Multi-agent simulation of human activity: a concretization in ergonomics of the technological “course of action” research program

*Simulation multi-agent de l'activité humaine : une concrétisation en ergonomie
du programme de recherche technologique « cours d'action »*

Yvon Haradji

Translator: Christopher Hinton

Electronic version

URL: <http://journals.openedition.org/activites/6196>

DOI: 10.4000/activites.6196

ISSN: 1765-2723

Publisher

ARPACT - Association Recherches et Pratiques sur les ACTIVités

Electronic reference

Yvon Haradji, “Multi-agent simulation of human activity: a concretization in ergonomics of the technological “course of action” research program”, *Activités* [Online], 18-1 | 2021, Online since 15 April 2021, connection on 17 April 2021. URL: <http://journals.openedition.org/activites/6196> ; DOI: <https://doi.org/10.4000/activites.6196>

This text was automatically generated on 17 April 2021.

Activités est mis à disposition selon les termes de la licence Creative Commons Attribution - Pas d'Utilisation Commerciale - Pas de Modification 4.0 International.

Multi-agent simulation of human activity: a concretization in ergonomics of the technological “course of action” research program

Simulation multi-agent de l'activité humaine : une concrétisation en ergonomie du programme de recherche technologique « cours d'action »

Yvon Haradji

Translation : Christopher Hinton

EDITOR'S NOTE

Article submitted 2 March 2020, accepted 5 May 2020

AUTHOR'S NOTE

This work would not have been possible without numerous contributions from researchers and engineers. First and foremost, certain members of EDF's R&D team made it possible for the project to go ahead whenever these works were not considered topical. From a technical standpoint, the idea of a multi-agent research program was developed with Alexis Drogoul; it was then mainly driven by Nicolas Sabouret, François Sempé, Quentin Raynaud, Thomas Huraux and Jérémy Albouys-Perrois. The required articulation with thermal building design is now being managed by Christian Inard and Benoit Charrier. On the ergonomics side, the idea was developed by the ACT'ING network, and took concrete form through the work of Mariane Galbat, Julien Guibourdenche and Germain Poizat. Élise Prieur for Design and Bruno Delenne for the load curves were vital to the validation of our work. Finally, Mathieu Schumann was a

committed contributor to the thermal design and a determining factor during difficult moments; he is now in charge of the project.

Introduction

- 1 This document deals with past and present research on the simulation of human activity and consumption in the home (SMACH¹). SMACH has become a service intended for energy experts (heating engineers, experts in tariff offers, consumption curves, electric vehicles, etc.) who need to anticipate a future situation: the realistic data produced by SMACH helps them to calculate the effects of their innovations on energy consumption. SMACH is also a set of research and engineering actions that aim to evolve the simulation at the same pace as major and current transformations in the world of energy (collective self-consumption, electric vehicles, etc.).
- 2 The SMACH platform is the result of a gradual construction over a period of several years (from 2007 to 2019). From the outset its originality has lain in a very structuring design principle: the primacy given to human activity. We consider that energy consumption is part of a technical universe (buildings, equipment), but that it is primarily the result of human activity in the home. It is the everyday living dynamics of people in their homes that structure the dynamics of the simulated ecosystem. This primary orientation would not have been envisaged if we had not been aware of the conceptual and technical possibilities of multi-agent systems (MAS). This current of Artificial Intelligence is based on a few simple principles: a distributed approach, agent autonomy, a central place given to interaction and a conception of emergence as a manifestation of the collective organization of the agents (Ferber, 1995). MASs have already been implemented in ergonomics to design complex cooperative systems (Dugdale, Pavard, & Soubie, 2000) and have made it possible to guide decisions concerning professional collectives in the French emergency medical service (SAMU) and in air traffic control (Pavard, 2002). So it was almost natural to turn to these systems to simulate everyday life in relation to problems of energy efficiency in the home.
- 3 In this document, we propose to retrace the history of this research in our industrial context. Our objective is to provide a reflexive look at our research practice in order to describe what a technological “course-of-action” research program might be in ergonomics (Durand, 2008; Theureau, 2006, 2009b). To this end, we propose a longitudinal analysis of this research, the principal objective being to show how the organic relationship with human activity structures a technological research program. We will also describe the internal dynamics of the research, the drivers of its growth, and the recognized quality that leads to the creation of a service for energy experts. To achieve this, we will discuss the three stages of SMACH research, along with the specific moments of uncertainty and research that led to this innovation. This article can be seen not only as an argument for strengthening the organic relationship between design and analysis of ergonomic activity, but also as a basis for generalizing and specifying the actual criteria for validating a technological research program.

1. A technological research program on the simulation of human activity

1.1. SMACH simulation to predict how human activity will affect energy consumption within the home

- 4 Simulation is a methodological tool known and recognized in ergonomics. Its function is very often to anticipate a future situation. The work environment is simulated (transformed workspace, architectural or interface model, scale 1 simulator, etc.) and the operators' activity is staged (Béguin & Weill-Fassina, 1997; Van Belleghem, 2018). These authors mainly use simulation to involve operators in the design of their future work situation according to the principles of participatory design. Our objective with simulation is to simulate situations in which human activity has an impact on a future technical-organizational-cultural system to be designed (Kashif, Ploix, Dugdale, & Le, 2013). Simulation is here a means of responding to the well-known problem of the paradox of design ergonomics (Pinsky & Theureau, 1984): it is possible to say something that is truly based on a work situation when it is already fully designed, but then it is too late to intervene in the design. Simulation favors anticipation, because it functions as a "virtual laboratory": it "opens up the design space" and nourishes interaction (discussion and negotiation) between the actors involved in the design process (Barcellini, Van Belleghem, & Daniellou, 2013).
- 5 The SMACH simulation is part of this perspective of anticipating a future situation: it is a tool to help designers make decisions and imagine solutions to energy efficiency issues (Guibourdenche, Salembier, Poizat, Haradji, & Galbat, 2007) in situations that do not yet exist (collective self-consumption, electric vehicle, etc.). Hypotheses concerning the transformation of human activity can then be used to anticipate the impact of technological innovations on energy consumption. It is a platform that can be used in studies at the scale of a household or a population. The simulation depicts computer agents organizing their individual and collective daily life in a digital habitat. They consume electricity as a result of their daily interactions with electrical appliances, their perception of comfort and a greater or lesser concern for energy efficiency. The general functioning of SMACH is as follows:
  - *The basic SMACH data* relate to a static description of a household and include the number of people, their age and gender, possible actions, comfort preferences, equipment and the type of habitat. These data are taken from surveys (INSEE in particular).
  - *The human activity engine* corresponds to the multi-agent engine which, when the simulation is launched, will create interactions between all of the descriptive elements of the simulated household. At each time step (corresponding to one minute of simulation), the agents can carry out individual actions and interact with the other agents in the situation (the members of the household) or with the environment (housing, heating, etc.).
- 6 In the simulation we thus distinguish (Figure 1) between the static framing of the simulation (the basic household data) and the dynamics of the agents (the human activity engine).

