A Multi Agent System for Understanding the Impact of Technology Transfer Offices in Green-IT

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Abstract. We present a multi agent system simulating the complex interplay between the actors of innovation involved in the development of technology transfer for Green IT. We focus on the role and the influence of technology transfer offices on the individual objectives of each other actor (researchers, research facilities, companies). We analyse also their impact on several parameters, including sustainability.

1 Introduction

Technology Transfer Offices (TTO) have been promoted in many research centers and universities as a mean for accelerating the adoption of research in the industry. While it seems obvious that these dedicated offices might have a positive role on the effective transfer, we did not see any computerized model of their impact. It would be too ambitious to analyse it through the wide spectrum of science, hence we focus on Green IT, the part of Information Technologies interested in environmental aspects, besides social and economical ones.

In the last decade, research on energy savings in IT has become important for both industry and academics. Several studies conducted by international organisations warn about the steady increase of energy consumption in various fields such as Datacentres, Cloud Computing [12], raising concerns on economic, social and ecological aspects. In laboratories techniques have been developed and show promising results in terms of energy consumption reduction. Unfortunately, the transfer (or even the knowledge) of these techniques to industries is limited. To understand the (positive or negative) impact of the presence of TTO on Green IT development, we analyse it through a simulation conducted with a multi agent system (MAS). The MAS helps to define the different actors involved in the technology transfer (including researchers, companies, funding agencies), and to observe the evolution of their objectives when parameters of the simulation evolves (external funding, company policies, ...). Previously we proposed [13] the concept of a generic multi agent system for technology transfer, where we observed the evolution of the actors objectives. In this work we design the implementation of this MAS and its extension to integrate TTO.

The main contributions of this research work are:

– An agent based model of technology transfer between researchers, companies, TTO and its implementation;
– An analysis of the TTO's presence and its impact on individual objectives of actors and on the overall objective of sustainability.

The article is organized in the following way: We present in Section 2 the multi agent system including the description of the selected actors and their links, the sustainability concept in Section 3 and the implementation of the model with NetLogo in Section 4. We present simulation results in Section 5 before state of the art in Section 6, and we conclude in Section 7.

2 Multi agent System for Technology Transfer

In [13] we have conceptualized a MAS for modeling the relationships between innovation actors in terms of technology transfer. The MAS has been built from a literature review and a detailed analysis of 80 responses to a survey sent to colleagues in the field of Green IT field. Their motivations and their links in the context of a transfer from research facilities to industry (and vice versa) were analyzed. The main players in the technology transfer, their general goals and their means of action were extracted and detailed.

In this paper, we detail the implementation of the MAS, focusing on researchers, research facilities, companies and TTO, together with their links. The full system adds funding agencies, standardization bodies, lobbying groups, governments and business angels in [1]. This simplified presentation highlights the keys for the transfer and is not exhaustive. Note finally that only the activities of the actors in direction of Green IT have been taken into account (leaving aside individual non related goals).

2.1 Researchers, Research Facilities and Companies

First concerned by technology transfer, they produce knowledge through publications that they seek to increase, and by building up projects with companies through their research institute. In the scope of this work, their primary goal is the number of publications where publications are related to their connections they create at conferences and / or collaborative projects, and the financial budget of their research centre. More links leads to more opportunities for publications. Researchers may be permanent or non-permanent. Non-permanent researchers (PhD candidate, PostDoc, ...) are supervised by permanent (and their number is limited by the number of permanent researchers) and have a limited contract duration.

The researchers are grouped in research facilities. Research facilities contribute to the technology transfer by giving incentives to researchers for publications. However they have their own objective (their reputation) that pushes them to build external contracts: collaborative projects (in a consortium) or direct cooperations with companies. The research facility's reputation is computed as the moving average (within a sliding window of 3 years) of its researchers' publications together with its contracts. Research facilities hire non permanent researchers within contracts.

Companies look to increase their profits by taking a competitive difference. Their goal is to increase their share in the market and therefore to increase their turnover. Participation in collaborative projects increase leadership when the project is successful, but requires initial investment that might be lost. They hire new employees to participate in projects. They dedicate a portion of their sales to research and development.

2.2 Technology Transfer Offices

Technology Transfer Offices (for instance SATT-Technology Transfer Anonymous Society- in France, PSB in Austria) are structures associated with research facilities, intended to facilitate and accelerate technology transfer. Their goal is to increase their turnover (and therefore that of their public shareholders) taking part in the implementation of contracts. In return they provide a permanent support and address book helping research facilities and businesses to contract better. While a contract between a research facility and a company lasts for a limited duration, the existing link through a TTO lasts beyond the duration of the contract. Also, the chances of finding a market for a research is higher when a TTO exists, increasing the chances of contracts for the associated research facility. In this work we will investigate in particular the impact of their presence on the goals of each of the other actors, but also on a general goal for improving society's sustainability.

