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HYBRID CITY 2015

DATA TO THE PEOPLE

PROCEEDINGS OF THE 3RD INTERNATIONAL BIENNIAL CONFERENCE

EDITORS
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UNIVERSITY RESEARCH INSTITUTE OF APPLIED COMMUNICATION

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Technology mediation and visualizing urban energy data

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Abstract. This paper discusses the 'Northeastern Energy Flows' research project that explores novel ways to valorize data from urban energy systems and complementary social and environmental data to better understand and optimize the energy consumption of buildings, support stakeholder engagement and decision making. A prototype of a data visualization system is presented that uses the Northeastern University campus in Boston as a testbed. The data visualization is analyzed as a tool in the context of mediation theory and the paper explores how this theoretical framework developed in the philosophy of technology can inform the design process of this kind of data driven interactive tools.

Keywords: energy; urban systems data; data visualization; mediation theory,

I. INTRODUCTION

With cities accounting for approximately two thirds of the global demand for energy, it is of particular interest to work with data generated by their energy systems to optimize energy usage. Large non-domestic buildings are a particular focus of attention, due to their sizable demands and associated environmental impacts such as CO2 emissions. Commercial buildings account for nearly 20% of the US national energy consumption, and 12% of the national contribution to annual global greenhouse gas emissions [23].

This paper discusses the 'Northeastern Energy Flows' research project that explores novel ways to valorize data from urban energy systems and complementary social and environmental data to better understand and optimize the energy consumption of buildings. The comprehensive research initiative uses the Northeastern University campus in Boston as a 'city-in-a-city' testbed and focuses on developing methods to identify drivers of energy consumption, predict accurate energy needs, and explore new modes of access to this information (through visual, physical and ambient interfaces). This paper discusses the first project phase that consists in a system of interactive data visualization to support data exploration. This system provides domain experts and stakeholders access to fine-grain data on electricity consumption, building occupancy, ambient climatic conditions and social activities to concurrently explore multiple dimensions for a deeper understanding of the dynamics related to energy consumption and to support decision making. The paper frames the data visualization system as a tool within the framework of mediation theory to explore the ways in which such a tool takes on a mediating role between the user and the environment and thus alters their relation.

"I have all the data but I do not have the tools to access them in the right way and at the right time in order to use them effectively in my workflow" is a phrase that is increasingly heard in environments pervaded by networked digital systems such as our cities today. This phrase was used by the energy manager at Northeastern University in an interview and has also inspired this research.

The phrase summarizes three key points for the work with urban systems data. The first is the fact that data exists. In fact, with the proliferation of networked digital technologies in the management of urban infrastructure, sensors of various kinds now monitor and log minute details of industrial operations, which used to require tedious manual readings. This data is now generated as a side product of the systems core operations [9]. It is useful to remember that systems data are for the most part not generated for the purpose of further analysis or use for novel urban service operations. Instead, they are generated as a function of the system's core operations. The result of this circumstance is that data generated by the system is biased towards the utility for said operations and it is in most cases not in an adequate form for other operations. Despite this, data exists and is continuously generated in real time as urban systems operate, providing a potentially rich source of information about a variety of contingent urban dynamics. The data is generated by systems that are in one way or another, in contact with people and thus the data directly or indirectly reflects human dynamics in urban space. Significant research is being done in this field [6; 22].

The second point is about having access to relevant data and at the right time. While data abounds and is generated at an ever increasing speed, the result is a lot of numbers filling more or less well structured databases that as such are hard to make sense of. When we speak of urban systems we speak of large numbers of data points generated from large numbers of sources that are

involved in multiple operations with their environment and capture diverse sets of values at any one time. Being able to read this data in appropriate ways and at the right times requires a translation of these numbers into an adequate form for both the audience as well as the context of consultation [17].

