Learning by Gaming: ANT and Critical Making

Sergio Minniti
Yachay Tech University (EC)

Stefano De Paoli
Abertay University (UK)

Abstract: Relationships among theory, gaming, learning and socio-technical design are explored in the two contributions which compose the section. The theory in question is ANT, re-interpreted through *critical making* - an umbrella term for various distinctive practices that link traditional scholarship in the humanities and social sciences to forms of material engagement. Sergio Minniti describes an ongoing project called *Game of ANT*, which draws upon the critical making approach to design an interactive technology and a workshop experience through which scholars and students can conceptually-materially engage with ANT, hence exploring and approaching it from novel points of view. *Game of ANT* adopts the Latourian vision of technoscience as war and physically embodies this idea by proposing a sort of war game during which participants play the roles of human or non-human actors engaging with the competitive dynamics of socio-technical life. The commentary by Stefano De Paoli proposes new directions to develop the project, by deepening the concept of game and its value for design and learning processes.

Keywords: Actor-network theory; critical making; critical technical practices; physical computing; game.

Corresponding author: Sergio Minniti, School of Mathematical Sciences and Information Technology, Yachay Tech University – San Miguel de Urcuqui, Hacienda San José s/n, Ecuador – Email: sminniti@yachaytech.edu.ec

A Critical Making Approach to Actor-Network Theory: Game of ANT

Sergio Minniti

Introduction: Making ANT

In the last twenty years, multiple spaces of intersection between design practices and Science and Technology Studies (STS) have emerged, differently contributing to a general attempt to bridge the divide between

the social and technical sciences (Berg 1998; Bowker et al. 1997; Ingram et al. 2007; Jensen 2008; Latour 2008; Suchman 2007; Woodhouse and Patton 2004).

More recently, scholarly interest in crossing the boundaries between Actor-Network Theory (ANT) and design has grown steadily as part of this endeavor, supporting the double movement of "ANT towards design" and "design towards ANT" (Storni 2015). In doing so, scholars of different disciplines have explored the manifold possibilities of intersection between ANT and design by reflecting, to cite just a few examples, on how ANT might contribute to the design of information systems (IS) (Díaz Andrade and Urquhart 2010; Hanseth et al. 2004), collaborative and participatory design (C&PD) (Binder et al. 2015; Storni et al. 2015), architecture and industrial design (Yaneva 2009), and Human-Centered Design (HCD) (Steen 2011).

In these researches - as well as many others whose discussion is beyond the scope of this article - the ways in which ANT and design, and theoretical and physical work, intersect each other are multiple and differentiated. Some common lines of inquiry include: the use of ANT as an analytic device to contrast the "obsession with 'objects'" dominant in design, as well as the asymmetrical human-centeredness of design practices (Binder et al. 2015, 152); the adoption of ANT as a design tool that can be used to problematize the "object-ness" of design objects by articulating the idea of designing "things" as socio-material assemblages or *objects-in-design* (Ehn 2008; Telier et al. 2011), thus rethinking design as a process of heterogeneous engineering (Nickelsen and Binder 2008) through which "things" are "drawn together" (Latour 2008; Storni et al. 2012); and the convergence of ANT and design to support a shared programmatic agenda towards socio-technical democracy (Binder et al. 2015; Storni et al. 2015), merging Latour's call for "making things public" (Latour 2005a) with the objectives of "political design" (Björgvinsson et al. 2010, 2012; DiSalvo 2010, 2012).

Such researches have mostly investigated the ways in which ANT might contribute to design theories, practices, and education, just acknowledging the need for exploring the other way around (Storni et al. 2012). Yet, to offer its best, the crossing of the boundaries between ANT and design should also follow the other direction, that is, it should actually explore the ways in which design might contribute to ANT, making actual the parallel movement of "design towards ANT" that has remained mainly programmatic (Storni 2015).

In this article, I illustrate an ongoing project I am carrying out at Yachay Tech University and in collaboration with Yachay FabLab, which aims at developing novel ways to approach ANT through the design of an interactive electronic game and the organization of workshops during which participants use pre-assembled and coded electronic components to create devices that let them behave as actor-networks, associate and dissociate with each other to gain "power" within an imaginary socio-

technical world, and discuss about their experience as actor-networks to foster both their socio-technical imagination and critical thinking about ANT.

In what follows, I propose some reflections on how a specific design method termed *critical making*, developed and practiced by scholar Matt Ratto in his Critical Making Lab[i] at the University of Toronto (Ratto 2011a, 2011b; Ratto and Hoekema 2009; Ratto et al. 2014), might enrich the ways in which we approach ANT by bridging the gap between physical and conceptual exploration.

In order to do so, in our project we adopt some tools and methods commonly used by *makers* and *fabbers* to rapidly prototype interactive technologies (Walter-Herrmann and Büching 2013). More specifically, we use Arduino-based *physical computing*,[ii] a technical practice that has been widely celebrated as a means to develop ways of thinking with our hands (Banzi 2008) and translate bits into atoms, and atoms into bits (Gershenfeld 2012). This presupposes the use of ANT not merely as a methodology for description, but rather its "translation" into an interactive gaming experience through which scholars and students can conceptually-materially engage with ANT, hence exploring and approaching it from novel points of view.

