CommonSENSE:

A participatory design toolkit for shaping physical space through real-time data

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***Abstract*— CommonSENSE is a participatory design toolkit which aims to support communities, neighbors, flatmates, researchers and hobbyists, to creatively explore the potential of their own living space and actively engage them in its design and re-arrangement. Through a sensor kit gathering real time space occupancy data and an online design engine where users access and act upon these data to produce or evaluate design solutions, the platform enables users to document and share their habits and desires, visualize design ideas and test them in physical space. CommonSENSE envisions an alternative definition of "environment intelligence" where embedded systems and information technology turn users into active participants in the design of their living environment. This paper presents the implementation details of this participatory platform prototype in the case of the Athenian typical apartment block (polykatoikia) and discusses its spatial and theoretical implications from three different perspectives: as a participatory design engine prototype, an "urban intelligence" tool and an open source development toolkit.**

Keywords-participatory design; distributed sensor network; design engine; greek polykatoikia; common space; urban intelligence; open architecture

I. INTRODUCTION

The ubiquitous use of computation and information technology renders urban and domestic activities increasingly data-centric, to the extent that one can talk about a "digital blanket" layered over the physical world [1]. The management of these data creates the prospect of developing responsive and interactive environments, which employ embedded systems, communication and information technologies in order to enhance user activity and produce an "environment intelligence". The vision of intelligent environments, from the level of the house to the level of the city, is to merge computation with the physical world to the extent that the used technological systems become invisible to the user [2]. In this condition, the user would only experience the outcome of a chain of computing and data manipulation, manifested as a spatial or environmental change.

This paper discusses a scenario where information technology and real time data are employed to engage users in an open negotiation of the physical, spatial and functional characteristics of spaces that they inhabit. In this scenario, the role of the user transcends that of an "actuator" and becomes that of a "designer" (Fig.1). This proposes an alternative "intelligent environment" diagram, where the collected data from the sensing of the users' living habits are processed by the users themselves, who use them to produce or explore design alternatives. The vision is to develop a collective design intelligence, by engaging users in reflection upon their living habits, investigation of the spatial expression of their needs and desires and negotiation of these intentions with their neighbors, in an open, collaborative process.

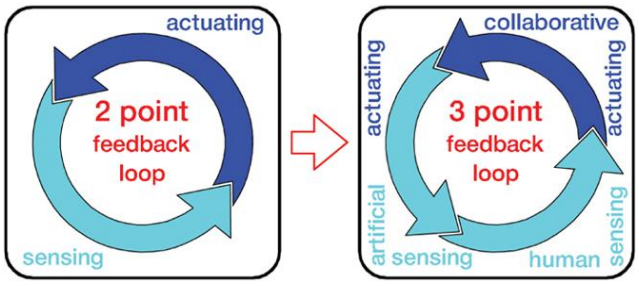

Figure 1. Data management loops: from sensing and actuating to active user participation through data access.

CommonSENSE is a participatory design toolkit which uses digital data to empower users to collaboratively intervene in the physical spaces they utilize. A distributed sensor network maps space occupancy data in real time, while an online design engine visualizes these data, provides design recommendations in response to user habits or declared needs and desires, or allows users to develop their own design solutions through

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interfaces for different levels of design "expertise". The duality of the platform, operating both at a physical and digital level, allows for local, small scale interventions to be interconnected, offering the possibility of exchanging design ideas and experiences, whose influence could potentially transcend the domestic level and acquire urban dimensions. In contrast to global systems, this platform aims to advocate for distributed, context-sensitive interventions which are combined to produce a larger impact.

Additionally, CommonSENSE participates in multiple discussions: first, it proposes a new design methodology which uses current design and fabrication technologies to engage users in the creation of their own environments; second, it gives the perspective of a bottom-up urban development tool, based on distributed interventions rather than global actions; third it advocates for an alternative model of peer to peer data management and explores the prospect of commons based design in physical space.