Figure 1: SMACH's operating logic.

Figure 1 : Logique de fonctionnement de SMACH

- 7 Different HMIs² are linked to the SMACH platform in order to make the simulation available to users with very varied profiles and intended uses (energy experts, residents, showroom visitors).

1.2. The course-of-action technological research program

- 8 In his speech at the 26th congress of the Société d'Ergonomie de Langue Française, Léonardo Pinsky (Pinsky, 1990a) proposed to develop a piece of technological research, a theory of practice. In this speech, he first of all pointed out that technological research cannot be reduced to a science or a discipline, because, quoting Koyré (Koyré, 1971), he said that practical thought is essentially different from theoretical, scientific thought, and that it differs due to its autonomy, which is manifested in the inventiveness and creativity it displays. It is even less reducible to a science in that it is fundamentally the result of an interdisciplinary approach to design. It is an extension of user-centered design (Norman & Draper, 1986; Pinsky, 1990b) and considers that the action of ergonomists in design involves the creation of a practical model, i.e. a model that aims at transformative action on the basis of the diagnosis/prognosis that the ergonomist makes of the situation. He also stated that the design of a new situation requires criteria with which to guide it. In his view, workload is one of the criteria which make it possible to direct technological research towards improving the conditions under which the activity will take place. Pinsky is careful to specify that workload is not for him a scientific notion, but a useful technological notion: "Just as 'workload' as a scientific, quantifiable or even just a formalizable notion is an aberration that ergonomics has rightly rejected, so 'workload' as a technological notion, informed by the progress of scientific research, is, in our opinion, to be retained and even developed" (Pinsky, 1990a). As indicated in the introduction to this issue, this text and that of 1987 (Pinsky & Theureau, 1987) are founding texts which lay the foundations of what we understand by technological research: research on interdisciplinary design practice that is based on knowledge of human activity (and more precisely, of course of action) and which integrates the ergonomist's diagnosis/

prognosis³ very early in the design process, through modelling, to contribute directly to the design of future situations.

- 9 Very early on, the Course-of-Action program distinguished between and articulated two research programs: “the empirical course-of-action research program” which concerns scientific knowledge of the activity and “the course-of-action technological research program” relating to the knowledge produced on design practice. Following the authors, (Durand, 2008; Pinsky & Theureau, 1987; Theureau, 2006, 2019) we characterize a course-of-action technological research program (TRP) as follows:
  - Like all technological research, a TRP is not the application of a science (an applied science), but results from a reciprocal influence between theoretical and empirical knowledge about human activity and theoretical and technical knowledge relating to the design of situations. The TRP is thus the result of an organic relationship with one or more empirical research programs, be they course-of-action or not.
  - The initial purpose of designing a TRP was focused on the question of assisting human activity. The design did not aim at artefacts that replace the operator, but rather to design an aid for users/operators during interaction, when making action decisions, and when assessing their actions (Jeffroy & Lambert, 1992; Pinsky & Theureau, 1987). Users/operators act and transform the situation from their point of view, from their flow of asymmetrical interactions; design in terms of assistance consists in designing an environment (technical, organizational, etc.) which will improve their asymmetrical interaction with the situation.
  - The design objective gradually widened. From the design of an aid system it progressed to the design of an appropriable situation (Poizat, Durand, & Theureau, 2016; Theureau, 2009b). Designing means anticipating a future situation while considering the overall effects it may have on the operator; it means building an environment (technical, cultural, organizational, etc.) which is part of the continuous process of transforming the activity. Theureau (Theureau, 2011) points out that the conception of appropriability must relate to appropriation of the situation (the coupling of the actor in activity with the environment and the other actors), appropriation of the body (becoming one with...) and cultural appropriation (relating to the user/operator’s value system).
  - A TRP can be assessed on the basis of two criteria. The first criterion is its heuristic power, i.e. its capacity to meet needs, to highlight new needs, to resist opposition from design actors, to formulate new design questions. The second criterion is that of its capacity for growth, i.e. its capacity to broaden its initial domain, its openness/development to other domains, its impact in terms of new questions posed to empirical research programs that are organically related to the TRP.
  - Finally, we also retain from these authors the primordial criterion of cultural technical-organizational efficiency which opens up towards criteria and indices of technological quality (such as utility, usability, workload, for example) and to a test/validation of this efficiency.
- 10 In this document, we will rely on the notion of technological research program (TRP) to report on the approach we implemented when designing the SMACH simulation. This design experience will serve as a basis for specifying what constitutes a technological research program. We will seek to highlight how we constructed the SMACH TRP in an organic relationship with human activity, and on what basis we assessed its technological quality, its heuristic power and its capacity for growth. Based on the SMACH experience, it will not therefore be a question of addressing the question of the

TRP in all its generality (generic TRP of the course of action), but rather of using a specific TRP that we call “simulating human activity in silico” as a basis for reflection.

1.3. The SMACH technological research program in several stages

- 11 The SMACH project required an approach that was simultaneously conceptual (relationships between activity and multi-agent models), methodological (qualitative and quantitative validation) and technical (development of the multi-agent platform). More specifically, it is a technological research program⁴ (TRP) specific to the in silico simulation of human activity. It has been progressively developed on the basis of a structural relationship between empirical research on knowledge of everyday human activity in the home and the computer design of simulated human activity and consumption in the home. As far as the SMACH simulation is concerned, we used this general design logic for the two constituent parts of the simulation: the HMI and the simulation engine (see Figure 2).

Figure 2: The two axes of activity-centered design in SMACH.

Figure 2 : Les deux axes de la conception centrée activité dans SMACH

- 12 As the diagram shows, we need to distinguish between two separate parts of a simulation platform:
- The HMI which deals with interaction with the user. It is designed from a user-assistance perspective, i.e. by defining useful functionalities and an easy-to-use dialogue. HMIs have been systematically evaluated in real or realistic situations whenever we have targeted energy experts or the general public;
  - The SMACH activity and consumption engine corresponds to the agent simulation of human activity and energy consumption. It was designed to ensure the most plausible simulation possible in order to propose calculation results that are relevant to the needs of the energy expert. Validation then consisted in qualifying the simulation with regard to the real phenomenon. This text will mainly focus on the design of the activity engine.

- 13 SMACH technological research is taking place over a 12-year period: there are 3 highly structuring stages, as shown in figure 3.

Figure 3: The stages of the SMACH technological research program.

Figure 3 : Les étapes du program de recherche technologique SMACH

- The initial stage concerned what might be called a proof of concept, during which we sought to learn whether it was possible to simulate a domestic activity while at the same time respecting the major generic characteristics of human activity.
  - Stage 2 was the stage that organized the program into the different axes of research necessary for the development of the simulation platform so that it was useful and usable.
  - The success of the previous stages led to the design of a simulation platform and will lead, in stage 3, to the development of service engineering and to renewed research questions due to the multiple requests made by energy experts.
- 14 This presentation of how the SMACH TRP has been organized over several years should not hide the fact that it is a process without any determinism: at any time and for various reasons (scientific, strategic, budgetary, regulatory, etc.), the research may be stopped or take different directions. In the following sections, we go back to the different stages of this technological research program in order to examine the main dynamics of its creation and organization. Technological research as we approach it corresponds to the construction of a “research course” which is developed through the articulation of different empirical and technical works of research.

