Application pour la modélisation d'Agencements Energétiques Soutenables (AES) – Identification des pratiques durables au sein des zones urbaines intelligentes (Smart Cities) pour favoriser pour la réduction l'empreinte énergétique

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Résumé

Les activités humaines à l'échelle mondiale ont un impact significatif sur la production et la consommation d'énergie (directe/indirecte). Cela conduit à une utilisation non durable des ressources naturelles (principalement fossiles) et une production de plus en plus importante de déchets. Les zones urbaines, où la majorité de la population mondiale réside, doivent faire face à de nombreux problèmes environnementaux notamment dans les pays émergents. Le déploiement d'infrastructure intelligente telles que les Smart Grid, vise à répondre à ces défis par l'optimisation de la production, la distribution et la consommation de l'énergie électrique, en particulier dans les zones urbaines. Ces réseaux intelligents permettent de gérer à la fois les flux énergétiques mais aussi les flux de données relatives à ces usages/consommations. Ces données issues des infrastructures énergétiques sont complétées et peuvent être enrichies par des flux d'informations (sociales) continus toujours plus importants (données massives) du fait d'une connectivité toujours plus importante des entités et objets (informatique ubiquitaire, intelligence ambiante) et de l'accès à des services numériques toujours plus nombreux. Ces informations reflétant les activités quotidiennes des acteurs au sein de leur(s) environnement(s) et en fonction du contexte de celles ci.

L'objectif principal de cet article est de proposer une méthodologie innovante se différenciant des approches classiques basées sur les paradigmes structuralistes et individualistes, en considérant les composantes de cette masse d'information, comme autant de traces digitales représentant des entités en relation dans le temps et l'espace et dans diverses dimensions. Ces traces pouvant être exploitées pour permettre l'identification de motifs d'activités et contribuer par leur agrégation à la modélisation de ces dites activités sous forme de structure de connectivité (via la théorie des Agencements) pour in fine représenter ces structures à l'aide d'Hypergraphes (en s'appuyant sur les complexes simpliciaux). Les résultats de cette modélisation consistent à mettre à disposition des interfaces permettant la représentation/visualisation de ces activités et leur(s) empreinte(s) énergétique(s) pour favoriser l'aide à la décision des utilisateurs de ces outils, de manière à supporter les comportements durables, contribuer à réduire cette empreinte énergétique et donc promouvoir la transition écologique.

Mots-clés : Agencement Energétique Durable, Complexes Simpliciaux, Lifestream, Smart City, Informatique ubiquitaire.

1. Introduction

Human activities are mostly carried out in urban areas, mainly due to the fact that for the first time since 2008, half of the human population lives in this type of environment (Desa 2008). Energy and the way that it is used can be considered as critical and as a key component, which support daily social and economic activities within societies. Unfortunately these activities usually cause many problems including, wastes production, unsustainable exploitation of natural resources, healthy issues (pollution), global warming, etc. (Barker, Ekins et al. 2005). As a key factor, lifestyles could influence the way in which the energy is used and is related to daily activities of users. Indeed, people's needs generate daily production and consumption of virtual or physic artefacts in many domains (Food, Mobility, Health, Leisure, etc.). Any activity, service, running infrastructure or manufacturing of goods, generate direct and indirect production/consumption of energy (use a car/bus/plane, purchase and use of consumer goods, build highway, datacenter, etc.). Needless to say, if there is energy consumption for a related need, there is a need to produce this expected energy. Actually, this energy is primary produced from fossil resources. Current approaches that attempt to solve these problems of production and consumption of energy to encourage the reduction of environmental impacts (avoid fossil resources, improve efficiency…), did not provide significant results. These approaches are actually based on individualistic and systemic paradigms and those remain ineffective (Spaargaren 2011). So far, measures, laws, incentives, technology infrastructures are not able to generate conclusive results, and finally lead to a worsening of the situation of the environment (Caragliu, Del Bo et al. 2009). Our proposition is to consider the methodological concept of Practice as a relevant alternative to above paradigms. The concept of practice could help to overcome the limits and drawbacks of systemic and individualistic paradigms. Practice as concept is even more relevant if we consider that each practice involves a potential act of consumption as defined by A.Warde (Warde 2005). We can consider that there are so much ways to consume, that there are potential consumers, each with its own practices, composed of multiple interconnected activities. Consumption is primarily a social act. When considering practices of consumption, the dimension of sustainability (Spaargaren 2003), (Spaargaren 2011), should be strongly encouraged to promote better use of resources based on lifestyles of users. Indeed, these lifestyles (especially domestic) clearly have a direct impact on the environment (Shove, Pantzar et al. 2012).