3 The Concept of Sustainability

A presented in [14], sustainability is a concept defined by the conjunction of three factors: environmental, social and economic. In a simplified way, an actor of a system improves its sustainability if at least one of these increases when the others do not decrease. As an example, in the field of Green IT, a more recent material often uses less electricity for the same computing power, but at the same time its production, transport, the recycling of the older equipment, all have a negative impact on the environment [15]. The SPI (Sustainability Performance Indicator) for each actor has 3 factors, weighted at 33% each: ecological, societal, economical. Each factor is itself dependent on several elements weighted differently. Full details of our proposal for the calculation can be retrieved in [1].

The ecological factor is reflected by (i) the awareness of green IT solutions by the actor and (ii) by its efforts in terms of Reduce, Reuse and Recycle, typically during collaborative projects.

The social factor shows the actor's role in society: (i) green employment represents the employees recruited to work on (green IT) contracts. Employment is an important aspect for social evolution in a society. (ii) the society's knowledge on IT consumption. Reports like [12] help develop this, and is based on studying the publications from researchers and press releases from companies. (iii) Rethink is the ability of an actor to rethink its green IT in terms of strategy. For instance, a company with more contacts can rethink its strategy better, while a researcher has more freedom of thoughts when not involved in contracts. (iv) the actor's image in society is dependent on its communication strategy, mainly based on contracts and publications. (v) the influence of an actor on the standardization organizations. Big companies have more influence in organizations like ISO or IEC than individuals.

Finally, the economic factor is valued by: (i) the economic impact of green solutions. It tracks the successful contracts, meaning ones that generated benefits. (ii) the turnover representing the richness of each actor. (iii) the attractiveness of an actor for investors is an important factor for the economic dimension since it allows companies, TTO and research facilities to grow their turnover, indirectly increasing their R&D efforts.

All these values evolve with actors' actions and time. For instance, the awareness of Green IT solutions increases with the number of publications and contracts and decreases as time passes.

4 Implementation of the Multi Agent System

4.1 Netlogo as a multi agent system framework

We implemented a multi agent system with NetLogo 5.3.1 [2]. NetLogo simulates the evolution and interaction of agents in complex systems. NetLogo was created in 1999 by U. Wilenski, and is regularly updated (last version in 2015) [3]. It is used in many scientific fields: social science, economics, commercial distribution, biology, modeling complex behaviorrs in a population, etc. In NetLogo we used the agents turtles, links and observers. The turtles represent the actors in our world, the links are their connections. Observers collect the information used for statistics. Each agent operates independently in discrete time-steps.

4.2 Representation of the actors and their evolution

Each agent has its own attributes, those values change with interaction and time. A researcher may be permanent or not. If they are not permanent, they are associated with a contract those duration is given (ttl for time-to-live). It may be extended in case of successful collaborations. Researchers are members of a research facility. This is represented by a link between them (see Sec. 4.3).

As explained earlier, the primary goal for a researcher (as seen in this work) is to publish and therefore should have an attribute reflecting this. However, this attribute is shared with other actors, like all the attributes given here: each actor is active in the system at different regular intervals (action_period). Contracts and publications are stored, as well as the interests of one actor for 3 technologies (cloud, virtualization and cooling) having potential for energy reduction. These interests are used to compute a compatibility between actors when trying to collaborate (euclidian distance is used).

Research facilities have a turnover (richness), an amount dedicated to green research, a reputation (sliding value over 3 years), and its active research contracts at any point in time (used for linking the contracts with the non permanent researchers). If a TTO is attached to this research facility, a link is set up (see Section 4.3).

The TTO have a turnover, the number of transactions they were involved in and the percentage they take on every contract. Finally, the companies have a turnover and a R&D budget, and a number of employees in R&D. Funding agencies were modeled simply by regularly launching funds to initiate projects.

Once the actors defined, their evolution is controlled by algorithms called every time step. In our model, a time step (ticks in NetLogo) is equal to one day. The algorithm for a researcher is given in Algorithm 1.

