens when society adopts new behaviours and most of that change I think is still in the future."*
> Clay Shirky

Tell me, I forget.
Show me, I remember.
Involve me, I understand
Chinese proverb

1 Concept

There is now overwhelming evidence that the current organisation of our economies and societies is seriously damaging biological ecosystems and human living conditions in the very short term, with potentially catastrophic effects in the long term. The enforcement of novel policies may be triggered by a grassroot approach, with a key contribution from information and communication technologies (ICT). Nowadays low-cost sensing technologies allow the citizens to directly assess the state of the environment; social networking tools allow effective data and opinion collection and real-time information spreading processes. In addition, theoretical and modeling tools developed by physicists, computer scientists and sociologists have reached the maturity to analyse, interpret and visualize complex data sets. EveryAware intends to integrate all crucial phases (environmental monitoring, awareness enhancement, behavioural change) in the management of the environment in a unified framework, by creating a new technological platform combining sensing technologies, networking applications and data-processing tools; the Internet and the existing mobile communication networks will provide the infrastructure hosting such a platform, allowing its replication in different times and places. Case studies concerning different numbers of participants will test the scalability of the platform, aiming at involving as many citizens as possible leveraging on the low cost and high usability of the sensing devices. The integration of participatory sensing with the monitoring of subjective opinions is novel and crucial, as it exposes the mechanisms by which the local perception of an environmental issue, corroborated by quantitative data, evolves into socially-shared opinions, eventually driving behavioural changes. Enabling this level of transparency critically allows an effective communication of desirable environmental strategies to the general public and to institutional agencies.

2 Introduction

The issue of sustainability is now on top of the political and societal agenda and is considered to be of extreme importance and urgency [1, 2, 3]. It is evident how the present economy structure and societies we live in are seriously threatening the biological ecosystems and slowly but steadily deteriorating the average human living conditions, with possibly disastrous future effects [4]. A lot can and must be done from the technological and policy-making perspective encouraging – for example, the development of renewable energies and energy-saving housing and transport. But it is only when people become fully aware of their actual environmental conditions and their future consequences that the much needed change of behaviour will truly happen. In a recent statement from the head of the European Environmental Agency, it has been clearly pointed out that bottom-up actions are necessary to deal with today's challenge: "The key to protecting and enhancing our environment is in the hands of the many, not the few.... That means empowering citizens to engage actively in improving their own environment, using new observation techniques..." [5].

The need for a re-organisation of the most impacting human activities towards a more efficient and sustainable development model has been recently raised by the public debate on several global environmental issues. Unfortunately, the achievement of such a goal has been undermined by the difficulty of matching global/societal needs and individual needs. Urban environments, with over 50% of the world population and a growth rate close to 2% [6], are crucial in this respect. Traffic-related air pollution accounts for a large part of the 300 million people suffering with asthma around the world [7]. Moreover, health risks are not homogeneous across urban areas, because micro-environments exhibit highly variable pollution rates [8, 9, 10]. As a consequence, it has been estimated that two million people die annually from indoor air pollution [11]. Nevertheless, the air quality of a city is typically monitored through a limited number of fixed out-door stations. Traffic is also a major source of excessive noise levels which, in turn, cause severe health effects (apart the auditory ones) on urban population [12, 13]. Therefore, a re-organisation of several urban activities would have a positive impact on this issue as well.

Research into the determinants of environmental behaviour has shown that an improvement of the individual and collective behaviour can be obtained if citizens are more exposed to information, and engaged as part of a community [14, 15, 11, 16, 17, 18]. Based on these assumptions, an innovative approach to address environmental issues is represented by "urban sensing", a domain of high significance in technological development over the coming years where information exchanges involving citizens equipped with mobile and web technologies play a crucial role [19].

From all this comes the idea of recruiting non-expert individuals in the very collection process of environmental data and to gather opinions about their perception of the urban environment, from various points of view (air quality, mobility efficiency, health conditions [20]). To address issues of data credibility the collected data should be processed and interpreted in a statistically and scientifically sound way [21, 22, 23, 24]. As a reward for their collaborative behaviour, users would be provided with targeted and personalised environmental information. This can generate pressure in favor of a more sustainable usage of commons as *'Real world data is useful in drawing attention to problems and advocating change'* [17].

However, in order to set up such a virtuous loop, there is an urgent need to create an ICT fabric in order to support local and hyperlocal actions by capturing information and providing usable feedback [25]. Additionally, while motivation for engagement, continuing participation and behavioural change has been examined for activities such as Wikipedia and Open Street Map, the question remains open for the field of 'urban sensing' [26, 27, 28, 22].

3 Why EveryAware?

The EveryAware project responds to the above mentioned societal needs by providing capabilities for environmental monitoring, data aggregation, and information presentation to users by means of mobile and web-based tools such as smartphones, computers and sensors.

EveryAware intends to integrate theoretical and practical techniques from the disciplines of environmental sensing, computer science, statistical physics and social science to collect and analyse physical measurements from sensors and associated subjective opinions of participants. Real-time analysis results will be provided to the users through the most commonly available communication networks.