To summarize the meaning of our project, it could be said that it is about *making* ANT in a double sense: on the one hand, it implies using makers' tools to create interactive physical devices reproducing the behaviour of actor-networks within the socio-technical world; on the other hand, it aims at enriching our understanding of ANT as a practice rather than a theory, respecting an already celebrated feature of ANT ("Far from being a theory of the social… it always was… a very crude method to learn from the actors", Latour 1999a, 20), while also proposing a novel point of view on how it can be engaged with, by moving from the realm of analytic deconstruction to that of conceptual-material construction. "What if ANT starts to be in the business of designing new pieces of technology and not just actor-network accounts of them?" (Storni 2015, 166).

Criticality, Technical Practices, and the Critical Making Approach

Critical making is an umbrella term for various distinctive practices that link traditional scholarship in the humanities and social sciences to forms of material engagement in order to explore new ways of studying the relationship between technologies and social life (Ratto 2011a). The aim of critical making is "to articulate and develop novel modes of intervention into dominant systems of information exchange and knowledge generation" that "focus on assembling rather than deconstructing within the modern technological society" (Ratto et al. 2014, 85).

In order to reach this goal, critical making practices "theoretically and pragmatically connect two modes of engagement with the world that are often held separate - critical thinking, typically understood as conceptually and linguistically based, and physical 'making,' goal-based material work" (Ratto 2011a, 253). Critical making has thus been described as a *materialist interventionist method* (Sánchez Criado et al. 2016), which seeks to "counteract the ineffectual linguistic bias of traditional critiques of technoscience" (Ratto et al. 2014, 86).

As such, it assumes the engagement between design and social research should aim at exploring societal issues and social theories through the fabrication of interactive prototypes, i.e. through *making*: it is "a kind of pedagogical practice that uses material engagements with technologies to open up and extend critical social reflection" (Hertz 2015, 1).

Examples of such a combination of critical thinking with hands-on making are the workshops organized by Matt Ratto, which are conceived as shared making experiences where participants explore and inform discussions about topics such as, for example, distance learning, or the rise of proprietary and closed *walled gardens* on the Internet, by constructing and using interactive *electronic agents* that metaphorically operationalize established sociological concepts through the execution of specific code subroutines (Ratto 2011a; Ratto et al. 2014).

Critical making shares its emphasis on the critical purpose of technical practices with other contemporary design and engineering practices, as well as forms of conceptual art, which also support a shift from focusing on technical sophistication and function to criticality and expression. Relevant examples of practices that explicitly refer to critical reflection as both an integral part and outcome of technical, material work include:

- *Critical design*, a design methodology popularized by Anthony Dunne and Fiona Raby (Dunne 2006; Dunne and Ruby 2001), which "leverages design to make consumers more critical about their everyday lives, particularly how their lives are mediated by assumptions, values, ideologies, and behavioural norms inscribed in designs" (Bardzell and Bardzell 2013, 3297);
- *Critical engineering,* a methodology introduced in 2011 by a group of artists-technologists signatories of the *Critical Engineering Manifesto* (Oliver et al. 2011), whose aim is to prototype devices that reveal the hidden socio-political assumptions embodied by mainstream technology. It looks "beyond the 'awe of implementation' to determine methods of influence and their specific effects," through a sort of hacktivist process of *reverse black-boxing*:[iii] "The greater the dependence on a technology the greater the need to study and expose its inner workings, regardless of ownership or legal provision" (Oliver et al. 2011; see also Parikka 2013, who interprets critical engineering as a more political form of *media archaeology*);
- *Critical technical practice*, an approach to engineering originally developed in the context of artificial intelligence research, which re-

> quires engineers to develop "an expanded understanding of the conditions and goals of technical work" (Agre 1997a, 23) and "a split identity – one foot planted in the craft work of design and the other foot planted in the reflexive work of critique" (Agre 1997b, 155). This is made possible by combining a reflexive analysis of dominant and marginalized socio-technical forces with the production of novel technologies that embody alternative socio-technical configurations and redistribute power within society.

However, notwithstanding the communal focus on merging critical reflection with hands-on practice, key differences between the aforementioned critical practices and the critical making approach exist. First, differently from the formers, critical making is *scholarship-oriented*: it establishes explicit connections between the constructive process and specific scholarly literature, which transform the shared experience of making into a site for analysis and scholarly exploration (Ratto 2011a, 253).

Second, critical making is *process-oriented*, in contrast to the general tendency of critical technical practices to be object-oriented (Hertz 2015, 2). Critical methodologies generally focus on building refined objects to generate critique, producing what have been defined as "critically made objects", that is, objects and technologies that overcome the limits of language in stimulating critical reflections:

> Things have the strength to hit you powerfully and forcefully. Critically engaged language can do detailed surgery on a topic; critical objects can hit like an emotional sledgehammer." "Critically made objects have the power to be evocative 'things to think with'… [which] enable individuals to reflect on the personal and social impact of new technologies (Hertz 2015, 4-6).

On the contrary, critical making places explicit emphasis on the process (as opposed to the product) of making:

> Critical making emphasizes the shared acts of making rather than the evocative object. The final prototypes are not intended to be displayed and to speak for themselves. Instead, they are considered a means to an end, and achieve value through the act of shared construction, joint conversation, and reflection. Therefore, while critical making organizes its efforts around the making of material objects, devices themselves are not the ultimate goal. Instead, through the sharing of results and an ongoing critical analysis of materials, designs, constraints, and outcomes, participants in critical making exercises together perform a practice-based engagement with pragmatic and theoretical issues. (Ratto 2011a, 253).