II. Managing the "Digital Blanket": An Alternative Definition of "Environment Intelligence"

A. Domestic Data: Ambient Home

The pervasive presence of digital technologies can be traced at a domestic level. Sensing and actuating is deployed within residential environments to increase comfort, provide safety or regulate user habits. Extensive research is conducted in the seamless integration of these technologies in the domestic environment so as to create a non-intrusive ambient intelligence, responding to the inhabitant's needs and desires. A characteristic example in this direction is the Newcastle University Culture Lab Ambient Kitchen project [3], which explores the use of pervasive computing in residential settings, with the intention to fully integrate the sensors and actuators in the fabric of the kitchen itself. The project comprises projectors, wireless sensor network, radio-frequency identification (RFID) readers, cameras, and floor sensors, which sense the user activities and perform multiple functions, from recipe recommendation to medication reminders.

B. Urban Data: Real-Time City

In the scale of the city, a growing number of activities, from navigation and way finding to transactions and communications, are mediated by information technologies. This ubiquitous cloud of digital data, corresponding to different manifestations of urban life, radically alters the way in which cities are represented and experienced. As the field of data visualization advances, mapping transcends the planimetric depiction of the city's physical settings and takes the form of dynamic representations of urban life, capturing flows of people and information in real time. Notions such as place and proximity, are thus redefined through an intensive relation between the characteristics of the physical and the topologies of the digital.

Apart from alternative conceptualizations of the city, the layer of digital data also generates the prospect of developing alternative ways of managing urban environments. The concept of the "real-time" [4] reflects the possibility of using data produced through urban activities in order to create more "responsive" and "intelligent" environments which can adapt in real time to the constant shifts of the life they foster. In fields such as urban mobility, fleets of smart vehicles and self-adjusting trajectories, bring the vision of a "smart city" [5] to the level of implementation.

C. Data Control: The Emergence of a Participatory Perspective

The ubiquity of information, either at urban or domestic level, is combined with human activity to produce a loop of sensing and actuating, which allows for augmentation of physical space, alternative modalities of use, or even for alteration of physical space's attributes (e.g. kinetic architecture). As environments become increasingly smarter the notion of control acquires a central role. The current conceptualization of such environments is often closely aligned with the vision of automation; of a technology so pervasive that becomes invisible. In this scenario, the "design" of the environment is based on a set of predefined rules, embedded in the system operation, which "respond" to various user actions. Other scenarios allow the user to adjust certain parameters of the system or even the degree of automation itself [6]. However, the operational modes of the underlying technological platform, which contains the design decisions regulating the "responsiveness" of the environment, is almost by default inaccessible to the user.

In an urban level, the discussion on user control acquires an additional dimension, in relation to data governance. Currently, the data produced by user activities are centrally collected and managed, for the interest of large public or private agents (telephone companies, government agencies etc). This condition finds the counterbalancing vision of a distributed, collective model of information management, engaging individuals and communities in processes of self-reflection and peer design. Cesare and Gabriella Padovano Blasi's article [7] in Nicholas Negroponte's collection "Reflections on Computer Aids to Design and Architecture" (1975), is an indicative example of the latent vision of collective information and information processing for self-planning communities, articulated since the early computational era.

III. The CommonSENSE Platform

The objective of the commonSENSE platform is to explore an alternative definition of "environment intelligence" along the lines of user control, collaboration and participation. It aims to take position in response to two crucial questions raised by the advancement of computational tools and information technologies: Is it possible for online collaboration and communication to go beyond virtual or immaterial premises and re-shape our material world? How can technological practices mediate a "designer-unmediated" space -or in other words- a "user-editable-space"?