2. Stage 1: Assessing the feasibility of human activity simulation

- 15 The question that arose during this initial stage of the SMACH research is whether it was technically possible and reasonable, without overly distorting a real phenomenon such as daily life in a home, to simulate a human activity “in silico”. We therefore felt that a multi-agent approach would be useful:
- Multi-Agent Systems have characteristics that make them suitable for simulating human behavior, partly due to the autonomy of the agents (Ferber, 1995). Multi-agent modelling thus makes dynamic simulations possible via interactions between agents or the interaction of agents with their environment.
  - It is possible to simulate certain dimensions of human experience using computer modelling which corresponds to a reduction of social processes (Lefèvre, 2016). Our idea was for

autonomous agents to represent human actors who organize their individual and collective activities in the home.

- 16 Based on the above, we organized our involvement in SMACH technological research in relation to two issues (see Figure 4): 1) what type of human activity modelling respects a sufficient level of similarity with human activity? 2) how to compare the simulated phenomenon with the real phenomenon to ensure this sufficient level of similarity?

Figure 4: A commitment structured around the issue of activity simulation and its validation.

Figure 4 : Un engagement structuré autour de la question de la simulation de l'activité et de sa validation

- 17 These two questions were to organize this feasibility stage and define its boundaries. We develop these two points below.

2.1. A synthetic model for an acceptable in silico reduction of human activity

- 18 Our commitment to this research was initially guided by an ontological hypothesis. We considered that the world of the living (empirical knowledge of human activity) should not be confused with a simulation of the living. The logics we created in the simulation only make sense for this computational world. The only function of multi-agent modelling of activity is to produce an acceptable imitation of human activity. Human activity is then a source of inspiration and we do not attribute any cognitive, emotional, cultural, etc. reality to the simulation we create. Our objective was therefore to reach a satisfactory level of imitation, to define the relevant reduction of the phenomenon which would not distort it: we could then talk about the plausibility of the simulation.
- 19 During this first stage, we carried out some unsuccessful multi-agent modelling tests, such as, for example, modelling the cognitive decision-making processes of different actors. We finally focused on the organizational level of human activity in the home: the individual and collective dynamics of the agents revealed how daily life was organized in the home. This first type of modelling was a synthetic model, i.e. a formal multi-agent model of human activity. This modelling test appeared to be satisfactory, because it was based on three theoretical hypotheses of enaction and course of action:
- The first hypothesis related to the autonomy of living systems in enaction theory (Varela, 1989; Winograd & Flores, 1986). Every living system is an autonomous system which must maintain its equilibrium within the dynamics of its interactions with the environment.

- The second hypothesis (Theureau, 2006; Varela, 1989) related to human actors who determine their activity according to their history and to the environment in which they find themselves. They transform their environment and are themselves transformed within the dynamics of their interactions. This interaction is asymmetrical, because it is the actors who define what is significant/relevant for them in the situation.
  - Finally, with the third hypothesis (Theureau, 2006), we considered collective activity as a totality whose organization is constantly challenged by individual activities and constantly reconstructed by these same individual activities. The collective is therefore not an autonomous unit, because it corresponds to a “totality” that is constantly “detotalized” and “retotalized” by the activity of its components.
- 20 In the automatically generated example below, we illustrate this incorporation of theoretical principles into the structuring of the simulation. In figure 5, each horizontal line corresponds to an agent and each color to an action. For example, agent-Luc (the father) is going to chain together a set of actions aimed at caring for agent-Tom (his infant son), coordinating with agent-Eve (his girlfriend) and then organizing his evening (meal and television).

Figure 5: Sequencing and coordination of individual and collective actions in the initial SMACH model.

Figure 5 : Enchaînement et coordination d'actions individuelles et collectives dans le modèle initial de SMACH

- 21 We consider that this synthetic modelling⁵ produces a plausible simulation of human activity, because it is structured around the following axes:
- It is a question of simulating an activity dynamic, i.e. a performance of actions which will evolve according to the environment and the agents. The actions and interactions are not predetermined: the agents have a certain level of autonomy⁶.
  - The activity of each agent is linked to the specific point of view he/she has of the situation (the room in which he/she is located, the actions performed and the actions that are possible).
  - The collective activity of the agents is possible, because they communicate so as to coordinate with one another, be it to eat together, get a child ready in the morning, etc.
- 22 During this stage our synthetic model was very limited: it only allowed simulations of a few hours, had no calculation that integrated the building, the equipment, the weather,

etc. It did however show that it is possible to create a plausible simulation of daily life in the home. This synthetic multi-agent model was an “acceptable in silico reduction of human activity”, because it was structured around a number of major theoretical principles of human activity and respected the dynamics of daily life described in our empirical research on human activity in the home (Guibourdenche *et al.*, 2007; Haué, 2003).

- 23 This synthetic design model was, to use the words of Vinck and Laureillard (Vinck & Laureillard, 1995), an intermediate design object that took account of collective construction in design. It was a mediator that materialized the intentions of the designers and went beyond their respective contributions. Yet it was more than that, because it corresponded to what Haué (Haué, 2003) calls a pivotal model: it was built by combining the description of human activity with computer modelling. There are similar distinctions in multi-agent design (Guyot, 2006; Le Page, 2017) where there are three separate types of model: the domain expert’s model, the intermediate, formal model (that is the design model) and finally, the technical model which is developed by the computer scientist. This general description is close to our modelling practice, though without being very specific about what is referred to as the “specialism-related model”. As far as we are concerned, the human activity model was based on our diagnosis/prognosis and the synthetic model integrated this within the framework of the formal logics of agent modelling. We took the Haué diagram (Haué, 2003) and modified it (see below) so that it corresponded to our practice.

Figure 6: The synthetic model as a pivotal design model.

Figure 6 : Le modèle synthétique comme modèle pivot de la conception

- 24 The synthetic model we propose is a **significant modelling result for technological research**: it gives concrete form to what might be an “acceptable in silico reduction of human activity”; it provides a solution to our need to simulate human activity. A significant modelling result plays a guiding role in future actions on the multi-agent platform: the choices that are made will be decisive for the work to come.

- 25 This synthetic model is a minimal basis for modelling structured around major theoretical and practical principles of agent activity and simulation: it is a limited model, an outline for a future model. If it is validated, it can no longer be challenged.