This brings us to the third point which is the workflow. Professionals develop a practice in which they carry out their work and utilize any tools that supports them. A new tool introduces the potential for new opportunity as well as new friction. The way data is represented for the consultation will both impact the practice of the user as well as the user will expect the tool to consider its way of working in order to accept it within its workflow [5; 26]. This points toward considering the situated activity that the audience of a data visualization system is engaged with.

The visual representation of urban systems data has become a particularly effective method both in the process of analysis as well as in the development of tools that allow stakeholders from diverse disciplinary backgrounds to join the conversation and develop novel functionalities [3; 10]. “Words and sentences must, by necessity, come only one at a time in linear, logical order. Systems happen all at once […] To discuss them properly, it is necessary somehow to use a language that shares some of the same properties as the phenomena under discussion. Pictures work for this language better than words, because you can see all the parts of a picture at once” [15].

Data visualization can effectively support processes of data exploration and data mining by "integrating the human in the data exploration process, applying its perceptual abilities to the large data sets available in today's computer systems" [8]. Systems that support humans in visual exploration of large amounts of data are particularly effective in early stages of analysis when the different types of data and their relation are not yet well understood and when specific questions for analysis are still being formulated. Visual data exploration can help in the formulation of questions and hypotheses that can then be more specifically addressed in automated statistical and machine learning techniques.

This aspect of visual data exploration renders the data visualization system proposed as a case study in this paper a tool. A tool, that provides a different view of the world. It is a tool that provides a representation of operations of technology systems that are integrated more or less tightly in an environment inhabited by people. Users of such a visual tool will have a view of the world that is very different from the view with a naked eye. It will differ depending on how this representation is structured and designed. In any case, however, a data visualization will take on a mediating role between the human and the world. The way this mediation happens is important to understand both for the designer as well as the user. Firstly, in order to be aware of this process of mediation as a function of design choices and for the latter, to understand that and how the tool provides a mediated view of the world and how it impacts the users understanding of the world in relation to the nature of the tool itself [25].

II. Related Work

The move towards connected digital metering of electricity consumption has facilitated the main objective: billing. In doing so, it has however also created a new situation of availability of data describing the behavior of buildings in terms of energy usage at a fairly fine granularity that has since inspired researchers and industry in seeking new uses for this data. One direction of these investigations focuses on the modeling of building energy consumption. This is complex because of the many factors of influence such as ambient climate conditions, building structure, and energy systems structure.

The availability of fine-grained consumption data over long stretches of time as well as the availability of this data in real-time has allowed for increasing work done on evidence based analysis and empirical models developed from historical performance data. The three main approaches to developing building energy consumption predictions are engineering methods, statistical methods, and neural network based methods [28]. Some studies consider building occupancy in their models. The challenge there consists in measuring occupancy and activity levels reliably. Multiple strategies have been developed to obtain finer grain occupancy monitoring. Using CO_2 sensors, passive infrared detection systems, image and sound detection systems, computer and network activity detection systems, etc. [13] Obtaining comprehensive fine-grained occupancy information for buildings remains difficult both due to the stochastic nature of human behavior as well as the limitation of available detection tools [11]. In all these approaches a common limitation is that the more accurate predictions are obtained by models that are highly complex and difficult to perform.

As part of many work processes both in research and in industry, data collected on building energy consumption as well as data generated by predictive models is made accessible to users and stakeholders in the form of data visualizations. The objective of these visualizations are manifold and include presentation of data for operations management, research, public and stakeholder engagement, public policy, etc.

As an example for public engagement and public policy, the *New York City Building Energy Map* [20], developed at Columbia University provides an estimate of the building energy consumption through a choropleth map interface that allows block level inspection of detailed information. The interface mediates effectively between a global overview as well as detailed finer grain information that can be easily accessed without loosing the higher level overview.

Similarly, the *City of Philadelphia Building Energy Benchmarking 2014* [1] project provides building-level energy performance data for the nearly 2,000 properties required to report utility information as part of Philadelphia’s energy benchmarking law. A graduated symbols map is used to convey energy performance

through variable circle sizes with circle color indicating building type.