A. *Toolkit Design Principles*

The commonSENSE toolkit proposes a potentially generalizable diagram (Fig. 2) for participatory (re)design of spaces with multiple stakeholders. Participatory design methodologies such as advocacy planning [8], have implemented a similar concept where user groups play an active role in the architect's design decisions. The proposed model is different than these methodologies in that it disengages the architect from the design process and gives control to the users, who become responsible for evaluating alternatives and making the final design decisions. CommonSENSE, as a computational platform/design engine, encodes a set of necessary design constraints, accommodates different levels of user "design expertise" and empowers users to engage actively in design through the negotiation of their space boundaries.

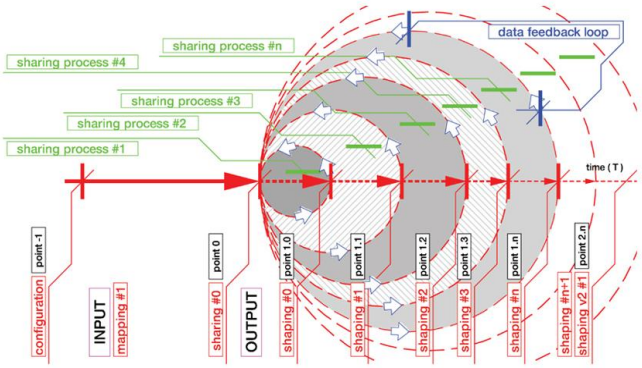

Figure 2. Diagrammatic depiction of the commonSENSE platform basic loop: 1. Data collection (sensing) 2. Collaborative data management - design negotiation in virtual model (sharing) 3. Implementation of design decisions in physical space.

CommonSENSE is based on a series of principles and realizations. It is supported that users have the right to determine, influence and design their space according to their beliefs, desires and wishes. Spatial configuration is not an architectural monopoly, although the architectural discipline is shifting towards morphogenetic, complex geometrically and structurally, parameterized motives. The platform's function is to promote design procedures, by employing the notions of the diagram, the event and the situation, rather than the plan, the territory and the border. Instead of translating needs, desires, habits, uses through the eyes of the expert, it advocates for the creation of a common ground of discussion and mutual involvement of all participating sides [9].

CommonSENSE comprises a low tech sensor kit, which can be installed at the intervention site, and an online design engine, where individual user design choices are combined into a virtual master-model of the space. The proposed platform's operational modes are thus based on the reciprocity between the virtual and the actual, the objective and the subjective, the individual and the collective. By bringing forth these tensions, commonSENSE does not only operate as a platform for design negotiation, but also as a tool for self- reflection on the user's living habits and the active exploration of their spatial implications.

Apart from encouraging user participation and collaboration, commonSENSE envisions to empower users to create their own designs without the protrusive mediation of the architect. This is manifested in the design of the interface, which aims to bridge the gap between verbal declarations of user intentions and their spatial representations. The design engine generates spatial configurations based on a series of organizational diagrams produced by the users in an intuitive visual editing interface. Users can freely operate their "zones of interest" (private space) and suggest modifications for the common spaces, which are evaluated by other participants. The design engine also makes recommendations, based on two types of data: user desires, which are declared through design decisions using the commonSENSE interface, and sense data which are drawn from the sensing infrastructure installed in the physical space.

B. *Potential Intervention Site(s): The "In-Between"*

The platform follows a conceptual scheme where physical space provides a set of data that can be subsequently managed in a digital layer of information; yet, it is important to insist on the rendering of this data elaboration back again into spatial terms. In other words, the notions of physicality and digitality cannot be approached discretely, but rather as two different aspects of reality, giving feedback to one another in a perpetual way.

The issue raised focuses on the actual characteristics that physical space should demonstrate in order to allow for such secondary spatial manifestations. What are the attributes of this spatial condition which would enable the hosting of emerging activities, unscheduled events, or even architecturally defined transformations, stemming from a bottom-up and decentralized decision making process? This question brings forth the notion of the 'in-between', which would dictate a negotiable, ambiguous and incomplete space, meaning a physical configuration without a clear or predefined identity. Such in-between spaces stand beyond certainties, representing rather a state of fuzziness, where different and incompatible scenarios can deploy. In-between spaces float among prevailing identities or strictly determined intentions and ideologies, allowing for their internal transformation, the experimentation of codes and the emergence of innovative correlations.