2.2. Participatory simulation to assess the limited synthetic model of human activity

- 26 In the context of this feasibility stage it is essential to ensure the potential of the synthetic model to simulate a human activity, to verify its ease of use and to estimate its capacity to evolve. The question which was raised at this stage was that of the construction of an observatory that was sufficiently realistic to be able to compare the simulated phenomenon with the real phenomenon.
- 27 Interactive participatory simulation (Le Page, 2017) is a methodological tool frequently used in agent-based approaches. Participatory simulation places the human actor at the heart of the system (Guyot, 2006) by involving him/her in the simulated situation. With SMACH's participatory simulation, a human actor can be located in a simulated home and perform everyday actions: the human actor, via his/her avatar, carries out actions (getting up, washing, etc.) and coordinates with other actors, etc.
- 28 An experiment was carried out to assess the plausibility of the simulation, to ensure that this minimal synthetic modelling was a suitable starting point for taking account of human activity in the home. The experiment was developed on the methodological bases of the ergonomic assessment designed to get as close as possible to a future situation (Pinsky & Theureau, 1984). To this end, we simulated a shared living situation that we proposed to three participants in the experiment, and defined two virtual characters interacting in the simulated scene. The experiment was thus composed of three human actors and two automated agents. The modalities of the experiment were as follows:
- The human actors were unaware of the role played by the other human actors. Nor did they know which characters were played by the automated agents.
  - The experiment took place over several phases representing several days.
  - The experiment was filmed and an interview was conducted at the end.
- 29 The most important result of the experiment was the validation of the synthetic model of the simulation. The human actors succeeded in creating or recreating realistic real-life moments. For example, one human actor actually living in a shared flat indicated that he had reproduced behaviors he had at home. We also saw significant collective behaviors that we had not anticipated: from one experimental phase to the next, some human actors constructed an experience and adapted their actions accordingly. For example, one person did not want to do the washing-up, because he/she had done it in the two previous phases. Moreover, the automated agents were only identified later on. The ability of human actors to "live" these moments and to interact "naturally" with the automated agents demonstrates the model's high level of plausibility.
- 30 This experiment showed that participatory simulation is a viable methodological tool with which to qualify the level of plausibility of a human activity simulation. By creating a realistic situation of use, we had created an intermediate design object which, this time, had a methodological purpose in relation to human experience. This construction was a **significant methodological result for technological research** on

the suitability of simulation to human activity. This choice of “validation-oriented participatory design” thus corresponded to a synthetic model test instance. We can take Haué’s diagram (Haué, 2003) and complete it (see Figure 7), in its lower half, to offer an account of this methodological construction. The choice of methodological design is, this time, the result of a reverse process in relation to the design: the technical considerations (synthetic model, HMI for the participatory simulation interaction...) are at the service of the pivotal experiment situation.

Figure 7: Participatory design as a pivotal methodology for simulation evaluation/validation.
 Figure 7 : La conception participative comme méthodologie pivot de l'évaluation/validation de la simulation

- 31 This participatory simulation experiment marked the end of this first stage of SMACH technological research. The design of a highly simplified initial model of activity in the home, and its comparison with human actors allowed us to go beyond mere intuition: the multi-agent simulation of human activity in the home became a real possibility. This initial work demonstrated the feasibility of this orientation of our research. It also showed the structural relationship that exists in this TRP, 1) between human activity and the design of a synthetic model 2) between this modelling and its comparison with an experimental situation of participatory simulation (Haradji, Poizat, & Sempé, 2012). The positive results of this stage were decisive: they opened up a new stage in our technological research.

3. Stage 2: The development of a Technological Research Program to simulate at the scale of a household and a population

- 32 The positive conclusions of the feasibility stage made it possible to further develop the SMACH technology research program. Two moments of research were important

during this second stage: 1) designing and validating the simulation of a household; 2) designing and validating the simulation of a population. These two moments of the SMACH TRP are described below.

3.1. The advanced synthetic model at the scale of a household and its validation

- 33 The limited synthetic model, developed during feasibility stage 1, proved to be promising. It was used as a starting point for a more complete model of human activity within its ecosystem. We initially wanted to simulate the continuity of human activity over long periods. To understand how human activity is organized from one day to the next, we again started from our empirical course-of-action studies of daily life in the home (Guibourdenche *et al.*, 2007). The initial synthetic model was thus completed so as to integrate life habits into the simulation process (Haradji *et al.*, 2018). We then wanted to model the home environment to create the most plausible interaction situation possible for the agents. We therefore integrated technical models of thermal building design (Plessis, Amouroux, & Haradji, 2014), weather, electrical equipment (e.g. refrigerator, heating, etc.) and tariff offers. The resulting multi-agent model was an advanced synthetic model that corresponds to an “acceptable in silico reduction of a household within its ecosystem” (see Figure 8): this allowed us to simulate a household’s activity and energy consumption.

Figure 8: Development of the advanced synthetic model for a household and its validation.

Figure 8 : Le développement du modèle synthétique avancé pour un foyer et sa validation

- 34 This advanced synthetic model is a formal multi-agent model that takes account of the complexity of interactions within the home and respects the theoretical hypotheses of enaction and course of action (see previous section). In the multi-agent scheme in Figure 9 we can thus identify:

- *The autonomy and dynamics of the agent’s individual activity.* Individual activity is driven by an agent (an *individual*?) who carries out tasks autonomously. *Habits* emerge during the simulation and are influenced by *lifestyles* relating to energy efficiency, comfort and budget.
- *The construction of the collective activity of an agent with other agents.* Collective activity is built by interaction between agents (individuals) who perform tasks together and who for this purpose form ephemeral groups (or collectives) made up of all or some of the members of the *household* (adults, children, relatives, etc.).

- *The asymmetrical coupling of the agent with his/her environment.* The structural coupling with the environment results from the agents (individuals) who, engaged in their individual and collective activities, interact with an *environment* composed of *equipment/appliances* (heating, hot water tank, refrigerator, etc.) and *rooms* that form a *dwelling* with a given level of insulation. In addition, the *supplier* proposes tariff offers.

Figure 9: The model of the multi-level organization of human activity.

Figure 9 : Le modèle de l'organisation multi-niveau de l'activité humaine

(Huraux, Sabouret, & Haradji, 2015)

- 35 As before, this was a pivotal design model, an advanced synthetic model, which gave rise to a computer model.
- 36 To validate the model, we went back to the methodological principle of participatory simulation and implemented it in natural situations involving real families. We followed three principles to improve the “natural” character of the experiment:
- *To use a reference situation based on real electricity consumption to allow comparison with the simulation.* EDF conducts a range of different experiments in real situations. We chose the “Une Bretagne d’avance” experiment because it provides quantitative data on the consumption of approximately 500 families.
  - *To put family members face-to-face with the simulation of their daily life.* To assess the realism of the simulation, we involved families using participatory simulation and confronted them with the simulation of their daily life.
  - *To articulate qualitative and quantitative validations.* We wanted to validate the simulation from both a qualitative angle (activity in the home), and a quantitative angle (energy consumption curves).
- 37 In order to create satisfactory experimental conditions, we 1) developed a participatory simulation interface that made it possible for a human actor to control an avatar and thus modify the course of the simulation (Figure 10); 2) conducted preliminary interviews with ten families from the ‘Une Bretagne d’avance’ experiment in order to

be in a position to run a one-week simulation for each of the ten families; 3) confronted a human actor from the family with the simulated daily life dynamics. He/she describes and comments on this “in silico” activity as it compares to his/her real activity.