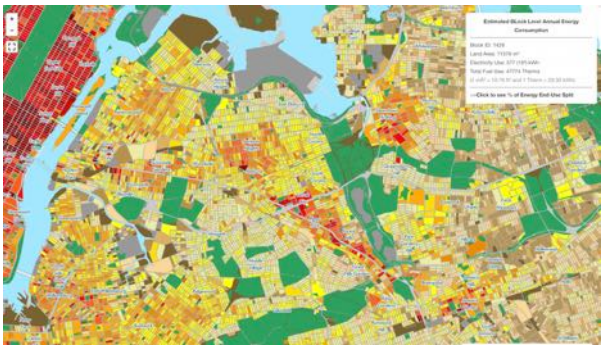

Fig. 1. New York City Building Energy Map

Three filter menus allow for reducing the number of buildings shown by type, category and energy performance. This level of interactivity provides a strong draw for users to engage with the visualization and with the data represented.

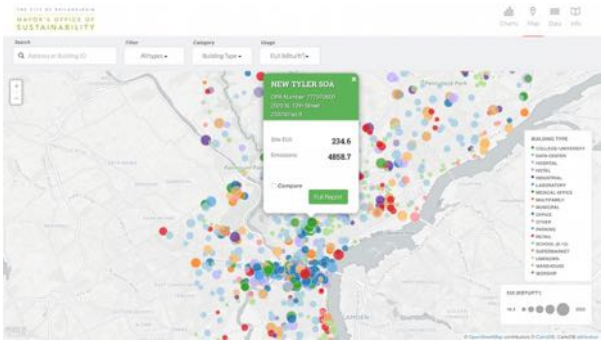

Fig. 2. City of Philadelphia Building Energy Benchmarking

In the context of building management systems (BMS), several systems exist from different developers that provide high and low level representations of systems functioning predominantly using pie charts, bar and line charts to represent data from building systems.

Fig. 3. Schneider Electric StruxureWare Power Monitoring Expert

The level of detail shown typically depends on the specific system setup. Limitations that have been identified regard the lack of integration in the case of different technology systems in place, lack of integration with data from other related contexts, and lack of effective combination of high-level overview and drill-down capabilities in the visualization setup [12].

Throughout the studies and projects discussed in this section two limitations can be observed with regard to the aspect of data visualization. Firstly, high-level views such as geographic maps ted to be offered for studies that regard large geographic areas and no or little building level information, while vice versa, in visualizations involving building level data, there tends to be a lack of high-level context in their representation. Secondly, while research in mathematical models and prediction techniques involve data from sources complementary to energy readings, there is a lack in data visualization approaches that offer users the possibility to visually interpret energy readings side by side with other types of data that would provide a richer description of the context.

III. MEDIATION AS FRAMEWORK FOR SYSTEMS DATA VISUALIZATION

In the process of working with large systems data, data visualization has become a powerful tool for both the representation of information as well as for the exploration of datasets and results of statistical analyses. Data visualization techniques can be used for presenting data in a specific way determined by the designer/developer as well as for exploring the data by offering the user direct manipulation with regard to what data is filtered/visualized and in what way. When affording exploration, a data visualization is a *tool* for seeing the world in a different perspective. As a conceptual metaphor, the macroscope has been invoked to describe tools that "help us understand complex systems" [21] in the wider design field as such and in the context of data visualization specifically [2; 4; 19]. Joël de Rosnay, the source of this inspiration, in his eponymous book, describes the macroscope as being a tool for the *big picture*, a tool that enables humans to see and understand the connections between the parts and the kinds of their relations: "Today we are confronted with another infinite: the infinitely complex. We are confounded by the number and variety of elements, of relationships, of interactions and combinations on which the functions of large systems depend. […] Now a new tool is needed by all those who would try to understand and direct effectively their action in this world […] I shall call this instrument the macroscope (from *macro*, great, and *skopein*, to observe)" [18]. In this perspective, data visualization as a macroscope becomes a *tool* - similar in nature to the microscope or the telescope - that stands in between the human and the world. A tool that conditions the very way a human perceives the world and interprets it. A tool that mediates a human experience of the world.