The comparison between sensor data and subjective opinions will expose the mechanisms by which the individual perception of a known phenomenon is translated into its social perception and eventually into choices and actions. A deeper understanding of this mechanism, grounded in real-life scenarios, paves the way to engineering better incentives for change, and poses the basis for an effective strategy of environmental communication, reducing the gap between the general public and institutional bodies with a stake in environmental policies. The appropriate and personalised representation of the collected data to users has the potential of triggering a bottom-up improvement of citizens' behaviors [14, 15, 11, 16, 17].

EveryAware's partners come from four different, yet complementary areas that are all directly relevant to achieve the objectives of the project. There are two complex systems oriented partners (ISI and PHYS-SAPIENZA). They will be concerned with analyzing and modeling the Social Dynamics that this project will generate and solving fundamental problems in the aggregation of massive noisy quantitative and qualitative data. Each of these partners has a very strong reputation in the field of statistical physics and complex systems and has demonstrated through prior work the ability to make major contributions in the application of complex systems science to the study of social dynamics, including semiotic dynamics (for example social tagging) and opinion dynamics. One partner is an important player in the domain of environmental monitoring

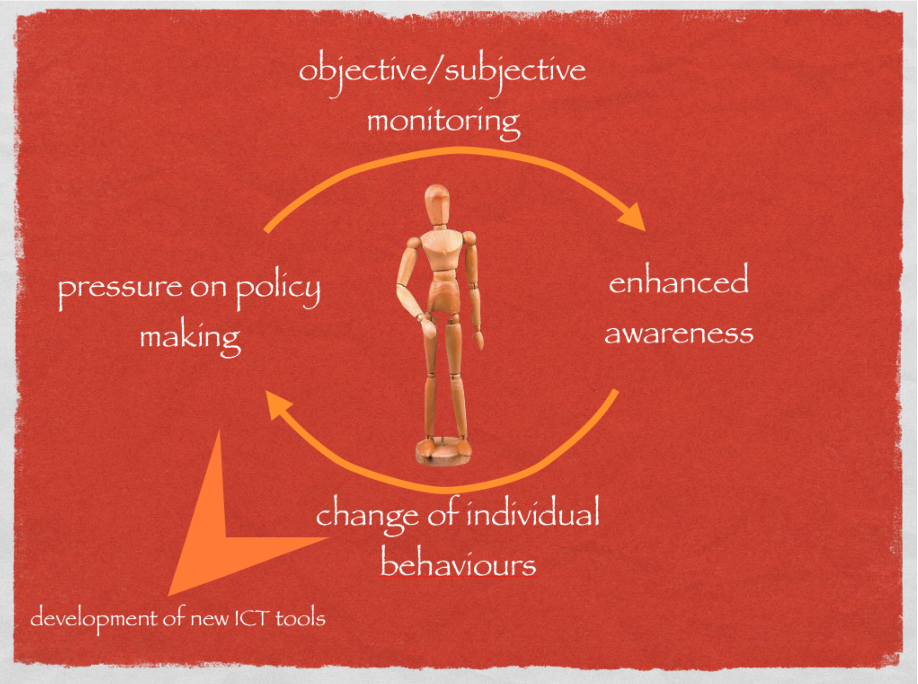

Figure 1: EveryAware Concept

and modelling (VITO), i.e. sensing and modelling the air quality condition. It is a state-owned research organisation dealing with environmental matters as its primary mission. It will ensure that the results of this project are relevant and realistic with respect to the issue of sustainability, which is the major focal point of this project. Then there is a partner coming from the domain of the social sciences (UCL), with specialised expertise in community building through the use of Geographic Information Systems (GIS) and participatory mapping. This partner has already been engaged in a wide range of projects and experiments conceptually similar to the ones that will be carried out in the present project. Finally, EveryAware enjoys the presence of a strong Computer Science partner (LUH) with a track record in research excellence and in pushing the state of the art in future and emerging technologies in several relevant domains: Web Science, Data Mining, Web 2.0, Semantic Web, Social Network Analysis.

The consortium is therefore strong and well balanced, spanning the full disciplinary range from complex systems science to environmental modelling and future and emerging ICT technologies, bringing together social sciences, mathematics and the physical sciences, and information technologies. It combines public research institutions, universities and state agencies, ranging from fundamental sciences to applied science. Additional information are available through `htt://www.everyaware.eu`.

Figure 2: EveryAware Consortium

4 New ICT tools

The latest evolution of Information and Communication Technologies (ICT) has increasingly concerned the inclusion of users in the production of information through multiple digital media such as PCs, smartphones, or cameras supported by an Internet access. Because of the increased amount of exchanged data, users' attention is often exhausted by the information overload. Therefore, the usability of such information is strictly connected to the availability of effective filtering methods and targeting tools.

To this end, most online communication platforms developed within the Web2.0 paradigm provide the users the opportunity of collectively categorizing, evaluating, and filtering the content they browse. The classification of digital resources is typically performed by assigning labels (called *tags*) or ratings to resources. This collaborative categorization has given birth to several web-based *folksonomies* (from "folks" and "taxonomies").

These socio-semantic systems have also attracted much attention from the scientific community, to investigate quantitatively how cooperative phenomena arise and can be harnessed to improve the performance of such collective tasks (see [29, 30, 31, 32] and the work accomplished by the authors, among others, in the framework of the EU project TAGora `www.tagora-project.eu`).