Figure 10: Designing a realistic environment for participatory simulation.

Figure 10 : Conception d'un environnement réaliste pour la simulation participative

- 38 The results of the experiment were conclusive with regard to the dynamics of daily life in the home. None of the basic mechanisms of the simulation (agent autonomy, individual and collective dynamics, coupling with the environment) were called into question. This qualitative validation of the advanced synthetic model was completed by a validation of consumption. We then compared the simulated load curves of these families with their real consumption recorded in the context of the 'Une Bretagne d'avance' experiment (Figure 11).

Figure 11: Example of comparison of the simulated load curve (in blue) with the family's actual load curves (in red).

Figure 11 : Exemple de comparaison de la courbe de charge simulée (en bleu) avec les courbes de charge réelles de la famille (en rouge)

- 39 The results of the SMACH engine evaluation were positive (Haradji *et al.*, 2018): at the household level, they were plausible in terms of human activity (qualitative validation), and energy consumption was comparable to actual consumption (quantitative validation).
- 40 The advanced synthetic model was validated: it can simulate household activity and calculate the resulting energy consumption. Initial energy efficiency calculations become possible (calculating the impact of a new tariff on energy consumption, for example).

3.2. The advanced synthetic model at the scale of a population and its validation

- 41 Anticipating energy consumption rarely occurs at the level of just a few households. Simulation must be envisaged at different levels of population in order to be able to respond to most of the specialism-related issues relating to energy in the home (assessing the impact of a new tariff offer, the impact of a regulatory change, the impact of eco-gestures, etc.). This transition from a small number of households to the simulation of a large population (see Figure 12) was a new challenge for the SMACH TRP: how to simulate the multiplicity and diversity of human groups present within a population while respecting the individual realism of each household. The shift to a large scale must not be accompanied by a “crushing” of the diversities relating to household activity and consumption: the global level must not be disconnected from the local level.

Figure 12: The development of the advanced synthetic model for a population and its validation.
 Figure 12 : Le développement du modèle synthétique avancé pour une population et sa validation

- 42 With this scaling up, we then had to deal with an epistemological problem: it is not possible to observe and analyze the activity of thousands of households in order to define, on such a scale, the synthetic models of each household within that population. To overcome this constraint, we separated that which related to the statistical global description of a population of households (population and time use) from what related to the local activity of each household in its home. We thus articulated two points of view. The first point of view was statistical and was based on INSEE's time-use survey where over a two-day period, and every ten minutes, each of the 27,000 households in the survey indicated what they were doing. This socio-statistical database had the advantage of 1) reflecting the state of actions carried out in the home, 2) describing diverse households carrying out diverse actions at the scale of a population. This global point of view on possible actions (the statistical descriptions for each household) was then combined with the local point of view provided by the SMACH activity engine: the agents would then "bring the statistical data to life". They would adapt to their thermal, tariff and meteorological environment and, with a certain degree of autonomy, would build their individual and collective interactions in the home. We thus combined the statistical method, based on models aiming to achieve global statistical realism, and the agent method, based on models aiming to achieve local realism in the home (Reynaud, Haradji, Sempé, & Sabouret, 2017). Coupled with the statistical data, the simulation corresponded to an advanced synthetic model that produced a "description of acceptable large-scale activity for anticipating energy consumption".
- 43 With this model, it became possible to calculate energy consumption on the scale of a group of households, a city, a country, etc. The first step of the approach chosen to validate large-scale consumption (Delenne, 2018) consisted of comparing 1,000 consumption curves simulated by SMACH with reference values from the distributor Enedis (see Figure 13 for an example). The second step was to compare simulated consumption curves with real aggregated consumption curves for 10 households that had taken part in an experiment in Lyon.

Figure 13: Comparison of weekly profiles for customers with a Base option.

Figure 13 : Comparaison des profils hebdomadaires pour les clients en option Base

- 44 The comparison between simulated and real consumption showed that SMACH is sufficiently realistic to analyze the impact of new behaviors, new materials or new offers on energy consumption.
- 45 The realization of the large-scale simulation and its validation brought this second stage of technological research to a close; it marked the end of the simulation platform design process. It was at this point in the technological research that the simulation of activity in the home proved very useful for energy professions. The ability to use SMACH to perform population-scale simulations opened the door to a significant use of activity diagrams and consumption curves. Several tens of thousands of data files have thus been produced to respond to specialism-related issues such as the presence of electric vehicles in the home, the impact of energy-saving actions on a national scale, or the evaluation of the impact of a tariff offer on the load curve, etc.

4. Stage 3: Developing the service and the related technological research

- 46 Numerous simulation requests have shown that the SMACH platform has been meeting a need. They have also shown that our commitment to the SMACH TRP needs to evolve. From an organization focused on the feasibility and development of simulation, we have shifted to an organization focused on producing realistic data to anticipate future situations⁸. It is the needs of SMACH customers that now drive the dynamics of our work, be it to evolve the platform (service engineering) or carry out research on models (see Figure 14).

Figure 14: The current stage for the development of a SMACH service.

Figure 14 : L'étape actuelle pour le développement d'un service SMACH

- 47 To meet the demand for realistic data (activity diagram and consumption curves) we designed a specialism-related HMI dedicated to energy specialists (economist, heating engineer, electrical network specialist, etc.). We followed a classic design process centered on human activity (Haradji & Faveaux, 2006) with 1) a definition of the experts' needs based on an analysis of their requests and on a series of interviews; 2) a specification of the HMI and a modelled evaluation with the experts (see Figure 15); 3) an IT development of the HMI specialism, the architecture and the database. From a service perspective, we also developed new technical models (building renovation models, heat pump models, electrical equipment models, etc.) which require no (or little) consideration of the human activity model.

Figure 15: Development of a mock-up and a specialism-related application for using SMACH.
Figure 15 : Développement d'une maquette et d'une application métier pour l'utilisation de SMACH

- 48 We must nevertheless distinguish this engineering (of HMIs and technical models) from research issues that require new human activity modelling. For example, in order to calculate consumption when recharging an electric vehicle at home, we need to model the types of journeys that people make with their vehicle, and whether they recharge the vehicle at their workplace, in a shopping center, in a public space, etc. The vehicle's charge level will determine their need for recharging at home. This research, which is currently being developed, puts forward hypotheses based on statistical data on people's activities when travelling.
- 49 SMACH's extension to include collective self-consumption opens up an even wider field of research, as it involves a new electricity consumption logic. With the current platform, all households are independent; but with collective self-consumption, agents, and more broadly households, will have to communicate to share energy. We are therefore faced with a twofold research question. Firstly, how can the SMACH simulation technically evolve in order to integrate multi-agent mechanisms for sharing energy between households or groups of households (Albouys-Perrois, Sabouret, Haradji, Schumann, & Inard, 2019). This is a profound transformation of agent modelling due to the creation of the notion of energy exchange, which opens up a higher level of modelling than that of the household. This design issue also forces us to transform the human activity model in such a way as to integrate individual and collective decision-making into the sharing of intermittent energy production

(photovoltaic, wind turbines) between households. Our previous work in ergonomics did not allow us to do this, as this type of human experience is rare. Research is currently underway in design and ergonomics (Bonnardot, Vial, Salembier, Prieur, & Haradji, 2021) which aims to document human activity, both individual and collective, for a future situation that will transform our relationship with energy, social relations and the economic dimension of the households involved in this transition. This research will make it possible to put forward realistic hypotheses for the evolution of future activity in a context of collective self-consumption.