A. Mediation in the postphenomenological perspective

As a tool for exploration of aspects of the world, a visualization of urban systems data stands in between the human observer and the world. As a conceptual macroscope such a tool takes on a mediating role. How

such a mediating role plays out, how a tool mediates between the world and a human observer is of great interest to designers in the process of transforming systems data into artifacts. They will shape users' interpretation and experience of the world they operate in and condition their behavior and actions. A better understanding of this mediating role can inform the design process as well as clarify the role of the artifact for the user.

While much attention has been given to the representational character of data visualizations, these data visualizations themselves become a tool at the moment of enactment, a tool that affords a new way of *perceiving the world* and ultimately of *being in the world*. This paper proposes to frame the data driven visual artifact in terms of its character of mediation and how it conditions processes of mutual constitution between humans and their world.

In the postphenomenological perspective within the philosophy of technology, a central focus is the analysis of the *kinds of relations* that human beings can have with different technologies and how reality's presence to humans is shaped by technologies [7]. The two dimensions for this analysis that Paul Verbeek discusses, based on Don Ihde's work, are *hermeneutical* and *existential* [25]. In hermeneutical terms, artifacts mediate the way in which humans have access to the world in terms of the role they play in the human experience. This dimension is concerned with questions such as the way in which others are present to us when we communicate to them through information technologies or how we have access to the world through tools such as the microscope, a night vision system, etc. In existential terms, human existence is mediated by artifacts and the focus is on questions such as how information technologies impact our social relations or how the cellphone conditions how we subdivide our day.

Don Ihde starts his analysis of the relation between human beings and their world with experience. He distinguishes two dimensions of experience that are always co-present, that cannot be separated and mutually require each other: (1) Micro-perception, in terms of the bodily experience on a sensory level. (2) Macro-perception, as the framework within which the sensory perception becomes meaningful.

B. Seven kinds of tool mediated relations

Based on these two dimensions of experience, the postphenomenological perspective articulates different *kinds of relations* between humans and their world, afforded by technologies, while putting particular emphasis on the mediation character of tools and technologies. Ihde proposes four different kinds of such relations that can exist between humans and their world when artifacts are involved [7; 26]:

1) Embodiment relation: This case is closest to Heidegger's case of *present-at-hand* equipment and which Merleau-Ponty later expands further as *embodiment* [16]. The tool that mediates between human being and world withdraws from awareness in its use, it is transparent and becomes one with the human experiencing the world. The world is perceived *through* the artifact. Examples for this kind of relation are eyeglasses, microscope, telephone, etc. We look *through* eyeglasses rather than *at* them.

2) Hermeneutic relation: In a hermeneutic relation with the world, a technology mediates by affording the interpretation of the world. Technology and world form a unity, we read the world by experiencing a form of representation provided by the tool which in this case does not withdraw, does not become transparent. It provides a representation of the world, it requires interpretation and must be read. Examples would be maps, brain activity represented by an MRI, hygrometer, etc. The world is perceived by means of the artifact in this case.

3) Alterity relation: In both the above first cases of mediated relation, tools transform the experience a human has of the world, they mediate between humans and their world. The third kind regards technology as *quasi-others*, with which humans can interact. The relation is in the world but between humans and artifact which is present as itself in this relation. Examples being the vast amount of objects such as, dispensing machines, toll booths, etc.

4) Background relation: In Ihde's fourth kind of relation, technologies are considered that are in the background, that form a closer tie with the context of our perception. Air conditioning units and central heating, refrigerators and lighting systems are not at the center of our perception of the world but they condition the context of our perception of the world. They rise to awareness mainly through their absence or malfunctioning.