With respect to the commonSENSE project, physical areas encompassing in-between characteristics are of great interest, as it is estimated that these could potentially form the ground for the realization of the platform's user-mediated decisions. Therefore, in an effort to trace the physical interpretation of in-between, it is considered essential to explore dipoles such as built/unbuilt environment or private/public space and to interrogate on the dynamic dialectic that emerges from these extremities.

In this context, instead of adopting a tabula rasa approach, commonSENSE acts upon the existing in order to activate its latent potential. CommonSENSE operates in, also in-between, commonplace spaces which are dispersed in the urban fabric

and resist the traditional categorizations of public or private. Although these spaces hold the potential for playing an active role as nodes in local and potentially urban level (from the neighborhood to the city), they remain inert and underused. The prospect of activating the potential of these spaces, has generated a range of projects, from architectural proposals on "parasites" and attached micro-architectures [10] to self-organized neighborhood level initiatives. This dialectic could actually lead to the activation of the pre-mentioned fuzzy space, where bottom-up, ephemeral events might occur, or even consolidate after a decision that results from a collectively conducted procedure.

These envisioned interventions bear the potential for creative, intuitive and sustainable solutions. However, these inhabitant initiated efforts usually do not escape impediments which neutralize their dynamic potential. Difficulties in decision making, the inertia of physical space and the different levels or lack of design expertise encumber the idea of a dynamically user-editable space.

IV. Case Study: The Athens Polykatoikia

Following the analysis of the fundamental design principles and objectives of the commonSENSE platform, this section presents an implementation scenario in the Athens typical apartment block, the so-called "polykatoikia" (Fig. 3). It is suggested that the application of commonSENSE into this particular type of building will contribute drastically to the activation and regeneration of polykatoikia underused communal spaces, such as corridors, pilotis, backyard, roof terrace, etc. In addition, it is argued that although the polykatoikia concerns a rather rigid and inflexible unit of inhabitance, it also constitutes a minimum cell-unit of collectivity, a spatial structure which encourages social life and collaborative performances. In this context, the commonSENSE implementation challenges the stimulation and re-activation of this collective potential, by supporting real-time communication and action, both in physical and digital space.

Figure 3. 'Polykatoikia' as the cell unit which produces the urban fabric of Athens.

A. Implementation Site: Spatial Rigidity And The Aspect of Collectivity

The polykatoikia building refers to a multi-storey structure which emerged in the Athenian landscape in the late 1920s as the derivative of political and economic conditions. It concerns an urban unit, consisting of approximately 4-6 floors, the form of which was mainly defined by the strict application of construction rules, as well as by an urgent post-war social demand for mass housing production. The polykatoikia block still constitutes a dominant element of the Greek city, by shaping both the urban and social organization of the modern-Greek society [11]. In terms of morphological articulation, the polykatoikia is composed by multiple architectural constituents, which refer to private, as well as to communal spaces. The apartments are characterized by a strict plan typology of rooms and linking corridors, while the communal areas serve as secondary spaces of movement, lighting and ventilation. Indicatively, these include the entrance foyer, a central core of staircase and lifts, the roof terrace and the skylight, a vertical hole within the interior of the building. Finally, the polykatoikia is also connected to a backyard, usually located in the inner part of the urban block. It can be accessed via the pilotis, a system of columns and pillars that lift the whole building mass above the ground, forming a transitional space of car and pedestrian movement underneath [12].

Since the form of polykatoikia stems from a considerably strict imposition of construction regulations, it offers a very limited perspective in terms of flexibility and adaptability (Fig. 4). The polykatoikia constitutes a rigid system of interconnected parts, which apparently do not correspond to the contemporary urban living model and can hardly meet the ever-changing personal and intuitive user preferences and desires [13]. In this direction, the commonSENSE platform serves as an appropriate means of overcoming the limits of physical space, allowing for the re-negotiation of boundaries and the activation of the collaborative potential. By analysing and translating the gathered data into feasible scenarios, commonSENSE does not only provide a ground for communication, but can also suggest spatial solutions that reflect the current common needs and collective intentions.