- 50 Our commitment to a SMACH service has thus taken two complementary directions. The engineering work aims to respond to requests from energy experts. These are distinct from the technological research questions which lead to new modelling in relation to both the technical dimension (equipment) and to the formalization of human activity (electric vehicles and collective self-consumption). Either way, the platform must be able to evolve in accordance with the energy-related stakes, and an understanding of human activity would appear to be central to the evaluation of the platform's capacity to meet the needs of energy experts on the one hand, and to the development of simulation models on the other.

5. Dynamics and organization of the SMACH technological research program

- 51 In this section, we first of all propose to explain the dynamics behind the creation of the SMACH TRP. Based on the modelling of the generic technological research program defined by (Theureau, 2009b, 2019), we believe that the internal dynamics of SMACH research resulted from the combination of the following tensions:

- The initial impulse related to the definition of our design object. From the outset, we approached simulation as a *user assistance*⁹ issue, to ensure that an expert can anticipate future energy-related transformations. It is therefore not a question of using a multi-agent system to replace the expert, but on the contrary of using the calculation capacities of artificial intelligence to help energy experts in making their action-related decisions.
- This initial impulse was also based on our theoretical stance. The *ontological and theoretical hypotheses* of enaction and course-of-action (dynamics of individual/collective activity, coupling with the environment, actor autonomy, etc.) mean that the simulated human activity must be realistic.
- This *in silico* realism was then deemed possible via the structural coupling between our research on the empirical knowledge of human activity and computer science research on multi-agent systems. It was this central core of *disciplinary* collaboration which then incorporated all the other contributions.
- *Engagement* in the research evolved, from one design stage to another and from one issue to another (feasibility, research development, service development) and framed the involvement in the different areas of research.
- The disciplinary contributions were structured around this objective of *in silico* realism and were based on an *observatory* of everyday real-life situations and on realistic situations of experimentation.
- The research tools (*the workshop*) allowed us to produce research results in terms of synthetic models for design and validation methodologies.

- 52 It was thus the conjunction of these different tensions that drove the internal dynamics of SMACH technological research. We represent it below (see Figure 16) using the hexadic sign formalism proposed by Theureau (Theureau, 2009b, 2019): this representation shows the convergence of forces for the production of a research result symbolized below (and in the other figures) by an orange dot.

Figure 16: Internal dynamic of SMACH technological research.
 Figure 16 : Dynamique interne de la recherche technologique SMACH

- 53 It is this general dynamic that determines the SMACH TRP and that will progressively generate organization in the different significant units that structure the technological research. These units are significant of the different levels of structural coupling that exist between the technique and the description of human activity. In Figure 17 we give details of these levels of organization within the SMACH technological research.
- 54 The first level of organization is that of the **significant results of the technological research**, represented in Figure 17 by an orange dot. As seen earlier, these results are the product of the TRP's internal dynamics; in SMACH they mainly correspond to modelling results (the synthetic model) or to methodological results (the participatory simulation). They correspond to technological design choices that are decisive in the development of research questions.

Figure 17: The significant levels of organization in SMACH technological research.
 Figure 17 : les niveaux d'organisation significatifs de la recherche technologique SMACH

- 55 The second level of organization is that of the **significant sequences of technological research**. This level of research organization takes account of the relationship between significant modelling results and significant methodological results (the arrows in Figure 17). Here there is a strong dependency between these two types of significant outcomes. For example, the “validity of the limited synthetic model” sequence corresponds to the articulation between the participatory simulation and the limited synthetic modelling.
- 56 The final level of organization is the **technological research stage**. This level of organization corresponds to the strategic challenges of the technological research program. For example, the feasibility stage is a moment of truth designed to either launch the research - or bring it to an end. This level is essential because it determines the type of commitment to the research, and in part determines the latter’s embedded levels of organization. Engagement in feasibility stage 1 will, for instance, lead to the creation of a limited synthetic model and a test of the participatory simulation method. It is then a question of evaluating the scientific and technical possibilities of this type of simulation. Furthermore, we would say that a stage can be composed of one or more significant sequences. For example, the platform development stage is made up of two significant research sequences (the “validity of the simulation of a household” sequence and the “validity of the simulation of a population” sequence).
- 57 Taking these different levels of research organization, we can now specify the criteria that define the SMACH technological research program:

- The **organic relationship with the activity** is present at several levels of the SMACH TRP. Each significant research result (be it a question of modelling choices or methodological choices) is developed in a structural relationship with empirical knowledge of human activity. Moreover, the significant research sequences are built around an iterative modelling/validation loop that reinforces the organic relationship with human activity.
- The **heuristic power** of the SMACH TRP is very visible in the significant sequences and stages of the research. The possibility of simulating human activity opens up the need to simulate at the scale of a household, then of a population, and also leads to new needs with the simulation of collective self-consumption and electric vehicles. Finally, these possibilities create a need for a data generation service for energy experts.
- The research’s **power to grow** was built during the sequence of significant results on the axes of modelling, methodology and service (see Figure 17), opening each time onto new research questions. For example, the research for a synthetic model evolved throughout the

TRP, from the limited synthetic model to the advanced synthetic model, then to the large-scale synthetic model and then to models for the electric vehicle and for collective self-consumption. The same is true of the methodological axis, where the research focused on the definition of a test instance, be it to validate the simulation of a human activity or the simulation of electricity consumption (participatory simulation, quantitative validation for electricity consumption).

- Finally, there is the **criterion of cultural technical-organizational efficiency** which opens onto criteria and indices of technological quality. We assessed this quality using the methodological axis where all the synthetic models could be evaluated within the framework of ergonomic experiments. We did the same using the service axis where the technological quality was verified when evaluating the help provided to energy experts (usability of the application), but also through the service rendered (usefulness of the service and of the application) to these experts in response to their requests for realistic simulation data.

58 On a more general level, and as we indicate in the dynamics of generation, the SMACH TRP is the fruit of a structural relationship with the different empirical and technical works of research that have nourished it or that it has solicited (Durand, 2008; Theureau, 2009b). The synthetic models were thus developed on the basis of the knowledge acquired in the various works of empirical research on everyday life in the home (Guibourdenche, 2013; Guibourdenche *et al.*, 2007; Haué, 2003). The SMACH TRP has also been informed by technical research on multi-agent modelling and simulation (Huraux *et al.*, 2015; Plessis *et al.*, 2014; Reynaud *et al.*, 2017). The SMACH technology research program is also generating new questions that interrogate empirical and technical research. This is the case, for example, for collective self-consumption. Bonnardot (Bonnardot *et al.*, 2021) poses the question of anticipating future collective experiments to share locally produced energy. From a technical standpoint, Albouys-Perrois (Albouys-Perrois *et al.*, 2019) raises the issue of creating multi-agent mechanisms to simulate collective self-consumption groups. As with any other TRP, the internal dynamics of the SMACH technological research program are structurally dependent on its organic relationship with empirical and technical research.