This ICT infrastructure has been applied not only to favour data exchange among people, but also to outsource productive tasks. Companies and institutions are increasingly relying on the recruitment of networking volunteers through the Internet to perform tasks of varying nature. Typical task proposals are submitted online by companies seeking technological or marketing solutions, or by research groups looking for volunteers for test and data mining activities [33, 34]. Not all the crowdsourcing systems rely on a financial reward to involve large number of users. A growing number of tasks are outsourced by transforming them into online games. A paradigmatic example is represented by the ESP game, where a pair of users are shown the same image and are rewarded by a positive score if both users assign a same tag to it [35]. Successful matches, thus, can be used to effectively classify images, and that is why the Google Image search engine has now incorporated the ESP game and data.

Cloud computing has strongly pushed the possibility of gather user-generated data, process it, and visualize them on the web. As a result, lots of collective mapping, or c̈rowdmapping; projects have been created, where users describe phenomena of interest, ranging from natural disasters to social turbulences, by representing them on online maps [36]. These kinds of infrastructures are particularly appropriate for the involvement of citizens in distributed sensing experiments.

5 Pervasive computing and participatory sensing

Devices employed in the connection to communication networks have converged in size and technological standards. Cell phones have integrated many functions traditionally accomplished by personal computers. In turn, computer manufacturers have privileged products designed for an easy mobile usage, such as new generation tablets. Moreover, cell phones and PCs incorporate sensors of increasing accuracy: GPS sensors, cameras, microphones, accelerometers, thermometers are already a default equipment in most of the mentioned devices. Networks have also accompanied this process, by expanding the availability of an Internet connection throughout daily life. Open-hardware platforms, such as the well-known programmable microcontroller based Arduino, will also facilitate the task of taking an input signal from the environment, process it, and deliver it through the Internet at a low cost.

The large number of sensors deployed has already suggested to turn urban areas into “smart cities”, that is, intelligent and complex organisms able to process the sensors signals, visualise them and possibly trigger the automatic execution of appropriate actions [37]. Everyaware’s goal, though, is to involve citizens into a techno-social integrated process.

The mobile, powerful, and permanently connected equipment described above makes any citizen a potential source of sensor data about her/his environment, with little or no required scientific skill. Participatory sensing experiments involve communities of such individuals in the monitoring of a particular issue, e.g.

the quality of a metropolitan environment [11, 38] or the redevelopment of urban areas [20]. This is not entirely new, since numerous čitizen scienceïnitiatives have been already launched in areas ranging from ornitology to astronomy, with or without the of help sensors. A recent trend is represented by the integration of crowdmapping and participatory sensing through the web. Online platform such as www.pachube.com have shown in practice how the data collection activity and its visual representation reinforce themselves. Particular events, such as the nuclear crisis following the Japan 2011 earthquake, have demonstrated that involving citizens in the environmental monitoring activity is an effective method to build accurate risk maps.

The participation of users in the monitoring affects both the resolution and the quality of the data collected. While traditional sensing generally involves a small number of highly controlled observation points, distributed sensing relies on the possibility of gathering large amounts of data from many uncontrolled sources, which cannot ensure high data quality standards; however, by means of statistical methods together with the possibility of storing and post-processing large datasets, this quality gap with respect to traditional sensing can be overcome. Therefore, the analysis tools should be able to detect and filter out deviations due to sensors misuse or to biases introduced by the users themselves. As we explain in the following, the knowledge of the underlying social interaction is crucial for such a task.

Monitoring the environment is a beautiful framework for ICT-based citizen science experiments: there is a strong connection between individual awareness and good collective practices aiming at a more efficient usage of commons. Of course, the most important issue is the effective recruitment of a number of active volunteers. Reasonably, users provide larger quantities of data if the observed phenomenon and its management directly concern the community involved in participatory sensing experiments, as shown in surveys about the volunteer motivation [39, 40]. A low required effort and an efficient feedback mechanism are likewise crucial in encouraging the participation. It is important, in particular in the preliminar stage of the recruitment, that users would benefit soon from their involvement without having to wait for a large participation. On the contrary, the need of a large number of participants would probably make the experiment fail, since it would require a sufficient large number of users to self-sustain the feedback mechanism [41], in perfect analogy with the physical concept of “critical mass”.

6 Empirical data and subjective opinions

Along with sensors, human themselves can act as a probe to monitor many phenomena, especially in the environmental area. In fact, the opinion of a citizen summarized by a numerical rating, a tag, or a social network message often conveys relevant information, although influenced by subjective biases, about a particular event or situation.