B. CommonSENSE Technical Infrastructure

1) Hardware: This section speculates about the potential technical implementation of the commonSENSE platform, given its conceptual and operational characteristics. The purpose of this section is not to provide a technical description of the platform, but to outline the fundamental technical requirements and identify corresponding solutions. One of the main inspirations from a technical perspective is the potential of sensor network technologies. The emergence of small and inexpensive sensors based on microelectromechanical systems (MEMS), their favorable comparison in relation to other monitoring technologies and the amplitude of their potential applications [14], has led to the identification of sensor networks as "one of the most promising technologies for the future" [15].

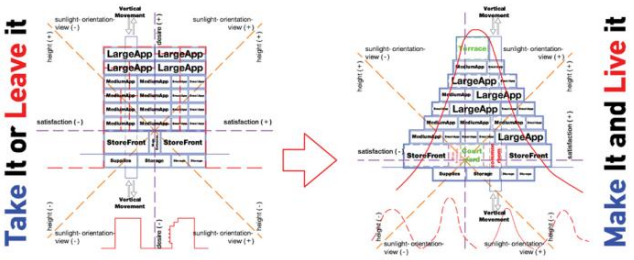

Figure 4. Towards a user-editable space.

The commonSENSE prototype comprises a sensor kit which allows users (the polykatoikia inhabitants) to collect space use and occupancy data, by installing the kit in their apartments and communal spaces of the polykatoikia (Fig 5). This self-monitoring process aims to provide users with awareness of their living habits and encourage them to start re-thinking, re-discussing and re-shaping their living environments. The kit may indicatively include accelerometers placed on windows so as to record their open/close motion/frequency, pressure sensors on the floors in order to measure a particular place's occupancy, or proximity sensors placed in selected locations so as to measure the distance between users and specific objects.

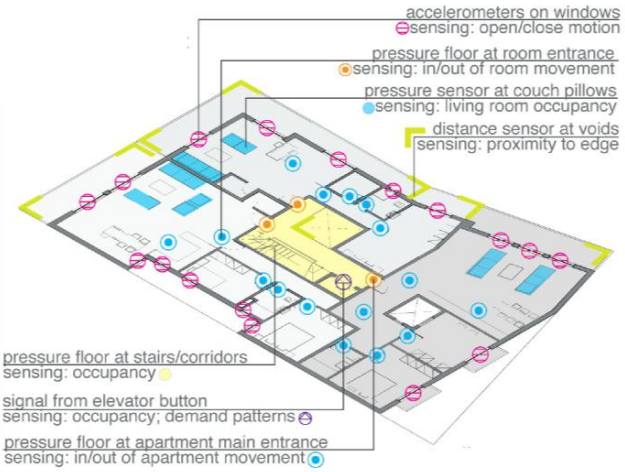

Figure 5. Sensor installation at the level of 'polykatoikia' floor.

A Distributed Sensor Network (DSN) is proposed as an adequate solution for this scenario, as it allows for a collaboration of spatially distributed sensing devices in order to produce meaningful results through the collaboration of local raw data [16], which can vary in kind, accuracy and resolution. An additional advantage is the independence of the sensor network from local node failures, due to its distributed nature. In order to specify in more detail the attributes of this DSN the taxonomy proposed by Vinyals, Rodriguez-Aguilar and Cerquides [17] is employed. In that sense, the sensor network which would be deployed in the CommonSENSE prototype is non-homogeneous (as it employs different kinds of sensors), ad hoc (as users have the freedom to select which kind of activities they desire to monitor and therefore which sensors from the kit to install in their space), dynamic (as nodes are bound to appear and disappear due to external influences), and finally multi-owned (as collective data ownership is one of the main programmatic principles of the commonSENSE platform). The nodes themselves are identified as easily deployable battery charged sensors, with a microprocessor and wireless communication.