Cities are centres, where physical and virtual flows emerge reflecting the interconnected activities involving multiple heterogeneous entities (human and non-human). The higher the density of these areas, the greater the number of activities is (due mainly to activities' opportunities). These activities generate a large number of physical and virtual data streams related directly or indirectly to these activities. In the past few years, the development and availability of the ICT infrastructure has helped cities to become more “intelligent” or “smart” and assist them to manage multiple streams in various dimensions, such economy, mobility, environment, security, heal, etc. . Pervasive or Ubiquitous computing potentially connects each device to a limitless network of other devices and generate every day more and more data related to global activities, status, context of human or non human activities. In fact, Information and Communication Technologies (ICT) are playing a critical role in new networks and infrastructure. All these technologies give especially for existing energy networks some kind of «intelligence» and transform actual passive networks in flexible, resilient Smart Grids.

Our research seeks to define how it would be possible to identify daily consumption practices and theirs related energy footprints based on massive data flows in Smart Cities**.** Practices are composed of multiple embedded activities and sub activities defined in time and in space with data flows providing by intelligent infrastructures such as Smart Grids or pervasive and mobile computing with Internet of Things. The goal would be, once consumption practices of inhabitants are identified and modelled, to promote those sustainable (after having calculate their energy footprint) and allow users on the basis of these information concerning their practices or those being carried out close to their location, to influence their lifestyle by the selection of the most relevant practice. Such behaviours allow users to move toward an ecological transition and support environmentally friendly behaviours. Our approach uses a structuring process with Simplicial Complex to model fragments of activities from aggregation of heterogeneous data.

After this introduction, that presented quickly the context, key concepts, research question, the current gaps in this problematic, we present in the following section a short review of the literature on key terms and concepts. In the following section we present the theoretical approach ("Assemblage", Complex Simplicial...) as well as methodology tools and technologies that allow us to identify, model and analyse daily activities and try to promote sustainable activities of users in Smart Cities using intelligent networks such Smart Grids. This article concludes with an overview of further perspectives and some reflections and finally the conclusion.

2. Literature Review

2.1 Sustainable practices of consumption

We consider that the practice can be described as a set or more precisely as an <u>Assemblage</u> of heterogeneous elements of any type, in relationship, in a given field of activity. This definition is based on analytical approach adopted in recent years by academic research on theory of practice (Giddens 1984), (Collins 2004), (Schatzki 1996), (Schatzki 2002), (Nicolini 2012), (Reckwitz 2002), (Shove and Walker 2010, Shove, Pantzar et al. 2012). Practice itself, is defined by the manner in which its heterogeneous entities come into interaction and by multidimensional connectivities between these involved entities and finally how these relationships evolved during the existence of this practice. Based on these theoretical aspects, we see a theoretical relationship with the theories of Actor Network (Latour 2005) as a viable mode of the existence of a coordination of heterogeneous elements that compose an active unit, a functional dynamic system.

We consider that any practice (activities and sub activities) needs an act of consumption (goods, services, infrastructure, etc.). This consumption induces the use of primary energy (fossil resources, electricity, gas, etc.) to make practice real or to allow the existence of the entities that constitute the practice itself. Each practice needs a production of energy to answer this act of consumption. By modelling structures of practices, this approach seeks to optimize sustainability by reducing energy footprint of goods or services involved in such practices.