Verbeek extends these four types of relations by three more categories in order to consider new kinds of technologies which do not fit well in any of Ihde's four types [26]. They are:

5) Cyborg relation: This relation regards technologies that are even more intimate with the human body than embodiment, such as brain implants. Not only do they withdraw from awareness, they are literally subtracted from what can be perceived within the domain of Ihde's micro-perceptions.

6) Immersion: The recent embedding of technologies with sensing, actuating, and computational capacities in the built environment goes beyond what can be described as background relation. Through these technologies the background becomes activated itself and part of interactive processes.

7) Augmentation: Finally, technologies such as smart-glasses or heads-up displays (HUD) can be neither considered only embodied nor hermeneutic, while a person perceives the world through them, this happens also through a process of interpretation and reading of the layered representation that is added.

These technologies have been referred to as augmented reality and Verbeek uses this term for this last kind of relation.

Verbeek illustrates the application this mediation theory can have for designers, intent to give shape to artifacts and he focuses in particular on the field of industrial design and on the object and process of that discipline [25]. This paper, instead, explores the possibility of applying the perspective of tool mediation to hybrid artifacts whose nature lies in actively bridging the digital and the physical domains and in particular to the case study described in the following section 4.

IV. A CASE STUDY

As part of the 'Northeastern Energy Flows' research project an initial prototype for an interactive data visualization system has been developed. This system provides domain experts and stakeholders access to fine grain data on energy consumption, building occupancy, climatic conditions and social activities to concurrently explore multiple dimensions for a deeper understanding of the dynamics related to energy consumption, to foster engagement across disciplinary boundaries and to support decision making.

Key to this system has been to not only focus on energy data alone, but to emphasize how a better understanding of dynamics related to energy consumption can be explored by connecting data from other domains. That is, complementing data from the techno-sphere (energy data) with data from the socio-sphere (events and academic calendar, twitter data as proxy for social activity) and from the bio-sphere (weather data). This has been a key point that emerged from interviews with the energy manager from our testbed environment as well as some of the literature [12].

The focus in the first phase of the project was to develop a system capable of providing interactive visual access to information contained in the above data types in order to facilitate exploration of possible connections between the different dynamics and formulate hypotheses for further analysis. A particular focus is on connections between urban climate conditions and energy consumption [28], as well as between building occupancy and energy consumption to explore the use responsiveness [11] of different buildings.

A. Context

The project uses the Northeastern University campus in Boston as a testbed. The spatial organization of institutional buildings in the form of a campus represents somewhat a 'city-in-a-city', a model of a comprehensive city. The setting of Northeastern's campus is urban and consists in 46 buildings over 73 acres with a population of some 22,000 students, faculty and staff. The campus is characterized by rather sophisticated energy systems due to the recent implementation of energy saving technologies and energy monitoring systems (Northeastern ranked in the top 10 among 301 schools from 60 countries in the 2014 Green-Metric Ranking of World Universities [24]). A growing number of sensors provide real-time monitoring of energy flows as well as readings of room occupancy (using motion sensors, CO2 sensors, and people counters at doors).

B. System setup

Data used for this visualization system come from different sources posing challenges both in terms of data integration as well as data structuring. We are using the following types of data in this first project phase:

TABLE I. DATA TYPES USED IN PROJECT

Data type	Description
Electricity consumption	46 buildings are metered at 15 minute intervals and the data is accessed remotely through the campus-wide data management system. While most buildings are monitored at a building level, some buildings are monitored at a higher level of granularity including networked meter readings for individual activity areas within buildings. Period: 2012-2014.
Building information	All 46 buildings are described in terms of surface area, number of floors, use type, year of construction, etc.
Planned classroom occupancy	Data indicating number of students in room as scheduled according to number of registered students for a class and room number of class. Period: 2012-2014
Climate data	Outdoor temperature, humidity, wind speed, cloud coverage, precipitation, etc. as measured by the city's meteorological station at Logan Airport. Period: 2012-2014.
Twitter data	Twitter data used as proxy for campus related activities and events. Number of tweets sent from University accounts. Period: 2012-2014.
Academic calendar	Class times, holidays, events, exams. Period: 2012-2015.