The comparison of sensor data and (geo-tagged) opinions has a twofold importance. On one hand, it allows to understand how users perceive combinations of multidimensional observations: which of the environmental characteristics (temperature, air quality, noise pollution etc.) has the stronger impact on their perception? On the other hand, the knowledge of both the environmental conditions and the social network a user has been exposed to, allows estimating how much social biases affect his/her perception of the quality of the environment and individual behaviour. Detecting the opinion leader in social networks, spotting the imitation mechanisms at work and the inertial effects as opposed to opinion shifts, is crucial if one seeks not only to monitor the existing practices, but also to induce better ones. At this aim, so called ”sociophysics” has developed many tools and models to study the opinion dynamics taking place on social networks. This interdisciplinary field employs concepts borrowed from the theory of complex systems in statistical physics. Statistical physics has proven to be a very fruitful framework to describe phenomena outside the realm of traditional physics [42]. The last years have witnessed the attempt by physicists to study collective phenomena emerging from the interactions of individuals considered as elementary units in social structures: from opinion, cultural and language dynamics to crowd behaviour, hierarchy formation, human dynamics, social spreading. In all these social phenomena the basic constituents are not particles but humans and every individual interacts with a limited number of peers, usually negligible compared to the total number of people in the system. In spite of that, human societies are characterized by stunning global regularities [43]. There are transitions from disorder to order, like the spontaneous formation of a common language/culture or the emergence of consensus about a specific issue. It may be surprising, but the idea of a physical modelling of social phenomena is in some sense older than the idea of statistical modelling of physical phenomena. The discovery of quantitative laws in the collective properties of a large number of people, as revealed for example by birth and death rates or crime statistics, was one of the factors pushing for the development of statistics and led many scientists and philosophers to call for some quantitative understanding (in the sense of physics) on how such precise regularities arise out of the apparently erratic behaviour of single individuals. Hobbes, Laplace, Comte, Stuart Mill and many others shared, to a different extent, this line of thought [44].

7 Data gathering, analysis and validation

Systems modelling relies on large-scale data structures but these ones are often inaccessible or not envisaged as important until a main event occurs. Systems modelling will rely in the future, more and more, on forms of data gathering involving individual agents moving across system domains. New ways of gathering and communicating data, enabled by ICT, produce new forms of involving the public. Sensor-based gathering of temperature and noise-level information, for example, allows collection of data on totally new scales. Use of mobile phones for this purpose seems a particularly powerful way of getting ordinary people involved, as it could integrate subjective data (moods, opinions) as well as scientific readings. The World Wide Web provides several tools, such as collaborative systems (e.g., del.icio.us), micro-blogs (e.g., Twitter), and other so-called Web 2.0 services to gather opinions in a user-friendly manner. It is possible to make more sense of the collected data when they are displayed over a base map of the local streets either via GPS readings or by captures through a map interface. Data gathered in this way could, if socially accepted, induce widespread opinion dynamics leading to changes in behaviour. The idea is that the availability of locally relevant digital data, together with their analysis, processing and visualization should trigger a bottom-up improvement of social strategies. On the other hand, the augmented awareness could be a source of pressure on the relevant stakeholders and policy makers. Data are of course relevant also directly for policy makers. Every policy ought to be tested with data. While there is indeed an over dependency of governments with assessing their policies with data (impact assessment), there is a problem of gathering data on the right level and of the right type. Often there is a mismatch of scale and type. Here comes the issue of data validation and interpolation. Tools and techniques able to cope with huge sets of heterogeneous and often unreliable data to efficiently reconstruct dynamic system models at multiple levels are crucially needed, along with more traditional methods of controlling the quality of the collected data [24]. This includes data-rich probing technologies, protocols and experiments to gain realistic data on what goes now under the denomination of techno-social systems. A techno-social system, in this sense, acts like a lens that captures information from the environment: one has to explore the peculiarities of having human agents as sensing nodes, the role of noise sources at different scales, the effect of opinion bias, information spreading in the community supporting the techno-social system, network effects, and so forth. More generally, reliable data play a crucial role also in refinement of models as Science looks at the available data and stimulates model corrections (see for example the modelling of climate change at the beginning of the 1990s where a mismatch between models and data led to introducing aerosols into the equations that yielded a far better match).

8 Modeling and predictability

The modelling activity is crucial to reach a deep theoretical and pragmatic understanding of social phenomena [42]. When coupled with a serious data analysis activity devoted to the discovery of emergent features, it can result in a virtuous loop, where measures inspire models, model analysis suggests new measures and observations, which in turn allow the evaluation and refinement of models. Once a satisfactory level of agreement between theory and experiments is achieved, the theoretical description can suggest and inspire control strategies and directions for improving systems.

The modelling and the simulation of such multi-level systems, should take into account the relevant technological, psychological and social dimensions as well as the realistic diversity of behaviours, social and spatial structures and knowledge. The theoretical foundations for understanding and modelling the behaviour of such systems lie in uncovering the basic interactions between the user and the ICT system, as well as the interactions between users mediated by the ICT system. Realistic models of these interactions are still lacking in a validated form grounded on experimental data. Not only the technological aspects of the ICT platform, but also the psychological and cognitive factors come into play at this level, together with the social structure of the community and the spatial structure of the environment where users act. It is important to provide theoretical foundations for the dynamical aspects, grounding theoretical constructions on data from real systems and exploring the space of possible behaviour by means of computer simulations.

One of the main objectives of the modelling activity is that of coming up with a notion of predictability for socio-technological systems. Several aspects are relevant here where the notion of predictability can be investigated. (i) Inertia and critical mass: an important aspect of the predictability in techno-social systems is related to the individual inertia, i.e., the resistance of an individual in changing his/her opinion and more generally his/her habits. The individual inertia, on its turn, will generally depend on the pressure exerted by the environment and by peers. It is thus important to investigate whether critical thresholds (critical mass) exist for triggering an opinion change and how these thresholds depend on the peer pressure or other social factors. (ii) Response to a perturbation: another crucial aspect to assess the predictability of a generic system is its response function to external perturbations, e.g., a specific policy change; (iii) Scale effects: an additional possible perspective of the notion of predictability is to consider the role played by the system size. The question can be posed as follows. Suppose one has observed a given phenomenology in a small community, how much of the acquired knowledge can be transposed to a larger (some-times much larger) community? This is a typical problem in statistical physics for which a lot of tools and methodologies are currently available.