A.Warde (Warde 2005) confirms this hypothesis by defining a link between theory of practice and the theory of consumption. The way we consume depends on how practices (activities, sub-activities, entities that compose practice itself) are organized (coordination of distinct heterogeneous elements) rather than an individual choice or the influence of infrastructure (individualistic and systemic paradigms).

Promote sustainable consumption and practices could help to move forward to a new way of consuming, but with fewer harmful effects on the environment and thus contribute positively to environmental and energy transition.

2.2 Smart Grids and Information Communication Technologies (ICT): New ways to better understand practices inside urban areas through larger data aggregation.

Daily, flows of data generated by Smart Grids infrastructure are growing due to the deployment of Smart Grids itself and the increasing number of entities that are connected to it (Power Plant, Buildings, Electric Vehicles, sensors, etc.). There is as well an increase and a multiplication of electronic communicating devices generating continuously information from everywhere and especially in urban areas due to the density of users and infrastructure potentially connected.

Ubiquitous or Pervasive computing describe this concept of computing through any device in any location and any time (Saha and Mukherjee 2003).

Pervasive or Ubiquitous Computing generate enormous amount of data and these data needs to be analyse to recognize involved entities (actors, objects, relationships) and from them be able to extract automatically activities depending on social context and relationships between these entities. Heterogeneous data that can be used to model structures of activities are becoming extremely important. These digital traces could define as a "digital shadow" of each actor.«Digital shadow is made up of information we may deem public but also data that we would prefer to remain private.» (Gantz and Reinsel 2011).

Chen and Khalilb (Chen and Khalil 2011) define activity recognition as "the process whereby an actor's behaviour and his/her situated environment are monitored and analysed to infer the undergoing activities. It comprises many different tasks, namely activity modelling, behaviour and environment monitoring, data processing and pattern recognition."

ICT infrastructures are playing a critical role in these new networks inside Smart Cities. In fact, all these new technologies give existing networks some kind of «intelligence» and transform passive networks in flexible, resilient Smart Grids. Every day, urban areas produce millions of data in multiple dimensions from a growing number of sources either from user activity or directly from the sensors or terminals and mobile devices (Yuan et al., 2012). To become smarter and be considered as the city of the future, these urban areas need to focus and improve the way they will collect and manage data (Marston et al., 2005).

The concept of the smart city can be considered (Giffinger and Pichler-Milanović 2007) as the next stage in the process of urbanization if cities are able to take advantage of massive data flows from multiple sources and dimensions in order to promote sustainable practices for users' lifestyles and improve their quality of life, support economy and preserve environment.

3. Hypothesis

By considering the theoretical elements presented previously, our hypothesis is to use as much as possible (depends on availability, privacy, volume, quality…) virtual and physical flows of information and all associated metadata generated by human and non-human daily activities, mainly in urban areas generated by Ubiquitous/Pervasive Computing (such smartphone, sensor, social application, etc.) . These massive aggregated data are could be used to model practices as decentralised, interconnected social structures built with heterogeneous entities connected in time and space. For this modelisation we will rely on "Assemblage" concept and topological mathematical tools like Simplicial Complex to represent these Practices (connected activities and sub activities in multi dimension).

We will be able then to evaluate energy footprint through digital traces associated to each moments of practice (Activities, fragment of activities) in order to focus on those, which have the lower energy footprint. Finally, based on these identified practices, we will try to understand which factors, special connectivity between social aggregate are relevant and critical. Finally with this information, it will be easier to provide decision support to help user/inhabitants to promote sustainable behaviours thanks to a better understanding of its activities.