Data are received from a range of departments on campus as well as in a wide range of formats ranging from real time streams from the energy group's building management system (BMS) to static csv files.

To structure and manage the data for the data visualizations a mongodb database was set up on a remote server accessed through a secure connection. Mongodb provides a Java MongoDB Driver which is used to connect to the database from within the Java based Processing IDE which is used to develop the data visualizations. From within the Processing environment, Javascript functions were used to execute queries to the mongodb database. A Processing library was developed that contains a collection of classes and functions specifically written to facilitate the database access and queries and allow for more effective focus on the data visualization tool development itself.

C. Visual representation and interaction

Our focus in this first phase of the project is to provide a system that is capable of providing interactive visual access to information contained in the above data types in order to facilitate exploration of possible connections between the different dynamics and formulate hypotheses for further analysis. The data driven visual interface we developed consists of two

distinct visual areas: a map area in the upper half and what we call a data-score area in the lower half.

1) Data-score area: The data-score area is inspired by the score structure of sheet music in musical notation for ensemble. In musical notation for multiple voices each voice is written on one five lined staff with multiple staffs connected by a vertical bracket that illustrates functional groupings of voices that function as a unit. On the left of each staff a label indicates the type of voice/instrument and at the beginning of the staff the clef indicates the pitch. In line with these conventions, our system proposes multiple data staffs, each representing data from a specific source in order to afford a parallel reading of dynamics from a diverse set of realms (socio-, bio-, techno-sphere). This data-score section is designed in a modular way allowing for different data types to be flexibly combined. It currently contains rows representing these data types: aggregate campus-level electricity consumption, ambient temperature (dry-bulb), aggregate planned campus classroom occupancy, academic activities, Twitter activity.

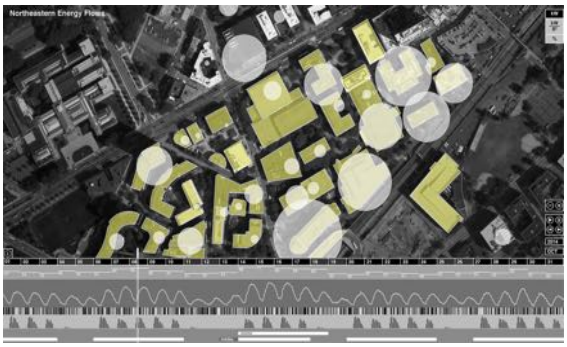

Fig. 4. Northeastern Energy Flows. Overview: Monthly view of comprehensive interface.

2) Flexible data-score combination: The purpose of this setup is to afford a parallel reading of data from different sources and contexts in order to visually explore possible correlations. While the establishment of correlations does require deeper analysis over bigger time frames, the challenge of any data analysis is the formulation of meaningful questions to begin with. It is to this point that this data visualization system aims to contribute and to stimulate exploration of multiple data dimensions to explore starting points for more in-depth analysis.

The data-scores can be dynamically composed in that the specific data types to be visualized can be changed and the order among them can be modified to support different modalities of exploration. As such the number of data-scores can be changed, we have set a current maximum of 5 rows.

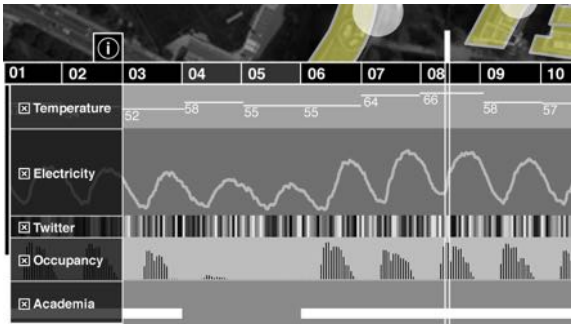

Fig. 5. Northeastern Energy Flows. Detail: Data-score area. Rows with cleff/label indication of data type and interface for data type selection and order.