59 We conclude this characterization of the SMACH technology research program by addressing the issue of research and engineering collaborations. Each stage, each sequence and each significant result of the technological research is built around the definition of a research object whose unity of conception is based on the limited rationalities of the different disciplines that contribute to it (Theureau, 2009a). The pivotal design models (the synthetic model, for example) and methodological models (such as participatory simulation) are the privileged moments of this disciplinary construction. Moreover, it seems to us that in this case technological research concerns a transdisciplinarity of design, i.e. the design of an object that transcends disciplinary differences: this object has a coherence that cannot be found in any of the disciplines taken independently of one another. The synthetic model would not have existed without contributions from activity ergonomics and multi-agent modelling. Participatory simulation would not have existed without contributions from ergonomic evaluation, interaction design and agent methodology. The cement of this design transdisciplinarity is provided here by the organic relationship between empirical knowledge of activity and technical design. This transdisciplinarity oriented towards

human activity is constitutive of our research objects, as well as of the engineering knowledge that we implement.

Conclusion

- 60 Our aim with this article was to provide a definition of a specific technological research program, drawing on several years of work within the SMACH research framework. We have mainly emphasized the importance of the organic relationship with human activity. Engaging in technological research means constant articulation between the technical aspects and the empirical knowledge of human activity; articulation from one stage of research to another, from one sequence to another and within each research result taken independently. It is this movement, built into an organic relationship with different scientific research programs (empirical and technical) and generating this dynamic of research growth, that allows us to respond to increasingly broad simulation requirements. It is also, certainly, this movement which drives the technological quality of the situation that is created.
- 61 To conclude, and to use Pinsky's words (Pinsky, 1990a), with this article we wish to be part of a reflection on design, and make a contribution to a theory of practice. We have described the specific "simulating human activity in silico" TRP based on SMACH research. One possibility for this work would be to compare it with other research integrating simulated human activity in order to set out the rules for this type of specific technological research program. Of course, by comparing different specific TRPs we would also contribute to a more general reflection on design and more specifically on the generic technological research program on the course of action.

BIBLIOGRAPHY

- Albouys-Perrois, J., Sabouret, N., Haradji, Y., Schumann, M., & Inard, C. (2019). A Co Simulation Of Photovoltaic Power Generation And Human Activity For Smart Building Energy Management And Energy Sharing. *Proceeding of 16th IBPSA International Conference & Exhibition Building Simulation 2019*. Florence, Italie.
- Barcellini, F., Van Belleghem, L., & Daniellou, F. (2013). Les projets de conception comme opportunité de développement des activités. In P. Falzon (Ed.), *Ergonomie constructive* (pp. 191–206). Paris: Presses Universitaires de France.
- Béguin, P., & Weill-Fassina, A. (1997). *La Simulation en ergonomie : connaitre, agir et interagir*. Toulouse: Octarès.
- Bonnardot, Z., Vial, S., Salembier, P., Prieur, E., & Haradji, Y. (2021). Créer des interactions humaines réalistes par le design : le cas de l'autoconsommation collective pour la transition énergétique (Texte soumis). *Actes Du 55^e Congrès de La SELF, Paris, 11-13 janvier 2021*.
- Delenne, B. (2018). Eléments de validation des courbes de charge simulées par SMACH. In *Document interne EDF. Mémo E74/18/010/A*.

- Dugdale, J., Pavard, B., & Soubie, J.-L. (2000). A Pragmatic Development of a Computer Simulation of an Emergency Call Centre. In G. Dieng, R. Giboin, A., Karsenty, L., & De Michelis (Eds.), *Proceedings of the 4th International Conference on the Design of Cooperative Systems* (pp. 241–256). Amsterdam: IOS Press.
- Durand, M. (2008). Un programme de recherche technologique en formation des adultes. *Éducation et Didactique*, 2(3), 97–121. <https://doi.org/10.4000/educationdidactique.373>
- Ferber, J. (1995). *Les Systèmes multi-agents : vers une intelligence collective*. InterEditions.
- Guibourdenche, J. (2013). *Préoccupations et agencements dans les contextes d'activité domestique : Contribution à la conception de situations informatiques diffuses, appropriables et énergétiquement efficaces*. Thèse de doctorat, Institut de psychologie Lyon 2.
- Guibourdenche, J., Salembier, P., Poizat, G., Haradji, Y., & Galbat, M. (2007). A Contextual Approach to Home Energy Management Systems Automation in Daily Practices. *Proceedings of the European Conference on Cognitive Ergonomics 2015*. <https://doi.org/10.1145/2788412.2788436>
- Guyot, P. (2006). *Simulations multi-agents participatives. Faire interagir agents et humains pour explorer, modéliser et reproduire les comportements collectifs*. Thèse de doctorat, Université Paris 6.
- Haradji, Y., & Faveaux, L. (2006). Évolution de notre pratique de conception (1985-2005). *Activites*, 03(1). <https://doi.org/10.4000/activites.1852>
- Haradji, Y., Guibourdenche, J., Reynaud, Q., Poizat, G., Sabouret, N., Sempé, F., Huraux, & Galbat, M. (2018). De la modélisation de l'activité humaine à la modélisation pour la simulation sociale : entre réalisme et fécondité technologique. *Activites*, 15(1). <https://doi.org/10.4000/activites.3106>
- Haradji, Y., Poizat, G., & Sempé, F. (2012). Human Activity and Social Simulation. *Advances in Applied Human Modeling and Simulation*. CRC Press.
- Haué, J.-B. (2003). *Conception d'interfaces grand public en termes de situations d'utilisation : le cas du Multi-Accès*. Thèse de doctorat, Université de Technologie de Compiègne.
- Huraux, T., Sabouret, N., & Haradji, Y. (2015). Study of Human Activity Related to Residential Energy Consumption Using Multi-level Simulations. *Proceedings of the International Conference on Agents and Artificial Intelligence*, 133–140. <https://doi.org/10.5220/0005197401330140>
- Jeffroy, F., & Lambert, I. (1992). An ergonomics framework for user activity centred software design. *Human Factors in Information Technology*, 9, 43–92. <https://doi.org/10.1016/B978-0-444-89301-7.50009-5>
- Kashif, A., Ploix, S., Dugdale, J., & Le, X. H. B. (2013). Simulating the dynamics of occupant behaviour for power management in residential buildings. *Energy and Buildings*. <https://doi.org/10.1016/j.enbuild.2012.09.042>
- Koyré, A. (1971). *Études d'histoire de la pensée philosophique*. Gallimard.
- Le Page, C. (2017). *Simulation multi-agent interactive: engager des populations locales dans la modélisation des socio-écosystèmes pour stimuler l'apprentissage social*. Université Pierre et Marie Curie, Paris.
- Lefèvre, A. (2016). Simulation sociale et simulacre structural. *Variations*, (19), 1–23. <https://doi.org/10.4000/variations.720>
- Norman, D. A., & Draper, S. W. (1986). *User Centered System Design. New Perspectives on Human-Computer Interaction*. CRC Press.