In the next section, I illustrate how we are adopting the critical making methodology to approach ANT, designing an interactive technology and a workshop experience that aim at fostering socio-technical imagination and generating critical thinking about ANT.

Game of ANT

Drawing upon the critical making approach, I am developing, in collaboration with José Gerardo Acosta Arias from Yachay FabLab, a project called *Game of ANT*, which focuses on the fabrication of interactive devices that reproduce the behaviour of actor-networks within the socio-technical world. Game of ANT adopts the Latourian vision of technoscience as war (Latour 1987) and physically embodies this idea by proposing a sort of war game during which participants play the roles of human or non-human actors engaging with the dynamics of socio-technical life. Using pre-assembled and coded components, participants construct and play with electronic "actors" that are able to associate and dissociate with each other, thus forming multiple actor-networks that compete for gaining "power" within an imagined socio-technical world. To win the game, an actor-network needs to crystallize and become a *black box* (Latour 1999b) before its competitors. The working of the game thus reproduces the basic principles of ANT and "translates" the sociology of translation into a gaming experience through which participants can conceptually-materially engage with ANT.

Though it is an ongoing project that has not been tested in the field, I will briefly describe the prototype and workshop parts of Game of ANT, to illustrate how we aim at crossing the boundaries between design and ANT by adopting the methodology of critical making.

The Prototype

The Game of ANT prototype includes two kinds of devices based on different Arduino microcontrollers: a master, based on Arduino Mega, and a number of slaves, based on Arduino Micro (fig. 1).

The master acts as a central unit, receiving inputs from and sending outputs to the slaves via wired connections, and regulating the game progression according to the players' actions. It emits sounds to communicate to the participants that a round is over, and plays a jingle when the process of black-boxing is complete and the game ends. The master also shows the current state of the game via a 16x2 LCD display, which indicates how many actor-networks exist in each round of the game, and how much "powerful" the strongest actor-network is (see below for a description of how "power" is calculated). From an aesthetics point of view, the central unit is designed as a cube made of black plexiglass, in order to translate the concept of *black box* into physical form (Latour 1999b).

The slaves represent the "electronic agents" through which players exert their agency during the game. Each slave is based on an Arduino Micro and has the following main components:

- 1 potentiometer, a variable resistor controlled by an adjusting knob, which allows players to operate selections within a range of options. By using the knob, at the beginning of the game participants choose whether they prefer to play as human or non-human actors. During the next stages, they use it to select which other player they want to *enrol* to create or empower their own actor-network (Callon et al. 1986);
- 1 7-segment LED display, which shows how much "power" the player has after every round;
- 3 buttons, through which players choose what kind of action they want to exert on the other actors (A, B, or C);
- 1 red LED and 1 green LED, which indicate if actions are successful or not.

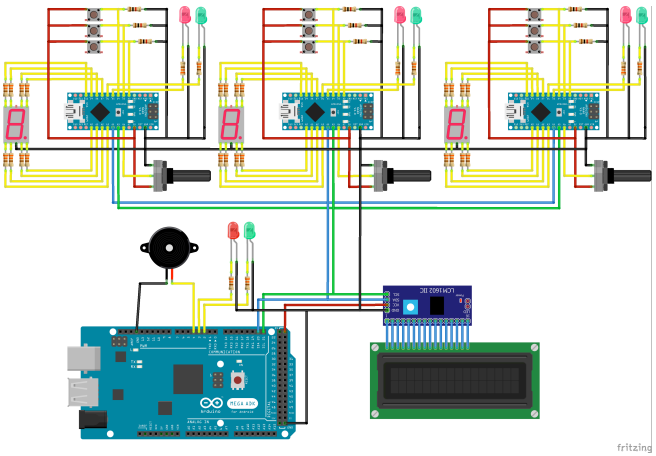

Figure 1: Electronic circuit of the Game of ANT prototype. For simplicity, it shows only the master (i.e. the *black box*, below) and three slaves (above). Courtesy of José Gerardo Acosta Arias.

The Workshop

The workshop during which Game of ANT is assembled and played with is divided into three phases, each one including different activities: (1) the construction and customization of the "electronic agents" (EA); (2) the game itself; and (3) the informal discussion amongst participants about their experience as heterogeneous parts of actor-networks.

Phase one: assemblage and personalisation of the "electronic agents"

During the first phase, each participant assembles her own EA using a pre-coded Arduino Micro and the other electronic components, under

the guidance of the researcher. When the EAs are ready, they are connected with each other, and with the pre-assembled central unit (*black box*), by wired connections.

A relevant activity, in this phase, is the customization of the EAs: participants will be required to elaborate a brief description of the human or non-human actor they want to impersonate, and to personalise their EAs accordingly, by using common materials such as cardboard, scissors, duct tape, and markers. The aim of this activity is twofold: on the one hand, it aims at differentiating the "actors" participating in the game, thus reproducing the heterogeneity which characterizes actor-networks (Callon 1986); on the other hand, its goal is to make participants develop emotional connections with the EAs through the creation and personalisation processes. This form of *attachment* (Gomart and Hennion 1999) is an essential part of critical making, within which emotional connections work as springboards for critical reflection (Ratto 2011a, 2011b).