9 Platforms for an experimental social science

Though only a few years old, the growth of the World Wide Web and its effect on the society have been astonishing, spreading from the research in high-energy physics into other scientific disciplines, academe in general, commerce, entertainment, politics and almost anywhere where communication serves a purpose. Innovation has widened the possibilities for communication. Blogs, wikis and social bookmark tools allow the immediacy of conversation, while the potential of multimedia and interactivity is vast. The reason for this immediate success is the fact that no specific skills are needed for participating. In the so-called Web 2.0 [45] users acquire a completely new role: not only information seekers and consumers, but information architects, cooperate in shaping the way in which knowledge is structured and organized, driven by the notion of meaning and semantics. In this perspective the web is acquiring the status of a platform for social computing, able to coordinate and exploit the cognitive abilities of the users for a given task. One striking example is given by a series of web games [35], where pairs of players are required to coordinate the assignment of shared labels to pictures. As a side effect these games provide a categorization of the images content, an extraordinary difficult task for artificial vision systems. More generally, the idea that the individual, selfish activity of users on the web can possess very useful side effects, is far more general than the example cited. The techniques to profit from such an unprecedented opportunity are, however, far from trivial. Specific technical and theoretical tools need to be developed in order to take advantage of such a huge quantity of data and to extract from this noisy source solid and usable information [46, 47]. Such tools should explicitly consider how users interact on the web, how they manage the continuous flow of data they receive, and, ultimately, what are the basic mechanisms involved in their brain activity. In this sense, it is likely that the new social platforms appearing on the web, could rapidly become a very interesting laboratory for social sciences. In particular we expect the web to have a strong impact on the studies of opinion formation, political and cultural trends, globalization patterns, consumers behavior, marketing strategies.

A very original example is represented by Amazon's Mechanical Turk (MT) (`https://www.mturk.com/mturk/welcome`), a crowdsourcing web service that coordinates the supply and the demand of tasks that require human intelligence to complete. It is an online labor market in which users perform tasks, also known as *Human Intelligence Tasks*, proposed by "employers" and are paid for this. Salaries range from cents for very simple tasks to a dollar or more for more complex ones. Examples of tasks range from categorization of images, the transcription of audio recordings to test websites or games. MT is perhaps one of the clearest examples of the so called crowdsourcing and thousands of projects, each fragmented into small units of Work, are performed every day by thousands of users. MT has opened the door for exploration of processes that outsource computation to humans. These human computation processes hold tremendous potential to solve a variety of problems in novel and interesting ways.

Thanks to the possibility of recruiting thousands of subjects in a short time, MT represents a potentially revolutionary source for conducting experiments in social science [48, 49]. It could become a tool for rapid development of pilot studies for the experimental application of new ideas. As a starting point for this new idea of experiments, the blog `http://experimentalturk.wordpress.com/` already presents a review of the results of a series of classic game theoretical experiments carried out on MT [50].

Despite its versatility [49] MT has not been conceived as a platform for experiments. This is the reason why it is important to develop a versatile platform to implement social *games*. Here the word game is intended as an interaction protocol among a few players implementing a specific task and it is used as a synonym of experiment. The development of such web games has to take into account the following points: (i) the running applications must be modular, so that they can interact with different services and interfaces and can be interchangeable; they must be event-driven in order to ease the real time interactions between users and have to possibly interact with social networks and cloud services through their own APIs; (ii) the transactions between synchronous (i.e., real time) and asynchronous mode should be the most transparent as possible; (iii) the cross-platform web-based graphical interface, either ajax, flash or java, must be differently designed according to the client platform (e.g. desktops, smart-phones, tablets, etc.); (iv) the hosting infrastructures have to be carefully designed to manage an expected heavy load and to process and store the relative amount of data. The advantage of this kind of experiments is that every useful piece of information and detail of the evolution will be fully available and leveraged for benchmarking as well as for the modelling activity. Moreover the effects of social interactions can be observed with a larger statistical basis and in a more controlled environment.

In the framework of EveryAware a first prototype of such a platform is being realized, dubbed *Experimental Tribe* (`www.xtribe.eu`) (ET). ET is intended as a general purpose platform that allows the realization of a very large set of possible games. It has a modular structure through which most of the complexity of running an experiment is hidden in a complex Main Server and the experimentalist is left with the only duty of devising the experiment as well as a suitable interface for it. In this way most of the coding difficulties related to the realization of a dynamic web applications are already taken care by the ET Server and the realization of an experiment should be as easy as constructing a webpage with one the main utilities for it (e.g., googlesite). There are different kind of users for ET: the system administrator who runs the whole ET Server and provides all the necessary API's for it; the experimentalists who run individual experiments through ET and the players who contribute to one or more individual games. Accordingly the ET has a modular structure with several components:

i) a Web Server through which users access the games;

ii) a Main Server that manages the whole status of the system: users registration and login, pairing online users, managing individual games, giving feedback and payoffs to users, etc. It is composed on its turn by several elements devoted to different main tasks: message handling service, game handling service, transaction handling service;

iii) a Manager that allows the configuration of individual games as well the corresponding data gathering and analysis. This Manager is handled by the experimentalists though the system provides a standard implementation;

iv) several different databases to store information about experimentalists, players, instances of the games, etc.