Algorithm 1 Evolution of a researcher agent

1: **if** not permanent **then** $ttl = ttl - 1$
2: **if** $ttl \leq 0$ **then** die
3: e = research facility employing the researcher
4: newpublication = 0
5: **for all** regular-neighbor **do**
6:     $money = funding\_research$ of e
7:     **if** random-float $1.0 < (0.20 * 1/90)$ and $money > 1000$ **then**
8:         $newpublication = newpublication + 1$
9:         ask e [$funding\_research = funding\_research - 1000$]
10: publication = publication + newpublication
11: ask my-regular-links [**if** random-float $1 \leq 1/180$ **then** die]
12: **if** count regular-neighbors < max_link_per_researcher **then**
13:     $bonus = \mathrm{P}(e)$
14:     **if** random-float $1 \leq (1 / 90)$ + bonus **then**
15:         r = random 100
16:         **if** $r < 50$ **then** p = partner-choice
17:         **else if** $r < 75$ **then** p = tto-choice
18:         **else** p = one-of find-neighbors-of-neighbors
19:         make-link p ”regular”

Each day, if it is not a permanent, its ttl is reduced (line 1). If it becomes zero, this researcher is removed from the system (line 2). Then, for each of its regular neighbors (loop in lines 5 to 9, definition of regular neighbors in Section 4.3), and if the research facility employing this researcher has sufficient funds dedicated to research (1000 in this case), then there is a probability of publishing with a neighbor (on average every 3 months with a probability of 20% -acceptation rate-). In this case, the research centre funds (1000) the publication (line 9). The number of publications by the researcher is updated (line 10). Contacts with neighbors can disappear (line 11, on average every 6 months), but also appear (lines 12 to 20). When a maximum of neighbors is not reached (line 12, this value is set to 10 in our experiments), a new contact might be established (a minimum of 3 months, line 14). As a function of the employer's performance, a bonus for creating new links is given (line 13): If a research facility has some contracts and/or is rich (high turnover), the bonus is increased and the new contacts are built more often. When a contact is built up, the question is with who should this researcher be linked: A survey we conducted within the Green IT community [1] has shown that new contacts are established 50% randomly with other researchers and businesses, favoring the compatibility of interests (line 16, function partner-choice). 25% come from the social network (line 18, function find-neighbors-of-neighbors). TTO helps to establish new contacts in 25% of the cases (especially with companies, line 17, function tto-choice).

The algorithm for a research facility is the following (details omitted by lack of space): First it updates its interests (average of those of its researchers) and its reputation. If the budget is critical, the research facility finishes the contract of some non-permanent researchers, and then it pays the remaining ones. Then, it will act depending on its action period. If the budget is comfortable, it will hire a non-permanent (for one year, to a maximum of 4 times more non-permanents than permanents) and it will dedicate an incentive as a percentage of its turnover to research. Finally, it tries to launch a collaborative project. These are projects that will create technology transfer, based on their success.

The algorithm for the project creation is too long to be detailed here: a research facility seeks to form a consortium (between 3 and 6 partners) according to its own links, links of its researchers and those of its TTO, if existing. The other research facilities and companies can be partners if all their permanent researchers are not already in projects. If the project is accepted (20% chances), research facilities and companies receive a share of the funding (a 50% fraction of what is taken as overhead costs), they hire non-permanents during the project (maximum 36 months, depending on the share received), and companies invest what they receive. For all research facilities where TTO are present, these TTO take a percentage of the share (20% in the experiments). Finally, links (project, see Section 4.3) are created between all partners.

For a company, the algorithm is quite similar to that of a research facility except that it tries to create a direct partnership with only one research facility (links partnership). The algorithm of TTO's evolution is simple. If it is time to act, it transfers a back_percentage amount to its research facility (a percentage of its turnover).

4.3 Representation of links and their evolution

We have defined 5 kind of links: (i) regular: contacts between researchers (from research facilities and companies) ; (ii) project: relationship between a research facility and a project consortium ; (iii) partnership: contract between a company and a research facility ; (iv) belongto: link between a research facility and its researchers; (v) ttolink: link between a research facility and its TTO.

The project and partnership links refers the collaboration's characteristics. Each link has its own attributes. For such link, the attributes are: original investment for companies, strength of collaboration linked to the compatibility between the partners of the link, number of contracts and turnover generated by the link, lifetime of the link, number of researchers in the research facility and company sides involved in this link, and finally the contract number.

Like all agents, links evolve at every time steps. For non-permanent links, the lifetime is reduced by one at each time step. When the lifetime is zero, if it is a project, it is finished and the permanent researchers of each partner of the consortium are available for new contracts. As a function of conversion rate (conversion is success-or failure of a project), it gains a profit up to 4 times the initial cumulative investment. This represents the success of a project and reflects the patents that may arise from the project. If it is a partnership, the principle is the same as for project except that only one company and one research facility are involved. Moreover the partnership will be extended for one year if it was generating a benefit (favoring the efficient partnerships, also controlled by conversion rate). Other links disappear.