Phase two: the gaming experience

The second phase consists of the game itself. Here, participants play by using their EAs to associate and dissociate with each other, thus forming multiple actor-networks that compete for gaining "power" within an imagined socio-technical world.

To create and dismantle associations, during each round of the game players accomplish two actions: (1) select the player they want to target; and (2) choose the kind of action they want to exert on their target (A, B, or C). Once these actions have been performed, the central unit associates the EAs according to the communications established and the actions chosen. This means, for example, that if the EA#1 establishes communication with the EA#2 and selects the option A, and the EA#2 also selects the option A, the EA#1 and EA#2 associate with each other, independently of the target chosen by the EA#2; if, during this same round, the EA#2 successfully associates also with the EA#3, hence the EA#1, EA#2, and EA#3 become part of the same actor-network. Through this mechanism, actor-networks are created according to the multiple choices of the participants and the relations resulting from the sum of their actions. EAs that participate in an actor-network, but are successfully targeted by other EAs, dissociate and change their membership.

The central unit also assigns a "power" value (PV) to the EAs which are successful in creating associations. This means that when two or more EAs associate with each other, their PV reaches the value of 1. This value increases when the association is maintained, and decreases to 1 or 0 when an EA becomes part of a new actor-network or is taken apart and isolated, respectively.

Since the same EAs might be attracted by multiple actor-networks at the same time, conflicts are resolved by assigning their membership according to the different PVs: when, for example, an EA is successfully targeted by two or more EAs participating in different actor-networks,

the former establishes an association with the EA that has the highest PV, becoming a member of its actor-network.

The game ends when two or more members of the same actor-network reach the PV that is pre-defined by the researcher, depending on the number of participants and the desired duration of the game. The reaching of this PV represents the conclusion of the black-boxing process, since it metaphorically means that the actor-network has gained enough power, through the strengthening of the association between some of its entities, to be considered as stable.

Phase three: the concluding discussion

In the last phase of the workshop, the participants who win the game will inform public discussion on their gaming experience. In order to develop their socio-technical imagination, they will be asked to elaborate and discuss, in a few minutes, a common narrative about how all the entities they had chosen to impersonate might stay together, as parts of an actor-network. Through this collective elaboration, prior identities are expected to be manipulated and made coherent with each other, reproducing the idea that the bringing together of actors (i.e. *translation*) is a process of transformation, where actors are changed though their performances and relations (Gad and Bruun Jensen 2010). This activity, together with the direct experience of playing ANT, is expected to be central for stimulating critical reflection on ANT.

The discussion completes the material-conceptual engagement of the participants with ANT, concluding a workshop whereby participants "together perform a practice-based engagement with pragmatic and theoretical issues" through a collective process of prototyping and a joint discussion of concepts and ideas, so as "to extend knowledge and skills in relevant technical areas as well as to provide the means for conceptual exploration," using the prototypes "to express, critique, and extend relevant concepts, theories, and models" (Ratto 2011, 253).

Conclusions

The notion of *critical making* suggests a new form of technical practice, through which theoretical issues are materialized by participatory means and explored both materially and conceptually. By developing Game of ANT I aim at exploring how the dynamics of technoscience, as conceptualized by ANT, could be projected onto an interactive technology, through which ANT can be materially-conceptually engaged with. By creating, personalising, and playing with this technology, as well as by informing discussion on how the singular identities and entities deployed during the game might stay together, the participants can enact a novel mode of "making" ANT through their shared and direct experience.

To accomplish this goal, the working of Game of ANT is designed to reproduce the basic principles and dynamics of ANT. Drawing on the

principle of *generalized symmetry*, the game allows players to choose if they want to play as human or non-human actors, to self-identify with entities of different scale and nature, and to exert their agency through a symmetrical mechanism.

Players also act according to the principle of *free association*, establishing associations between heterogeneous entities that are always unstable, can be loose or strong, and only partially result from deliberate actions, since the process of association depends on the sum of players' actions, as well as their different membership and "power". This way, Game of ANT replicates the process of *translation* through which actor-networks form: each successful action of the players corresponds to a successful translation, which leads to the *enrolment* of the targeted player. By forming actor-networks players automatically become *spokespersons* capable of enrolling other entities to gain more power (Callon 1986).

Game of ANT takes seriously the Latourian vision of technoscience as war (Latour 1987) and physically embodies this idea by proposing a war game that reproduces the competitive dynamics of socio-technical life. It "translates" the sociology of translation into a gaming experience through which scholars and students can conceptually-materially engage with ANT, hence exploring and approaching it from novel points of view.

Acknowledgements

I thank José Gerardo Acosta Arias from Yachay FabLab for helping me transform my ideas into working technologies. I also thank Andrés José Cueva Costales, Director of Innopolis, for supporting my collaboration with Yachay FabLab.