ET will be shortly online and ready to host experiments by the community at large.

10 The EveryAware Platform

A key technological novelty of EveryAware is the design and the implementation of the so-called EveryAware platform that will handle both sensor and subjective data acquisition. The platform will be a modular system based on two hardware components: a smartphone controlling the data acquisition and a modular sensor box with several pluggable sensors. This approach guarantees high scalability of the overall system and allows an optimal distribution of sensors (e.g., wearable sensors for air or noise pollution). At the same time associated software platform will allow users to easily upload their sensor readings, and equally easily tag these with subjective information. The ICT challenge here is that of making this upload process as automatic and natural for the user as possible.

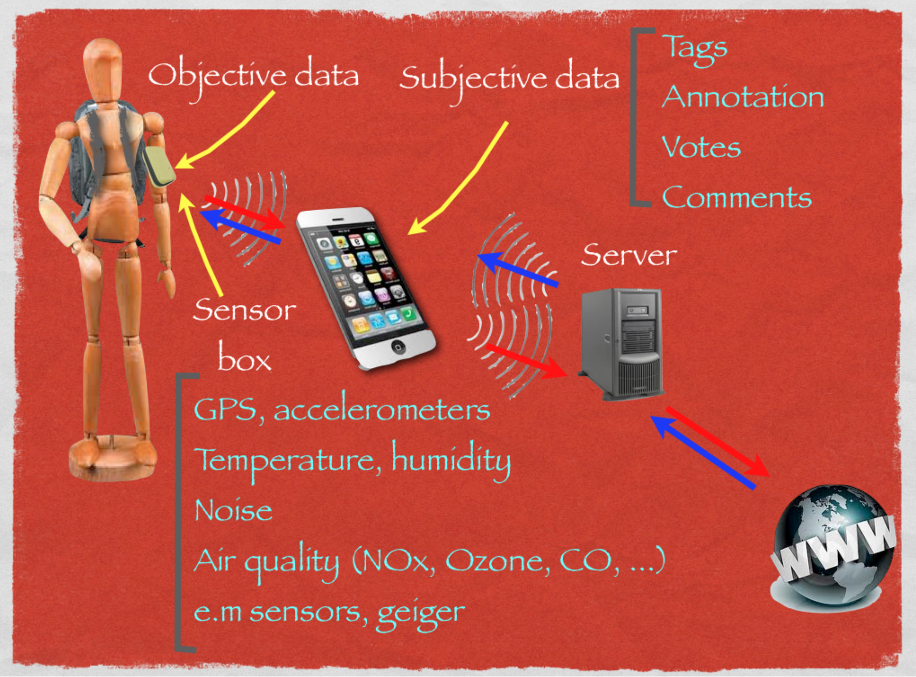

Figure 3: Cartoon illustrating the structure of the EveryAware platform

More specifically the EveryAware platform will contribute:

- to develop a **hardware platform** enabling citizens to effortlessly capture personal environmental information. The platform will incorporate an interoperable set of sensors for environmental parameters connectable to a smartphone, a central server unit for data storage and processing. The platform is thought to be intrinsically scalable allowing the integration of progressively miniaturized, embedded or wearable sensors with increasingly powerful smartphones and interfaces.

- in conjunction with the above, to develop a **software platform** enabling citizens to effortlessly capture information related to their behaviour and choices. This platform will be seamlessly integrated with the **hardware platform** and will also pass data to the central server unit for data storage and processing. A suite of personal computer and smartphone applications will allow users to exchange sensor data and opinions to and from the central unit and the social network composed of other participants.

- to develop **protocols** for community engagement in urban sensing experiments, enabling communities to perform the monitoring activity at grass-roots level, in a decentralised fashion. Here the core research challenge is the development of validated engagement schemes to encourage initial and ongoing community participation. Additionally, research is required to validate whether such techniques can be generally applied across borders and with community groups having differing interests and focus.

- to develop **methods** for real-time analysis of subjective and objective data from users. Here the core research challenge is the development of validated schemes for geo-spatial data fusion, efficient enough to provide appropriate feedback to users in a timely manner. The methods must aggregate distributed, geo-localised, noisy information sources ranging from multi-channel sensor data with subjective opinions of individuals, building a real-time picture of environmentally-relevant factors. Here crucial issues concerning spatial and temporal scale, as well as community size, will need to be dealt with. Targeted research will be carried out to interpolate and model the acquired data, to enhance the understanding and the predictability of the monitored environments, and to feed back context-relevant information to individual contributors.

- to develop **interfaces** and software to feed back the results of the analysis to users in a manner that is both related to their interests and immediately understandable by users with little or no specialist knowledge about environmental issues or geospatial datasets. The information will be fed back by mashing it up with other bodies of user-generated content. The challenge here is to design an appropriate feedback mechanisms using an interface that is suitable for the mobile devices in use and provides sufficient information, in a timely manner, to have potential impact on behaviour. Additionally, this interface should be seamlessly integrated with that developed for the subjective and sensor data capture.

- to develop a deep quantitative **understanding**, at the theoretical and empirical level of the opinion formation processes as well as of how the aggregated opinions of individuals shift over time, driven by localised environmental communication, and how this triggers subsequent changes in individual and group behaviour. The envisioned data fusion affords an unprecedented scientific opportunity to observe and model these phenomena in a way that can immediately impact real-world systems.