4. Methodology

The main process, Sustainable Practices Analysis, aims to aggregate data from multiple and different sources and use them (depends on target's scope) to model and calculate, with Assemblage Theory and Simplicial Complexes tools, interconnected practices of inhabitants in intelligent urban areas and try to promote sustainable behaviours by reducing practice's energy footprint based on provided information related to these practices and interaction with others practices inside global structure (described below in the figure 1)

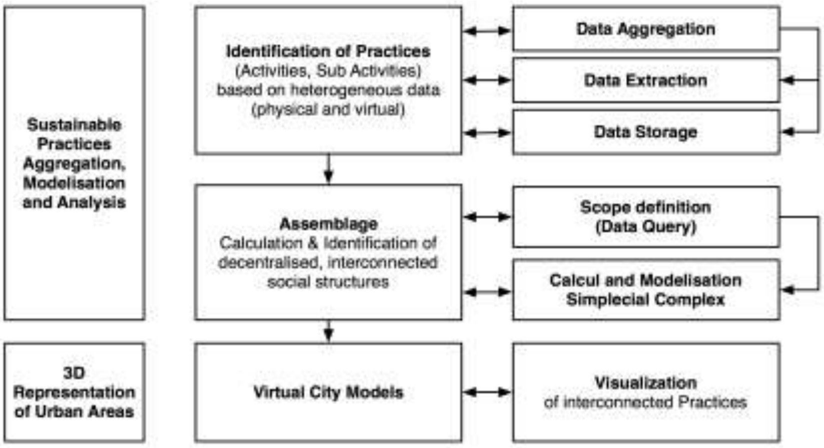


Figure 1: Value chain for Identification of Sustainable Assemblages of Energy (SAE).

This methodology aims to help us to identify and manipulate what we called "Sustainable Assemblage for Energy" (SAE) as an innovative artefact, from our point of view, to promote sustainability through better comprehension of lifestyles' impact on daily practices in order to visualise energy footprint to intent to reduce it.

We follow over the time and the space, digital traces provided by the Smart Grid in Urban areas. Users generate these data during a day, full of many activities with related activity's information (metadata). The figure 2 below shows this kind of itinerary for one user.

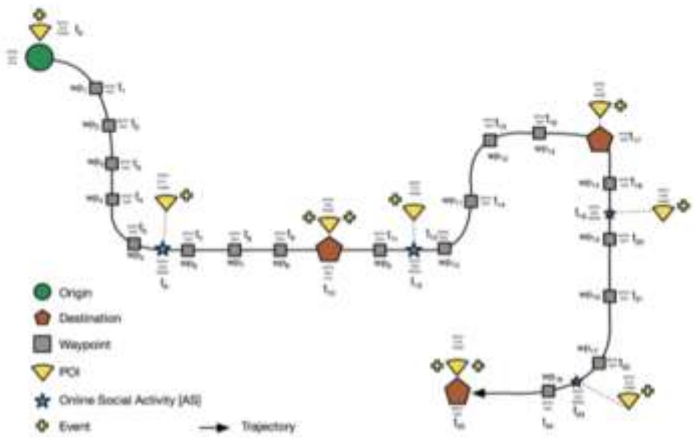
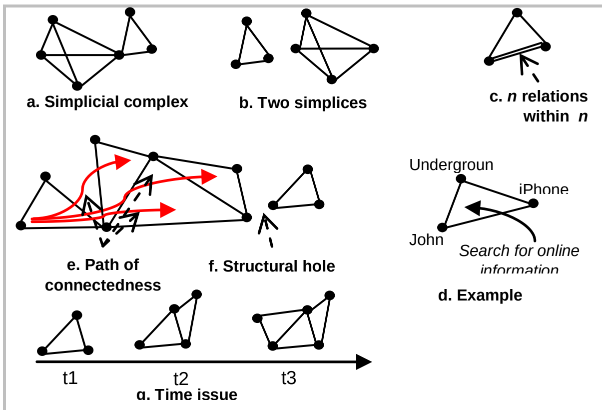