* * *

Commentary on "A Critical Making Approach to Actor-Network Theory: Game of ANT"

Stefano De Paoli

When confronted with the problem of telling what the Actor-Network Theory (ANT) is all about, it is not always easy to present concepts or convince the audience (Latour 1996). This is often true especially for conveying the notions of what it means to treat human and non-human actors symmetrically and to be agnostic about the actors' own accounts of matters. Discussing this with students, especially social sciences

ones, which have been heavily trained in the "sociology of the social" (Latour 2005b), is sometimes even more so difficult, as teachers need to overcome existing preconceptions such as the foundational idea that social actors are by definition humans or institutions with defined roles. Experiencing the critical power of ANT thus is sometimes not easy unless one has spent a great deal reading the core books and articles, or unless one is an engineer or a scientist of course (Bijker et al, 2012). The contribution by Minniti A critical making approach to Actor-Network Theory: Game of ANT has interesting elements to address the problem of telling the ANT to students and the public but also, especially, for experiencing it. The game of ANT translates ANT critical experience from texts and language to a material-designed world via the assemblage of open source electronics and then a phase of playing a game and a final discussion. This offers students (or the public alike) a first-hand practical experience of ANT.

A core point of the discussion with which Minniti opens his contribution is the relation of ANT with other fields and their reciprocal influence. Earlier in the paper, Minniti claims that it is relatively straightforward to see how ANT has influenced other fields. Minniti concentrates in particular on the influences of ANT on the field Design (e.g. Storni 2015). However, Minniti also states that observing the opposite movement, of how Design or material practices more generally could influence ANT is a much less explored area, only perhaps just acknowledged in literature. The umbrella of critical making has some potential in this regard as the making, which entails using cheap and widely available open source electronics that are assembled to produce Do-It-Yourself innovations, is an actor-networking sort-of design practice. This perspective relies on the notion of critical making (Ratto 2011). It does seem then possible to start from the making and move subsequently toward the theory. I am not sure, however, that at the current stage of development, the game of ANT achieves the goal of influencing ANT, but the potential may be there for the future.

The aspect I would like to focus mostly to understand the previous point is the gaming aspect of the contribution. This is perhaps the less theorized area of the manuscript. Minniti proposes a game-like situation (game of ANT) in which participants assemble a circuit (with different Arduino boards, acting with different capacities and other electronic components) and play a game whose goal is to create associations among actants, which then could lead to a black-boxing and the winning of the game. The critical part of this making-gaming exercise is the final discussion of participants (e.g. students) on their respective translation processes. The making part is the assemblage of the game by players. The game effectively seeks to translate concepts such as association or black-boxing into a practical process experienced with the material at hand.

I understand that the author focus is on the strengths of the critical making approach. However, I was intrigued by the fact that Minniti rather than sticking to the notion of Making of ANT, which features in the

introduction title, translates this into the game of ANT. This translation from making to gaming does come with a string of implications, which do not appear acknowledged. There is indeed a question, which lies at the centre of exercises like this one, which has to do with the notion of games and gaming and how they are used to produce or experience knowledge. Going back to the earlier point of the reciprocal influence between ANT and other fields, a few years ago, at the EASST conference in Trento, one of the conference sub-themes was on Digital Games and STS. The convenors had it clear that there was much potential for the use of Science and Technology Studies, with Actor-Network featuring heavily, to better understand and theorise digital games. However, during the opening of the sub-theme, the convenors also raised the point that the relative opposite movement was highly required, focusing on how digital games study could influence and increase the capacity of Science and Technology Studies. Like for the discussion on Design we touched before, this point was just acknowledged but there was hardly any input on this from the participants. Does the game of ANT have this potential to influence the theory?

According to an established definition: "a game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome" (Salen and Zimmerman 2003, 80). Minniti's game of ANT adheres to this definition. The game is a conflict among actants (ANT as war, in the author's words), within a set of rules (the selection of opposing actors, a selection among three actions, the way actants win over associations or lose them) and a quantifiable outcome (the reaching of a set Power Value, or PV). To this extent, then the question translates into whether the game of ANT brings something new to ANT or to the understanding of ANT, that other games may not be capable of bringing. To avoid immediately one potential misunderstanding, I think we should bracket for a moment the question of whether games can be critical or not. That games can have a powerful critical element is something we have known for some time. La molleindustria for example has been producing critical games for over fifteen years.[iv] The question we should ask is rather, in what ways the game of ANT differs from other games? Is there new potential in the game that other games do not have? Does the game of ANT really reflect the dynamics of an actor-networking process?

There certainly is an important element associated with the process oriented nature of critical making on which Minniti relies. The focus is not, apparently, on the object (e.g. the game) but on the making of it, or better the assembling of it. However, the game of ANT is only partially a process. The artificial conflict composed of the rules of the game, its game space (or magic circle as it would be called in games literature) and the winning outcomes are defined by the scholar from the outset. There is an object-oriented component in the game of ANT, which does seem unavoidable to an extent. Otherwise, we would be required to let participants also create the rules and set the space of the game. In other words,

to be entirely process-oriented as the approach of critical making does require, also the rules, the space and the outcomes of a game of ANT should be in themselves a critical making process. Players, although effectively connecting the Arduino boards (and the other required electronics) and creating their "cardboard" characters/actants, play within a set of rules and toward an objective which are defined from the outset. It is not difficult to see that, for instance, we do this every time we play a board game, like Snakes and Ladders or Risk. We take the board out of the box, we assemble the game in the way that it is prescribed by the manual (for instance in Risk we place our tanks on the world map depending on the Territory cards that we have received) and, very likely, more experienced players help out those that are new to the game. We throw the dices after having declared which of the other player we want to attack and the consequences of an attack may have varied impacts on the game for all the players. Thus, the process of the critical making of the game of ANT advocated by Minniti is only partial as it is effectively the assembling of a game-object that somehow already exists (putting together the Master and the slaves, connect them and add the other electronic component such as the switch or resistors, according to the game). The game of ANT does seem to share this aspect with other games, which may perhaps also have the potential of being themselves games of ANT.