11 Dissemination

A proper dissemination is a crucial aspect of the whole concept of participatory sensing. The goal is to raise awareness about the long-term benefits that can be reached with a self-sustained feedback mechanism, involving the public, the scientific and technological communities, and crucially, policy makers, relevant stakeholders and governmental organisations. In order to raise a larger public awareness into the capabilities of present day, particularly in young generations, so to reach the above-mentioned critical mass, it is necessary to develop demonstrators, to start up case studies, and to make a massive use of international popular and scientific press. Most importantly, the creation of on-line social communities, their interaction with the collected and processed information and a direct bridge with policy institutions can be largely favoured by the use of the Internet, at rather low costs.

12 Relevance for a long-term vision

Europe faces a number of challenges: environmental and climate changes, economic and financial difficulties, social and democratic solidity. EveryAware expects to contribute to the solution of such challenges, in several respects:

i) fostering awareness and improving environmental monitoring will contribute to the reduction of pollution and energy waste in urban areas;

ii) the innovative integration of mobile technology, sensors, and socially-aware ICT represents a contribution to a shift towards a green and sustainable economy, that a large policy makers' consensus indicates as one of the exit strategies from the current financial and economic crisis;

iii) fostering the birth of environmentally positive communities, stimulating bottom-up participation, collecting public opinions and perceptions in a trusted way, are all factors that will empower policy makers with tools to gauge and orient the democratic processes of decision making.

iv) stimulating the development of ICT-based infrastructures for an empirical, computational and theoretical approach to social dynamics processes.

References

[1] Al Gore. An inconvenient truth, 2007.

[2] Randers J. Meadows D. and Meadows D. *Limits to Growth*. Chelsea Green Publishing, 2004.

[3] N. Stern. *The Economics of Climate Change*. Cambridge University Press, 2007.

[4] J. Corfee-Morlot, M. Maslin, and J. Burgess. Global warming in the public sphere. *Phil. Trans. R. Soc. A*, 365:2741–2776, 2007.

[5] J. McGlade. Climate crisis needs empowered people, 2009. `http://news.bbc.co.uk/1/hi/sci/tech/7893230.stm`.

[6] Department of Economic United Nations and Population Division Social Affairs. World urbanization prospects: The 2009 revision. available at www.unpopulation.org, 2010.

[7] E. Paulos, R.J. Honicky, and B. Hooker. Citizen science - enabling participatory urbanism. In M. Foth, editor, *Handbook of Research on Urban Informatics: The Practice and Promise of the Real-Time City*, pages 414–433. IGI Global, 2009.

[8] R. Milton and A. Steed. Mapping carbon monoxide using gps tracked sensors. *Environmental Monitoring and Assessment*, pages 1–19, 2007.

[9] Anthony Steed and Richard Milton. Using tracked mobile sensors to make maps of environmental effects. *Personal Ubiquitous Comput.*, 12(4):331–342, 2008.

[10] B. Hillier B. Croxford, A. Penn. Spatial distribution of urban pollution: civilizing urban traffic. In *Proceedings of the Fifth Symposium on Highway and Urban Pollution*, 1995.

[11] E. Paulos, R. Honicky, and E. Goodman. Sensing atmosphere workshop - position paper for the sensing on everyday mobile phones in support of participatory research. *ACM SenSys*, 2007.

[12] V. Regecová and E. Kellerová. Effects of urban noise pollution on blood pressure and heart rate in preschool children. *Journal of Hypertension*, 13(4):404–412, April 1995.

[13] Stephen A Stansfeld and Mark P Matheson. Noise pollution: non-auditory effects on health. *Br Med Bull*, 68(1):243–257, 2003.

[14] L. Francis M. Haklay and C. Whitaker. Mapping noise pollution. *GIS Professional*, 2008.

[15] M. Stevens N. Maisonneuve. Measure and map noise pollution with your mobile phone, 2008.

[16] The digital geographers, 2009.

[17] P. Aoki, R.J. Honicky, A. Mainwaring, C. Myers, E. Paulos, S. Subramanian, and A. Woodruff. A vehicle for research: Using street sweepers to explore the landscape of environmental community action. *proc. CHI 2009 ACM Conference on Human Factors in Computing Systems*, pages 375–384, 2009.

[18] S. Darby. Why, what, when, how, where and who? developing uk policy on metering, billing and energy display devices. In *Proceedings of ACEEE Summer Study on Energy Efficiency in Buildings*, 2008.

[19] D. Cuff, M. Hansen, and J. Kang. Urban sensing: out of the woods. *Commun. ACM*, 51(3):24–33, 2008.

[20] Burke J., Estrin D., Hansen M., Parker A., Ramanathan N., Reddy S., and Srivanstava N. B. Participatory sensing. In *Proceedings of the World Sensor Web Workshop, ACM SENSYS (Boulder, CO, 2006)*, 2006.

[21] M. F. Goodchild. Citizens as sensors: the world of volunteered geography. *GeoJournal*, 69:211–221, 2007.

[22] A. Flanagin and M. Metzger. The credibility of volunteered geographic information. *GeoJournal*, 72:137–148, 2008.

[23] M. Goodchild. Commentary: whither vgi? *GeoJournal*, 72(3):239–244, 2008.