Figure 2: User's Itinerary which Digital Traces

To resolve constraint of structuration of data, we rely in this approach on the ActivityStream (AS) protocol [http://activitystrea.ms/]. The basic idea of ActivityStream concept is to take existing streams of content, which represent all of the activities coming out of networks, web sites, applications, repositories, emails, tweets and so on, and provide the metadata necessary to differentiate all the distinct activities coming from these different sources. Activity Streams tells the story of an actor (person, captor, system) performing an action on or with an object. The Activity Stream format, as in JSON Activity Based Schema, presents an "Actor - Verb - Object" tuple, with an optional information about the "Target". The ActivityStream protocol allows a structuration of information that facilitates the manipulation of data for modelling activities. While it is potentially possible to take any type of data source for modelling Practices with Assemblages Theory and Simplicial Complex, for obvious reasons we have limited ourselves to few data sources such Facebook, Twitter for example or Foursquare for Point of Interest.

The figure 3 below shows main concept and overall process to build simplecial complex from heterogeneous entities and the use of adjacency/ incidence matrices to go over the calculation process.



R: Part Of	Action										
Entity	a1	a2	a3	a4	a5	a6	a7	a8	a9	a10	an
E1	1	0	1	0	1	0	0	0	0	0	0
E2	0	0	0	0	0	0	0	0	1	0	1
E3	0	0	0	1	1	0	0	0	1	0	0
E4	0	0	0	1	0	0	1	0	0	0	1
E5	0	1	0	0	0	1	0	0	0	0	0
E6	0	0	0	0	0	0	0	0	1	0	1
E7	0	0	1	0	0	1	0	0	0	0	0
E8	1	0	0	0	0	0	0	0	1	0	1
E9	0	0	1	0	1	0	0	0	0	0	0
E10	0	0	0	0	0	0	1	0	0	0	0
E11	0	1	0	0	1	0	0	0	1	0	0
En	0	0	0	0	0	0	1	0	0	0	0

Figure 3: Main notions of the simplicial approach and example of Incidence Matrix

From incidence matrices, we build a structure (represented as a graph) composed of primary level of connected simplexes (Fragments of Activity) in Activities. Activities are built from fragments of activity, which share common entities. A this stage of building an Assemblage with Simplecial Complex, we define and calculate all incidence matrix for all R:Relation related to each fragment of activity (for a specific timeframe). The aggregation and build of structure of activities go further as we connect activities with locations and typologies such we can have activities classified with domain/typology and related to location. Locations are place where activities take place. The figure 4 below represents the last stage of the process which is the Hypergraph representing the whole structure of practice (after adjacency/incidence Matrices)

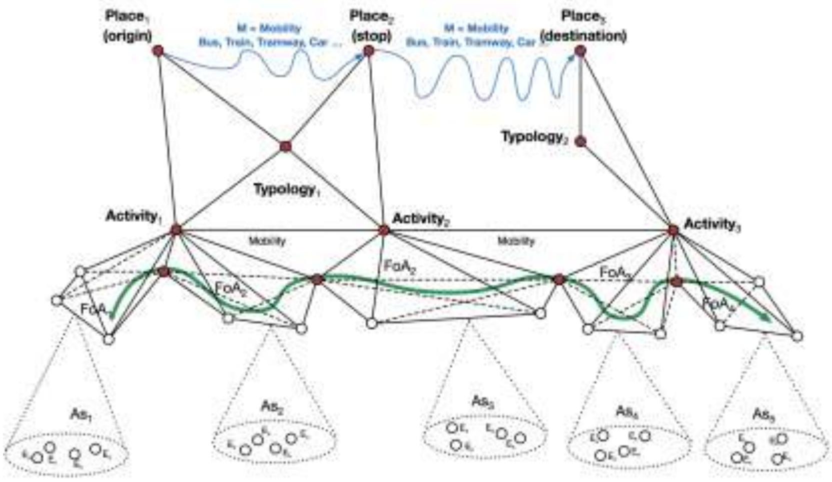


Figure 4: Modelling of Hypergraph with trajectory

Base on this structure and to estimate energy footprint of each level of consolidation we need to link identifier practices to meta domain of practices. For this, based on academic work of Spaargaren, we defined 6 main Domains/Typologies (Housing, Food, Mobility, Leisure, Health