Further focusing on the gaming aspect, there is another relevant question to ask: whether a game of ANT could be an "experience through which participants can conceptually-materially engage with ANT", as Minniti suggests. The achievement of this relates ultimately with how we come to say what is ANT. In ANT there are a topological and an ontological components to account for the process of actor-networking (Latour 1996). The point then is whether these components can translate into a game in the first place and then into a game of ANT. There is this very interesting passage in *A Thousand Plateaus Treatise on Nomadology – The War Machine* where Deleuze and Guattari (2004) use game theory as explanatory case for the differences between the State and the war machine. They compare the game of Chess with another board game called Go. Both games have their own space (a board), with rules and pieces that are placed on the board. They notice that "chess pieces are coded: they have an internal nature and intrinsic properties from which their movements, situations and confrontations derive" (Deleuze and Guattari 2004, 389).

We could see chess pieces as actors in a sociological sense, with essential properties, whose properties codify in a rather strict and binary way the relations among the pieces. Stretching a little bit this idea, we could see chess pieces as actors possessing social roles in a Parsonsians way, where the unfolding of social relations is dependent on the properties-roles of social actors. On the contrary, "go pieces are elements of a non-subjectified machine with no intrinsic properties, only situational ones" (Deleuze and Guattari 2004, 389).

Go pieces are not coded like bishops or towers in a game of chess, they are simple disks and have a "milieu of exteriority". They are actants whose agency is dependent on the relations they have with other actants. This is an interesting intuition because it draws attention on the differences between games (or more generally social organisations) whose elements are in non-essential relations of becoming and games whose elements are in pre-defined binary relations (such as object and subject, us and them). In games of becoming, the movement is not that of going from point A to point B (like in chess) but one of occupying a smooth space (topology) and the pieces relate to a non-essential ontology that allows this topology to unfold, as a Go piece can be anything like "a man, a woman, a louse, an elephant" (Deleuze and Guattari 2004, 389). The right question to ask then is whether the game of ANT is a game of becoming like Go with a non-essential ontology and a topological construction of networks or a game of binaries with elements or pieces having already codified properties which then determine a more or less linear spatial unfolding of the game. The shape cutting of the actants (the Electronic Agents or EAs) at the beginning of the game of ANT is an open ended, becoming process. However, at the beginning of the game these actants seem to play largely a non-human figurative role (Latour 1992), with limited or no agency. The game of ANT evolves with players' targeting of one of the other participants and selecting to exert one among three actions (A, B, C). The properties of each of these actions are not specified in advance in the game rules (it is not A a punch, B the use of a sword or C a diagonal movement or else), they possess exteriorities. This makes it a promising indication that these actions can be anything, depending on the shaping topology of the actor-network. They are not pre-codified in the game as properties or roles of the actants. They seem indeed relations of becoming. Moreover, the associations (or failed associations) which are outcome of the selected action are not limited to the targeted participant but independent and can extend to other actants in the network depending on their power. When there are conflicts in the potential associations, brute force determines which actor-network is successful. It does seem there is also a component of becoming in the association process. The final discussion, although not strictly part of the game, sees network-builders (the players) offering an account of their actor-networking. This is where the agency of the non-human figurative actants, shaped at the beginning of the game, is revealed by players. There is, in my view, thus great potential in the game of ANT to "enrich the way we approach ANT", though the game is not yet there to offer something that can influence ANT.

To conclude, it was enjoyable learning about this experience, but I would suggest that what is perhaps worth developing further in the contribution is a reflection on the game of ANT as a game in the first place and as a game of becoming in the second place. While from what I see the game displays the right topological and ontological elements, much of

the discussion seems conflated on the making aspect rather than accompanying this also with a discussion of the gaming aspect. Both aspects should be acknowledged and theorised upon. I would speculate indeed that it would be possible to have a critical-making experience by designing a game in which actors have defined properties and where the game unfolds with a linear spatiality, like a game of chess with Arduinos. This game may still be classed as critical making, but an imaginary game thus conceived will not enrich our understanding of ANT. This is the translation from making to gaming that I was signaling earlier in the commentary, which is somehow implicit in the paper. The implications of this translation I would suggest deserve reflections.

References

Agre, P.E. (1997a) *Computation and Human Experience*, Cambridge, Cambridge University Press.

Agre, P.E. (1997b) *Toward a Critical Technical Practice: Lessons Learned in Trying to Reform AI*, in G. Bowker, S.L. Star, W. Turner and L. Gasser (eds.), *Social Science, Technical Systems and Cooperative Work: Beyond the Great Divide*, Hillsdale, Erlbaum, pp. 131-157.

Banzi, M. (2008) *Getting Started with Arduino*, Sebastopol, O'Reilly Media.

Bardzell, J. and Bardzell, S. (2013) *What is "Critical" about Critical Design?*, in W.E. Mackay, S. Brewster and S. Bødker (eds.*), Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI 2013), New York, ACM Press, pp. 3297-3306.

Berg, M. (1998) *The Politics of Technology: On Bringing Social Theory into Technological Design*, in "Science, Technology & Human Values", 23 (4), pp. 456-490.