3) Map area: The map area shows the geographical map with campus buildings indicating the predominant use type by color. Overlaid on top of these buildings are the building-level indicators for electricity use and by opening a pop-up label, building level classroom occupancy data can be observed in addition.

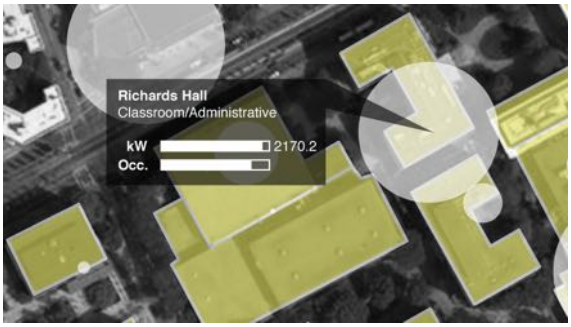

Fig. 6. Northeastern Energy Flows. Detail: Map Area with Building detail label.

The electrical load indication can be toggled between three different values: building load at 15 minute intervals in kW, load normalized over square-feet of building surface in kW/sq ft, and a percentage indicator showing at what percentage of daily peak load the current load stands.

Using the geographic map as an entry point emerged as valuable from conversations with the campus energy group. Operators are extremely familiar with the location of buildings within the campus space and conceive of a number of campus wide systems through their spatial structure.

4) Time line and temporal scale: The primary entry point for the user is the interactive timeline which informs about the time associated with the represented data and indicates the time range the data will be looped through. By changing the zoom level of the timeline (day, week, month, year), the user also determines the temporal level of aggregation displayed. By interacting with the timeline and with the data indicators on the right side of the time line, the temporal scale can be changed providing views of the following time ranges: year, month, week, day. The

objective of this is to allow the exploration of patterns and dynamics related to daily and weekly cycles, as well as to seasonal and semester related changes.

At the prototype's current state, we hope that enabling a broader audience to explore large amounts of systems data from diverse sources on energy consumption and social/environmental factors will facilitate greater awareness, understanding and ultimately better decision making for the optimization of energy usage. Future work will focus on additional data types as well as the inclusion of data from simulations and predictions based on these data.

D. A perspective of tool mediation on a data visualization system

By analyzing the mediating roles, outlined in section 3, that the case study system is involved in, we can distinguish between two levels of mediation. On the first level, this data visualization tool is made up of connections (data streams) to technologies (electricity system and connected devices, temperature sensors, occupancy monitors, etc.) that are present in the environment and that condition themselves the relation between humans and their environment in different ways. On a second level, the visualization tool itself is a technology that mediates between users and their world. The co-presence of these two levels of mediation is a key characteristic of connected hybrid artifacts. These are artifacts that appear as such in front of the user, affording direct interaction, at the same time as they are connected to other technologies. While these connected technologies can be spatially remote, there exists a real-time connection that forms a constitutive part in the existence of the hybrid artifact. Both levels of mediation are required. It cannot exist without appearing in the world as a tool as such, but can neither do away with its digital connections to other technology systems in order to unfold its functionalities.

In looking more closely at the first level of mediation in the case study, we can identify technologies related to electricity systems, Twitter broadcasts, and room occupancy monitoring. While the building level electricity data currently used in this project does not provide information on end-use appliances, a substantial part of eletricity consumption in office buildings relate to lighting and HVAC (heading, ventilation, air conditioning) systems. Both these groups of systems condition the context of a human's relation with their environment in a way described as *background relation*.

Twitter data is a result of a user engaging with a Twitter client on a smartphone, tablet, laptop, PC, or similar, in what we can describe as *embodiment relation*. A user of a Twitter client does not so much interact *with* that client software but acts *through* it when broadcasting messages.