2) Software: CommonSENSE allows users to document their habits and desires, share them with their neighbors, develop their own design ideas and test them in physical space. It thus constitutes a virtual space for encounter, reflection and action which is directly interconnected with matters of physical space.

The commonSENSE software has three fundamental functions: first, it visualizes the collected data from the distributed sensor network and translates them into meaningful conclusions on space occupancy and use. Second, it operates as a computer-aided design tool, allowing users to spatialize their desires through "views" for different levels of expertise and third, provides design recommendations based on a set of design principles which are encoded in the system.

More specifically, the data visualization part of the software allows for the translation of the collected raw data from the accelerometers or pressure sensors installed in intervention spaces, into information on user habits. The user has access to all these data pertinent to his/her private space, as well as to the generic statistics on the common spaces of the polykatoikia. Depending on the user's decision, the produced data can either be disclosed or shared with other platform participants/ neighbors.

As far as the design engine is concerned, through an intuitive interface comprising an expandable library of space symbols (e.g. common: staircase, lift, rooftop etc. and private: living room, kitchen, bedroom etc.) users create a linkage of their common and private spaces which is then translated into a spatial diagram (Fig. 6). The level of abstraction in which users operate can vary: hypothetically, the design engine could be supplied with the general polykatoikia building permit drawings and thus have exact dimensional representations of the intervention space. Alternatively, the CAD platform could "pack" the spaces designated by the linkages into "bounding" property shapes. A third scenario would be a collaborative modeling of space, through the collaboration of expert and non-expert users into an open project. This multiplicity of visualization options allows for a low floor-high ceiling conceptualization of the computer aided design platform. In other words, non-expert users can start spatializing their design descriptions or decisions by designating space kinds and connections, while the same model can serve as a framework or initial diagram to be further expanded in order to correspond to an architectural or even three-dimensional model.