Bijker, W. E., Hughes, T. P., Pinch, T., & Douglas, D. G. (2012). *The social construction of technological systems: New directions in the sociology and history of technology*, Cambridge, MA, MIT press.

Binder, T., Brandt, E., Ehn, P. and Halse, J. (2015) *Democratic Design Experiments: Between Parliament and Laboratory*, in "CoDesign", 11 (3-4), pp. 152-165.

Björgvinsson, E., Ehn, P. and Hillgren, P.-A. (2010) *Participatory Design and "Democratizing Innovation"*, in K. Bødker, T. Bratteteig, D. Loi and T. Robertson (eds.), Proceedings of the 11th Biennial Participatory Design Conference (PDC '10), New York, ACM, pp. 41-50.

Björgvinsson, E., Ehn, P. and Hillgren, P.-A. (2012) *Agonistic Participatory Design: Working with Marginalised Social Movements*, in "CoDesign", 8 (2-3), pp. 127-144.

Bowker, G., Star, S.L., Turner, W. and Gasser, L. (1997) *Social Science Research, Technical Systems and Cooperative Work: Beyond the Great Divide*, Hillsdale, Erlbaum.

Callon, M. (1986) *Some Elements in the Sociology of Translation: Domestication of the Scallops and the Fishermen of St. Brieuc Bay*, in J. Law (ed.), *Power, Action and Belief: A New Sociology of Knowledge?*, London, Routledge, pp. 196-229.

Callon, M., Law, J. and Rip, A. (1986) *Mapping the Dynamics of Science and Technology: Sociology of Science in the Real World*, London, Macmillan.

Deleuze, G., and Guattari, F. (2004) *A Thousand Plateaus*, London, Continuum.

Díaz Andrade, A. and Urquhart, C. (2010) *The Affordances of Actor Network Theory in ICT for Development Research*, in "Information Technology & People", 23 (4), pp. 352-374.

DiSalvo, C. (2010) *Design, Democracy and Agonistic Pluralism*, in D. Durling (ed.), *Proceedings of the Design Research Society Conference (DRS '10)*, Montreal, Université de Montréal, pp. 1-10.

DiSalvo, C. (2012) *Adversarial Design*, Cambridge, MA, MIT Press.

Dunne, A. (2006) *Hertzian Tales: Electronic Products, Aesthetic Experience, and Critical Design*, Cambridge, MA, MIT Press.

Dunne, A. and Raby, F. (2001) *Design Noir: The Secret Life of Electronic Objects,* Basel, Boston and Berlin, Birkhäuser.

Ehn, P. (2008) *Participation in Design Things*, in J. Simonsen, T. Robertson and D. Hakken (eds.), *Proceedings of the Tenth Conference on Participatory Design (PDC'08)*, New York, ACM, pp. 92-101.

Gad, C. and Bruun Jensen, C. (2010) *On the Consequences of Post-ANT*, in "Science, Technology, & Human Values", 35 (1), pp. 55-80.

Gershenfeld, N. (2012) *How to Make Almost Anything: The Digital Fabrication Revolution*, in "Foreign Affairs", 91 (6), pp. 42-57.

Gomart, E. and Hennion, A. (1999) *A Sociology of Attachment: Music Amateurs and Drug Addicts*, in J. Law and J. Hassard (eds.), *Actor Network Theory and After*, Oxford, Blackwell, pp. 220-247.

Hertz, G. (ed.) (2015) *Conversations in Critical Making*, Victoria, CTheory Books.

Ingram, J., Shove, E. and Watson, M. (2007*) Products and Practices: Selected Concepts from Science and Technology Studies and from Social Theories of Consumption and Practice*, in "Design Issues", 23 (2), pp. 3-16.

Jensen, C.B. (2008) *CSCW Design Reconceptualised Through Science Studies*, in S.P. Gill (ed.), *Cognition, Communication and Interaction: Transdisciplinary Perspectives on Interactive Technology*, London, Springer, pp. 132-147.

Latour, B. (1987) *Science in Action*, Cambridge, Harvard University Press.

Latour, B., (1992) *Where are the missing masses? The sociology of a few mundane artefacts.* In: Bijker, W.E., Law, J. (Eds.), *Shaping Technology/Building Society*, (pp. 205–224), Cambridge, MA, MIT Press.

Latour, B. (1996) *On actor-network theory: A few clarifications*, in "Soziale Welt", 47, 369–81

Latour, B. (1994) *On Technical Mediation: Philosophy, Sociology, Genealogy*, in "Common Knowledge", 3 (2), pp. 29-64.

Latour, B. (1999a) *On Recalling ANT*, in "The Sociological Review", 47 (S1), pp. 15-25.

Latour, B. (1999b) *Pandora's Hope: Essays on the Reality of Science Studies*, Cambridge and London, Harvard University Press.

Latour, B. (2005a) *From Realpolitik to Dingpolitik: Or How to Make Things Public*, in B. Latour and P. Weibel (eds.), *Making Things Public: Atmosphere of Democracy*, Cambridge, MA, MIT Press, pp. 4-31.

Latour, B. (2005b). *Reassembling the social: An introduction to actor-network-theory*, Oxford, Oxford university press.