& Well Being and Miscellaneous). This Domains/Typologies Model is also based on the United Nations Classification COICOP (classification of individual consumption by purpose (Nations, Commission et al. 2009)) and also integrates the dimension of the professional activities with four specific typologies such Transport, Work Station, Food - Hotels and Miscellaneous.

This model aims to provide a framework to monitor and evaluate the energy footprint of practices. It is obvious that given the number of entities involved in the practices and the variety of these entities, it is difficult to get automatically a comprehensive energy footprint. So we rely on this international framework (COICOP) to try to give an estimation of this energy footprint of practices that we identify with our approach.

5. Perspectives

This approach attempts to use tools and theories to help to answer in a sustainable way, energy challenges in urban areas. At this point of our research, there still exist many challenges with this approach. A major difficulty is to access to data sources (quality of provided data and with similar format such ActivityStream). The variety of formats and the difficulty of access to sources make aggregation process very difficult to program. Ultimately, quality and access have an impact on the modelling due to not having all available involved traces.

In the same time, it is of course difficult to have the precise energy footprint of each entity involved in a fragment of activity or activity. The Energy model of this approach based on U.N COICOP provides estimation for these activities for each domain on a daily basis. But the granularity of the energy footprint remains an obvious challenge.

About perspectives, we include now further steps to our previous work to connect these computation and 2D representation of Hypergraph of Sustainable Practices to a 3D Virtual Model to display practices with real layers of information from specific urban areas (ex: Shanghai) such transport infrastructure, population or building density.

6. Conclusion

The main goal of this approach is to model activities and related sub activities (fragments of activities) within a specific temporal or spatial window for inhabitants of urban areas in order to allow them to reduce energy footprint and promote sustainable practices.

This approach can be considered innovative for several reasons. The chosen theoretical concept of Practice, allow us to go beyond the limitations of current paradigms (individualist and holist). For this, we use innovative conceptual and methodological theory and tools (theory of Assemblage, mathematical tool of Simplicial Complexes) aiming to model and render more accurately the complexity of human and non-human activities and especially their interdependencies in several dimensions.

Based on massive and heterogeneous data, this approach attempts to reveal the links that may exist between entities that do not have a priori immediate and obvious connections. These entities by their connectivities, create structures of activities that can be represented by Hypergraphs. The visualization of Hypergraphs allows understanding interactions and potential impacts that a creation, transformation, loss of relationship can generate on the overall structure of activities for a specific area or a specific actor/user/inhabitant.

Results of academic research, actual position and results presented in this article, highlight the importance of the data and the way of aggregating them and how its plays a critical role in the development of solution which are able to follow the itinerary or journey of the actor and their daily activities. Its decisions are influenced by the topology of its environment in a form of reciprocity. Flows of activities, which represent connection between entities in relationship, generate a continuous stream of data. When these data are considered as stable, recurrent and predictable then we are confronted to a "classical" statistical analysis. When however, these data are heterogeneous, multidimensional and not predictable, the concept of Assemblage rises up and helps us develop the concept in social decision making for Energy Management.

The significant payoff of this approach is to include heterogeneous information sources (business, sensor, social, context, pervasive computing…) with classical energy data sources (monthly bills, energy provider information, Demand Side Management, etc.) to provide decision tools, which helps end users to manage Energy Production and Consumption through better understanding of theirs activities impacts. So far this approach can be used to represent potential and performed activities inside situation(s) made by actors during a timeframe and provide visualization tools for understanding (a posteriori) their energy footprint within their lifestyle.

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