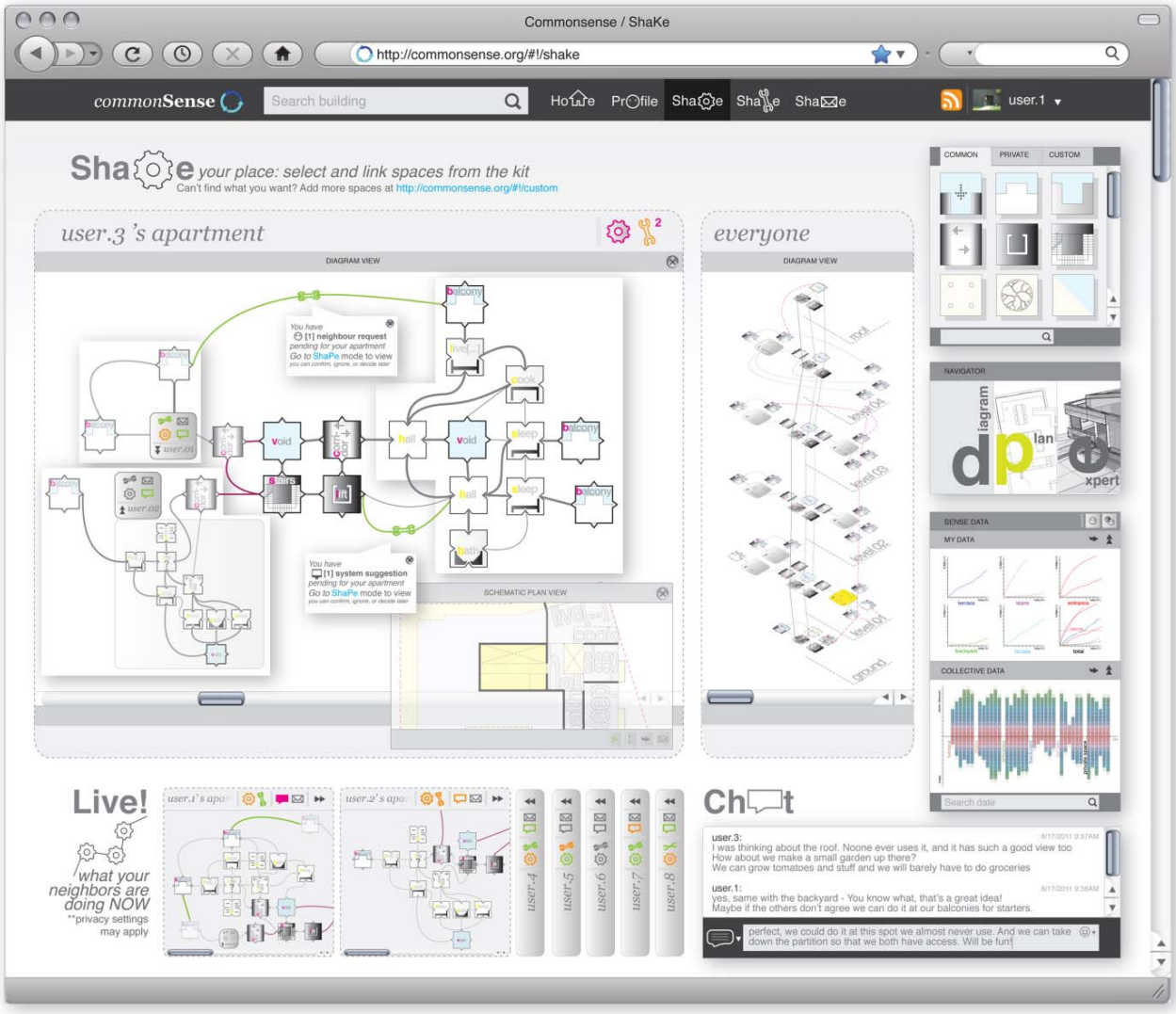

Figure 6. The commonSENSE interface

The purpose of the operation engine is to present design alternatives to the users, based on an evaluation of the collected data. Users/ inhabitants receive the proposed spatial scenarios, evaluate, set them under discussion with their neighbors, keep or alter them and finally test them on physical space. The proposals mainly concern the in-between, underused commonplace spaces and parts of polykatoikia, i.e. the terrace, the entrance, the stairs, the backyard or the façade of the building block. More specifically, the platform proposes the enhancement of vacant or idle spaces with new and somehow unexpected uses (grocery garden, playground, meeting area, renewable resources installation etc.), the rearrangement of standard building elements, as well as the re-negotiation of old and rigid boundaries. CommonSENSE suggests spatial scenarios and architectural solutions, pointing towards a sustainable living system and a collectively defined inhabiting harmonization.

V. Discussion: Three Levels of Openness

As the discussion on "Open Source Architecture" [18] is emerging in academia and practice, questions around "design expertise", "architectural knowledge" and the share-ability of architectural solutions, given the advancement of design and fabrication technologies, come to the foreground. The commonSENSE platform takes part in this discourse by discussing the notion of "Open" from three different perspectives: the platform operation (computer aided participatory design), urban development (collective urban intelligence) and the platform computational design (open source tool).

A. Computer- aided Participatory Design: Opening Architecture

CommonSENSE is founded on the convergence of the digital and the physical. The platform proposes a system which

incorporates learning mechanisms and modulates between supervised and unsupervised procedures, both from the perspective of the platform operation and from that of the users who are producing, evaluating and altering its proposals. From this perspective, commonSENSE recasts the vision of computer-aided participatory design which characterized the early computational proposals such as Nicholas Negroponte's Design Amplfiers (1975) [19], Yona Friedman's FLATWRITER (1971) [20] and Cedric Price's GENERATOR (1979) [21]. These proposals envisioned a new kind of do-it-yourself architecture enabled through a user-machine partnership. The commonSense proposal draws its references, amongst others, from Yona Friedman's FLATWRITER prototype, presented in his book "Toward a scientific Architecture" [22]. The FLATWRITER is a speculative computer application which allows users to produce designs (models of spaces) through combinatorial diagrams of different types of spaces, which are consecutively evaluated according to a self-monitoring of the users living habits. CommonSENSE builds upon this legacy of design engine prototypes, which are currently being revisited by research groups such as the MIT House_n [23], presenting nonetheless a series of fundamental differentiations.