[24] Andrea Wiggins, Greg Newman, Robert D. Stevenson, and Kevin Crowston. Mechanisms for data quality and validation in citizen science. In *"Computing for Citizen Science" workshop at the IEEE eScience Conference*, Stockholm, Sweden, 12/2011 2011.

[25] Goodman Elizabeth. Three environmental discourses in human-computer interaction. In *CHI EA '09: Proceedings of the 27th international conference extended abstracts on Human factors in computing systems*, pages 2535–2544, New York, NY, USA, 2009. ACM.

[26] M. Haklay and P. Weber. Openstreetmap: User-generated street maps. *IEEE Pervasive Computing*, pages 12–18, 2008.

[27] Oded Nov. What motivates wikipedians? *Commun. ACM*, 50(11):60–64, 2007.

[28] Y. Benkler. Coase's penguin, or, linux and the nature of the firm. *Yale Law Journal*, 112:369–446, 2002.

[29] Adam Mathes. Folksonomies – Cooperative Classification and Communication Through Shared Metadata, December 2004. `http://www.adammathes.com/academic/computer-mediated-communication/folksonomies.html`.

[30] Scott A. Golder and Bernardo A. Huberman. Usage patterns of collaborative tagging systems. *J. Inf. Sci.*, 32(2):198–208, April 2006.

[31] Ciro Cattuto, Vittorio Loreto, and Luciano Pietronero. Semiotic dynamics and collaborative tagging. *Proc. Natl. Acad. Sci. USA*, 104:1461, 2007.

[32] Ciro Cattuto, Alain Barrat, Andrea Baldassarri, Gregory Schehr, and Vittorio Loreto. Collective dynamics of social annotation. *Proc. Natl. Acad. Sci. USA*, 106(26):10511–10515, 2009.

[33] D C Brabham. Crowdsourcing as a model for problem solving: An introduction and cases. *Convergence: The International Journal of Research into New Media Technologies*, 14(1):75–90, 2008.

[34] Aniket Kittur, Ed H. Chi, and Bongwon Suh. Crowdsourcing user studies with mechanical turk. In *CHI '08: Proceeding of the twenty-sixth annual SIGCHI conference on Human factors in computing systems*, pages 453–456, New York, NY, USA, 2008. ACM.

[35] Luis von Ahn and Laura Dabbish. Labeling images with a computer game. In *CHI '04: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 319–326, New York, NY, USA, 2004. ACM.

[36] Ory Okolloh. Ushahidi, or 'testimony': Web 2.0 tools for crowdsourcing crisis information. *Participatory Learning and Action*, 59(1):65–70, 2009.

[37] Urbanos home page. `http://www.urbanlabs.net/index.php/UrbanLabs_OS_(English)`.

[38] L. Steels and E. Tisselli. Social tagging n community memories. In *AAAI Spring Symposium on Social Information Processing, Stanford CA*, 2008.

[39] M. Jordan Raddick, Georgia Bracey, Pamela L. Gay, Chris J. Lintott, Phil Murray, Kevin Schawinski, Alexander S. Szalay, and Jan Vandenberg. Galaxy zoo: Exploring the motivations of citizen science volunteers. *Astronomy Education Review*, 9(1):010103, 2010.

[40] Jill Lindsey Harrison. Parsing participation in action research: Navigating the challenges of lay involvement in technically complex participatory science projects. *Society and Natural Resources*, 24(7):702–716, 2011.

[41] Nicholas D. Lane, Shane B. Eisenman, Mirco Musolesi, Emiliano Miluzzo, and Andrew T. Campbell. Urban sensing systems: opportunistic or participatory? In *Proceedings of the 9th workshop on Mobile computing systems and applications*, HotMobile '08, pages 11–16, New York, NY, USA, 2008. ACM.

[42] Claudio Castellano, Santo Fortunato, and Vittorio Loreto. Statistical physics of social dynamics. *Reviews of Modern Physics*, 81(2):591–646, Apr-Jun 2009.

[43] M. Buchanan. *The social atom.* Bloomsbury, New York, NY, USA, 2007.

[44] P. Ball. *Critical Mass: How One Thing Leads to Another.* Farrar, Straus and Giroux, London, UK, June 2004.

[45] T. O'Reilly. What is web 2.0, 2005.

[46] K.J. Arrow. Information dynamics in the networked world. *Inform. Syst. Front.*, 5(1):5–5, 2003.

[47] B. A. Huberman and L. A. Adamic. Information Dynamics in the Networked World. In E. Ben-Naim, H. Frauenfelder, and Z. Toroczkai, editors, *LNP Vol. 650: Complex Networks*, pages 371–398, 2004.

[48] Lydia B. Chilton, Clayton T. Sims, Max Goldman, Greg Little, and Robert C. Miller. Seaweed: a web application for designing economic games. In *Proceedings of the ACM SIGKDD Workshop on Human Computation*, HCOMP '09, pages 34–35, New York, NY, USA, 2009. ACM.

[49] Gabriele Paolacci, Chandler Jesse, and Panagiotis G. Ipeirotis. Running experiments on amazon mechanical turk. *Judgment and Decision Making*, 5:411–419, 2010.

[50] Siddharth Suri and Duncan J. Watts. Cooperation and Contagion in Networked Public Goods Experiments. *Computing Research Repository (CORR)*, 2010.