In the current state of the case study prototype, room occupancy is based on the registrar's database of classroom occupation. While updated on a daily basis and reflecting variation in class attendance, it cannot be considered an accurate reflection of people's presence in rooms as such but rather of planned presence. This data is used as we prepare for the inclusion of data from occupancy sensors installed in multiple classrooms. These sensors are embedded in the room infrastructure and are based on different technologies (camera based people counters, CO_2 sensors, motion sensors). The primary use for these sensors is to fine tune the functioning of the HVAC systems, ensuring proper temperature and ventilation for the number of room occupants and enabling reduced energy consumption as fewer people occupy rooms. These sensors are also used to control temperature settings and room lighting, providing auto-switch-off functionality when rooms are empty, to reduce energy consumption. As such, this layer of technologies is part of relations of both *background* and *immersive* nature, conditioning the context of perception as well as activating that background under specific conditions.

Considering the second level of mediation, the data visualization tool becomes itself an element that conditions the way a user perceives an environment.

The data dealt with in this project is generated by systems that are complex in themselves and that have complex interrelations with each other and with their environment. The representation of this data offers users a view of their environment that is impossible to obtain with the naked eye. The types of data represented, the statistical processes employed and the visual encoding will condition a user's view of the world.

There is naturally a focus on the *hermeneutical* kind of relation in that data visualization involves the design of representations of systems and their operations. Enabling users to create their own data compositions in the data-score area of the project allows them to take part in the composition of the tool for the interpretation of their environment. Having a user engage in the process of tool composition, then, creates awareness about the way the tool conditions the view of the world, allowing for the tool use as such to become a more conscious one in the formulation of reality.

A tool mediated relation of *embodiment* necessarily involves the practice of using the tool. It involves the physical device (PC or mobile device) that is used to access the data visualization and which is not part of this project phase. It does, however, also involve levels of familiarity with the visual encoding of information and the relation of such encoding with existing elements of formal and informal knowledge as well as planned and situated actions in the work process. Choosing a map view besides time series charts as a key element of the interface was an acknowledgement that this *high-level* view of the environment of operation of both expert and non-expert stakeholders provides an extremely familiar perspective that comes *naturally* to a wide range of users. By arranging campus buildings by their geographic location and in relation to each other as opposed to building names, use categories or other aggregations, we make use of an experience of campus exploration that is fully embodied when moving across campus on ones own feet, as is customary to all stakeholders of the system.

An interesting dynamic emerges between the systems data visualization tool in regards to the *background relation* involving building lighting and HVAC systems. The data visualization tool brings effects of these technologies from the background to the center of attention. We become aware of energy consumption levels driven by technologies that condition the background of our relation to our environment. The data visualization tool, in this way, is capable of *altering the kind of mediation* that connected technologies are part of. It changes the nature of mediation of other technologies, by bringing them from background to foreground. This adds a novel facet to the discussion on the scarcity of attention in information rich environments for further exploration [14; 27].

V. CONCLUSION

This paper proposes a mediation theory based perspective for the analysis and the design of dynamic visual tools based on urban systems data. As pervasive digital technology networks in urban environments generate increasing amounts of data in real time, there is an increasing potential for new use scenarios and tools based on these data streams. Frameworks for the analysis and the development of such new tools though are still in their infancy and this paper proposes an approach rooted in the philosophy of technology and specifically in the postphenomenological perspective to better grasp the nature of these new tools.

A case study is presented in which data from urban energy systems and complementary sources is used as a basis for the development of a data driven visual tool to support data exploration, stakeholder engagement, and support decision making. The prototype of this project is described in terms of system setup, its interface and interaction design components and is then analyzed in the context of the mediation theory framework.

While this approach has been applied towards the design of physical artifacts and the domain of industrial design, this paper proposes its relevance for the analysis and design process of hybrid digital-physical artifacts and networked systems due to their involvement in relations of mediation on multiple levels.

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