First of all, commonSENSE adopts the concept of a "conversational" interaction between user and design engine, both in order to encourage self-reflection on user assumptions by bringing forth conflicts between desires and actual living habits. The ubiquitous sensing in the case of commonSense, allows a non-intrusive mapping of these habits. The control of the sensor network data by the users prevents the often observed transition from sensing to censing. The collected data are not employed to create external "models" of the users, but are readily available to them for study and modification. Second, the commonSense platform, opposite to the early computational models, embraces conflict as a creative condition and an opportunity for user negotiation. In that sense the design engine becomes merely a platform for the expression and resolution of these conflicts via real-time communication in virtual and/or physical space and not a regulatory framework ensuring their avoidance. Finally, the commonSense design engine allows for a meta-control by the users. Its open source character allows for the modification of the platform design constraints themselves.

B. Urban Collective Intelligence: Towards An Open Urban Development

On the larger scale of the city, commonSENSE is producing a stimulus, by expanding, a summative, qualitative and not merely quantitative effect. This expansion is made, while bearing in mind a distributed field of relations, affects, communication and coordination between individuals and communities. Stemming from the cell-size urban level, it is extending into the gradual development of a swarm of organisms, governed by alternative attitudes on margins, distinctions, production and affection. The two basic points of its sprawl into the urban is generating large- and macro-scale effects by the implemented self-orchestration of small fragmented, however networked, units of collectivity and maintaining open-ended terms and conditions of the desired peer-to-peer emerging connectivities.

C. Open Source

CommonSENSE is an open source tool both from a literal and a metaphoric perspective. The platform operates under the principles of access, knowledge sharing and open development in order to accommodate the different needs and desires of the communities which utilize it. Along these lines, each application bears the characteristics of the specific locality and typology. The running of the program is structured as a continuous loop: a(n architectural design) model initiating from the construction of the problem and distinguishing its spatial characteristics (territorialized), moving into its generic configuration (deterritorialization) and modified at its every unique operation, as well as through a coordination and correlation of those (constant reterritorialization). This sequence implies that its outcome cannot be predefined or presupposed and adding to that, no distinction or discrimination is being made towards the course it is able to take.

VI. CONTRIBUTIONS

Taking as a point of departure the ubiquity of information technologies both in an urban and a domestic level, this paper proposed a model of "environment intelligence" aiming to engage users and communities in a process of active design and rearrangement of their living space. It articulated a participatory digital platform prototype based on the combination of a distributed sensor network mapping occupancy and use data and a design engine empowering users to produce designs or evaluate design recommendations stemming from the processing of these data. After outlining the main goals and objectives underlying the commonSENSE platform design, the paper presented its implementation in the case of the polykatoikia. Its ubiquity and rigidity as well as its latent spatial and social potential, rendered the polykatoikia a particularly productive implementation site. The paper specified the technical characteristics of the platform, both from a physical (Distributed Sensor Network) and from a digital perspective (design engine). Focus was placed on the multifaceted operation of the design engine, as a visualization tool, a "low-floor" computer aided design interface and a design recommendation platform. CommonSENSE advocated for three levels of openness granting users access not only to the shaping of their environment in local and global scale but also to the computational infrastructure which enables these operations. User empowerment in design, collective urban intelligence through peer-to-peer design processes and open source technological infrastructures are designated as three inextricably linked layers pointing towards an Open (Source) Architecture.

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