Latour B. (2008) *A Cautious Prometheus: A Few Steps Toward a Philosophy of Design (with Special Attention to Peter Sloterdijk)*, in J. Glynne, F. Hackney and V. Minton (eds.), *Networks of Design: Proceedings of the 2008 Annual International Conference of the Design History Society*, Boca Raton, Universal Publishers, pp. 1-13.

Nickelsen, N.C. and Binder, T. (2008) *Design and Heterogeneous Engineering: Toward an Actor Network Perspective on Design*, in "Artifacts", 2 (3-4), pp. 164-175.

Oliver, J., Savicic, G. and Vasiliev, D. (2011) *The Critical Engineering Manifesto*, in: http://criticalengineering.org/ (Retrieved March 14, 2018).

Parikka, J. (2013) *Critically Engineered Wireless Politics*, in "Culture Machine", 14, pp. 1-26.

Ratto, M. (2011a) *Critical Making: Conceptual and Material Studies in Technology and Social Life*, in "The Information Society", 27, pp. 252-260.

Ratto, M. (2011b) *Open Design and Critical Making, in P. Akinson*, M. Avital, B. Mau, R. Ramakers and C. Hummels (eds.), *Open Design Now: Why Design Cannot Remain Exclusive*, Amsterdam, BIS Publishers, pp. 202-209.

Ratto, M. and Hoekema, S. (2009) *Flwr Pwr: Tending the Walled Garden*, in A. Dekker and A. Wolfsberger (eds.), *Walled Garden*, Rotterdam, Virtueel Platform, pp. 51-60.

Ratto, M., Wilie, S.A. and Jalbert, K. (2014) *Introduction to the Special Forum on Critical Making as Research Program*, in "The Information Society", 30, pp. 85-95.

Salen, K., and Zimmerman, E. (2004) *Rules of play: Game design fundamentals*, Cambridge, MA, MIT press.

Sánchez Criado, T., Rodríguez-Giralt, I. and Mencaroni, A. (2016) Care in the (Critical) Making. Open Prototyping, or the Radicalisation of Independent-living Politics, in "ALTER - European Journal of Disability Research", 10 (1), pp. 24-39.

Snake-Beings, E. (2016) *The DiY ['Do-it-Yourself'] Ethos: A Participatory Culture of Material Engagement*, PhD Thesis, University of Waikato, in https://researchcommons.waikato.ac.nz/bitstream/handle/10289/9973/thesis.pdf?sequence=3 (Retrieved March 10, 2018).

Snake-Beings, E. (2017) *Maker Culture and DiY Technologies: Refunctioning as a Techno-Animist Practice*, in "Continuum: Journal of Media & Cultural Studies", 32 (2), pp-121-136.

Steen, M. (2012) Human-Centered Design as a Fragile Encounter, in "Design Issues", 28 (1), pp. 72-80.

Storni, C. (2012) *Unpacking Design Practices: The Notion of Things in the Making of Artifacts*, in "Science, Technology & Human Values", 37 (1), pp. 88-123.

Storni, C., Linde, P., Binder, T. and Stuedahl, D. (2012*) Exploring ANT in PD: reflections and implications for theory and practice.*, In *Proceedings of the 12th Participatory Design Conference: Exploratory Papers, Workshop Descriptions, Industry Cases*, Vol. 2, ACM, New York, pp. 145-146.

Storni, C. (2015) *Notes on ANT for Designers: Ontological, Methodological and Epistemological Turn in Collaborative Design*, in "CoDesign", 11 (3-4), pp. 166-178.

Storni, C., Binder, T., Linde, P. and Stuedahl, D. (2015) *Designing Things together: Intersections of Co-design and Actor–network Theory*, in "CoDesign", 11 (3-4), pp. 149-151.

Suchman, L. (2007) *Human-machine Reconfigurations: Plans and Situated Actions*, New York, Cambridge University Press.

Telier, A., Binder, T. De Michelis, G., Ehn, P., Jacucci, G., Linde, P. and Wagner, I. (2011) *Design Things*, Cambridge and London, MIT Press.

Walter-Herrmann, J. and Büching, C. (eds.) (2013) *Fab Lab: Of Machines, Makers and Inventors*, Bielefeld, Transcript Verlag.

Woodhouse, E. and Patton, J. (2004) *Design by Society: Science and Technology Studies and the Social Shaping of Design*, in "Design Issues", 20 (3), pp. 1-12.

Yaneva, A. (2009) *Making the Social Hold: Towards an Actor-Network Theory of Design*, in "Design and Culture", 1 (3), pp. 273-288.

[i] Http://criticalmaking.com/ (Accessed March 12, 2018).

[ii] Arduino is a single-board microcontroller created at the Ivrea Interaction Design Institute, commonly used for fast prototyping and to build interactive devices that can sense and control objects in the physical and digital world. See https://www.arduino.cc/en/guide/introduction (Accessed March 13, 2018).

[iii] According to Latour (1994), the notion of *reverse black-boxing* describes the process through which the invisible features of a technology become visible due to an 'error' or failure to function correctly. Recent contributions by Snake-Beings (2016, 2017) highlight how DIY practitioners and makers often re-function technologies on purpose, transforming reverse black-boxing into a strategy for increasing the participatory potential of materials. Here I adopt the notion of reverse black-boxing in a similar way, to underline how critical engineers intentionally reveal the hidden features of mainstream technology through their creations.

[iv] http://www.molleindustria.org/ (Accessed March 12, 2018).