- Pavard, B. (2002). Complexity paradigm as a framework for the study of cooperative systems. *Revue d'intelligence Artificielle*, 16(4-5), 419-442. <https://doi.org/10.3166/ria.16.419-442>
- Pinsky, L. (1990a). Définir l'ergonomie comme une technologie. *Communication au XXVI^e Congrès de La Société d'Ergonomie de Langue Française, Montréal.*, pp. 1-10.
- Pinsky, L. (1990b). User activity centered design. In Elsevier (Ed.), *Work with display units* (L. Berling (pp. 119-150). North-Holland.
- Pinsky, L., & Theureau, J. (1984). Paradoxe de l'ergonomie de conception et logiciel informatique. *Revue Des Conditions de Travail*, 9, 1-15.
- Pinsky, L., & Theureau, J. (1987). *L'étude du cours d'action*. Collection d'Ergonomie et de Neurophysiologie du Travail CNAM N°88. Paris.
- Plessis, G., Amouroux, É., & Haradji, Y. (2014). Coupling occupant behaviour with a building energy model-A FMI application. *Proceedings of the 10th International ModelicaConference*, 321-326. <https://doi.org/10.3384/ECP14096321>
- Poizat, G., Durand, M., & Theureau, J. (2016). The challenges of activity analysis for training objectives. *Le Travail Humain*, 79(3), 233. <https://doi.org/10.3917/th.793.0233>
- Reynaud, Q., Haradji, Y., Sempé, F., & Sabouret, N. (2017). Using Time Use Surveys in Multi Agent based Simulations of Human Activity. *Proceedings of the 9th International Conference on Agents and Artificial Intelligence*, 67-77. <https://doi.org/10.5220/0006189100670077>
- Theureau, J. (2006). *Le cours d'action : méthode développée*. Toulouse: Octarès.
- Theureau, J. (2009a). Comment l'interdisciplinarité peut-elle être un rassemblement fécond des ignorants? In *La mise à l'épreuve. Le transfert des connaissances scientifiques en questions* (QUAE, (pp. 121-139). Versailles.
- Theureau, J. (2009b). *Le cours d'action : méthode réfléchie*. Toulouse: Octarès.
- Theureau, J. (2011). *Appropriations 1, 2, 3. Appropriation, Incorporation, In-culturation*. Retrieved from <http://www.coursdaction.fr/02-Communications/2011-JT-C136.pdf>
- Theureau, J. (2019). *Cerisy : La construction de programmes de recherche technologique en relation organique avec des recherches en sciences humaines & sociales*. Cerisy.
- Van Belleghem, L. (2018). La simulation de l'activité en conception ergonomique : acquis et perspectives. *Activites*, 15(1), 0-22. <https://doi.org/10.4000/activites.3129>
- Varela, F. J. (1989). *Autonomie et connaissance : essai sur le vivant*. Éditions du Seuil.
- Vinck, D., & Laureillard, P. (1995). Coordination par les objets dans les processus de conception. *Journées CSI - "Représenter, Coordonner, Attribuer"*, 13. Retrieved from <https://hal.archives-ouvertes.fr/hal-00134434>
- Winograd, T., & Flores, F. (1986). *Understanding computers and cognition : a new foundation for design*. Norwood: Ablex.

NOTES

1. The meaning of the SMACH acronym has evolved. It initially meant Simulation Multi-Agent des Comportements Humains (multi-agent simulation of human behaviour). It now means Simulation Multi-agent de l'Activité humaine et des Consommations dans l'Habitat (multi-agent simulation of human behaviour and consumption in the home).

2. Here, HMI means Human-Machine Interaction, focusing on the assistance that HMI provides during interaction with user activity.
3. The ergonomist's prognoses/diagnoses are based on assistance criteria (workload, ease of use, utility, etc.) and on the description they give of human activity.
4. We mainly use the abbreviation TRP to refer to the "course of action's" Technological Research Programme. The terms "specific technological research programme", "SMACH TRP" and "SMACH technological research" will be used as equivalents in this text.
5. The design of the synthetic model and its relation to the empirical analysis of the activity of everyday life are presented in (Haradji, Guibourdenche, Reynaud, Poizat, Sabouret, Sempé *et al.*, 2018)
6. An agent will be able to perform an action in accordance with preferred periods (for example, wishing to sleep at night), preferred actions (reading rather than doing housework), reactions to the environment (being warm or cold), coordinating with other agents (going out for a walk), etc. Each of these constraints is calculated on the basis of a one-minute time step and determines the respective weight (numeric value) of each action for each agent: an action can thus be activated, continued, interrupted, etc.
7. The terms in italics relate to the terms used in Figure 9.
8. The works of research set out in this section are ongoing and cannot be discussed with the same level of detail as those presented in previous sections.
9. The terms in italics relate to the components of the hexadic sign shown in Figure 16.

ABSTRACTS

SMACH (Multi-Agent Simulation of Human Activity and Consumption in the Home) is a simulation platform that is part of EDF's research and development framework. It aims to use simulation to anticipate and reduce energy consumption at different levels of analysis (housing, neighborhood, city, country). The aim of this article is to characterize a "course-of-action" technological research program by referring to several years of SMACH research work. We mainly focus on the importance of the organic relationship between technology and human activity and we show the evolution of this organic relationship as we follow the different stages that characterize this technological research program. This article can be seen as a basis for generalizing and specifying the effective criteria for validating a technological research program and as a contribution to a reflection on design in ergonomics.

SMACH (Simulation Multi-agent de l'Activité humaine et des Consommations dans l'Habitat) est une plateforme de simulation qui s'inscrit pour EDF dans un cadre de recherche et développement. Elle vise à utiliser la simulation pour l'anticipation et la réduction des consommations d'énergie à différentes mailles d'analyse (habitat, quartier, ville, pays). Notre objectif, avec ce texte, est de caractériser ce qu'est un programme de recherche technologique cours d'action en nous appuyant pour cela sur plusieurs années de travaux de recherche SMACH. Nous insistons principalement sur l'importance de la relation organique entre technique et activité humaine et nous montrons l'évolution de cette relation organique au fur et à mesure des différentes étapes qui caractérisent ce programme de recherche technologique. Cet article peut être vu comme une base pour généraliser et préciser les critères effectifs de validation d'un

programme de recherche technologique, comme une contribution à une réflexion sur la conception en ergonomie.

INDEX

Keywords: technological research program, synthetic model, design, participatory simulation, course of action, activity analysis, multi-agent system

Mots-clés: programme de recherche technologique, modèle synthétique, conception, simulation participative, cours d'action, analyse de l'activité, système multi-agent

AUTHORS

YVON HARADJI

yvon.haradji@gmail.com