5 Experiments

5.1 Methodology and objectives of experiments

The proposed multi agent system is complex (about 2000 lines of code), and has a large number of parameters. We varied its main parameters in extensive experiments. We give here the results of a representative subset showing the impact of the TTO presence, the others can be found in [1]: number of TTO, number of companies, back_percentage rates (the percentage a TTO returns to its research facility). When not specified otherwise, back_percentage rates is set to 30% in the experiments. The action_period for research facilities is set randomly (uniform) between 3 and 9 months, while for companies it is between 1 and 2 years, and for TTO it is between 1 and 3 months.

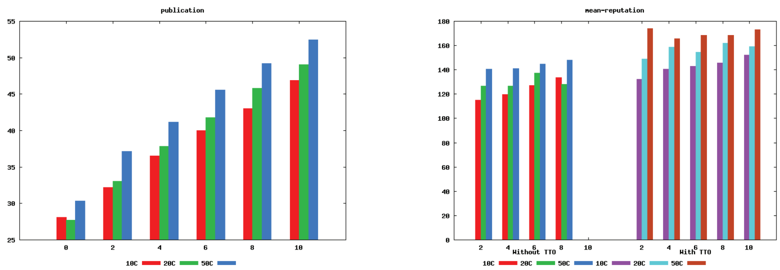
We compare the results on the objectives of each actor and on the SPI value. In the selected experiments we selected the following indicators:

- publications: the sum of the publications of the permanent researchers
- reputation: the mean reputation of the research facilities
- SPI : the mean value of the SPI value of research facilities and companies

The studied system simulates 10 research centres, 50 permanent researchers. We vary the number of TTO (from 0 to 10, i.e with 10 all research centers have a TTO) and companies (from 10 to 50). Larger experiments were conducted but did not give more lessons while significantly increasing the simulation time. Each experiment simulates 3640 days (10 years). We present boxplot values for 50 experiments with the same parameters.

5.2 Results

Figure 1(a) shows the impact of the number of TTO (x-axis, from 0 to 10) on the publications of the researchers. In this graph we see that the number of publications increases with the number of TTO. This exhibits the positive influence of TTO on the work of individual researchers. It increases also with the number of companies, whatever the number of TTO. This is expected since more companies means more potential contacts for researchers, leading to more publications. In Figure 1(b), we studied the direct influence of TTO on the research facilities they are attached to: on the left the reputation of research facilities without TTO, on the right with TTO. One can observe that, the reputation for research facilities with TTO is higher than the one for research facilities without TTO, whatever the number of TTO and companies.



(a) Publication

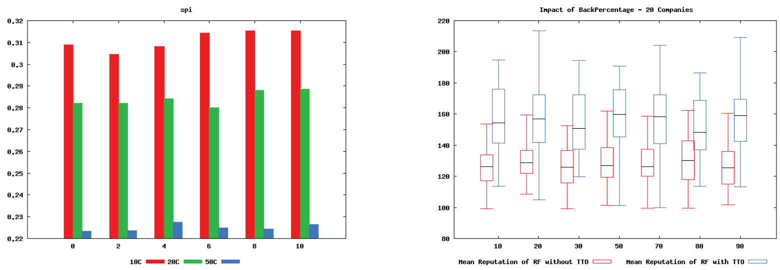
(b) Reputation

Fig. 1. (a) Mean publications of permanent researchers, as a function of number of TTO (0 to 10) and companies (10, 20 and 50 companies). (b) Mean Reputation of research facilities, as a function of TTO and companies numbers. (left: research facilities without TTO, right: research facilities with TTO)

Figure 2(a) shows SPI value. Here also the values are quite insensitive to the TTO number. This indicates that the influence of TTO on companies and sustainability is not important in our simulation. Finally in Figure 2(b) we show the mean reputation of research facilities as a function of the back_percentage experiment with 4 TTO and 20 Companies. We observe again the positive influence of TTO on research facilities, but the influence of back_percentage is negligible, indicating that the presence of the TTO is more important that the percentage it returns (see also in parallel Figure 1(b)).

6 Related Work

Few studies have focused on modeling technology transfer and links between the actors. A review article [5] is interested in multi agent systems for the diffusion of innovation. Although the setting is a different (towards marketing and customer targeting), it sheds much light. Social network's dominance in the adoption of innovation is highlighted [6]. The spread in social networks has received much attention in recent years [7], [8], [9], [10]. Actors dissemination (individuals, groups, organizations), a broadcast medium (diffusion environment, strong and



(a) Publication (b) Reputation

Fig. 2. (a) SPI value, as a function of TTO and companies numbers. (b) Mean reputation of research facilities, without (red) and with (blue) TTO, as a function of back_percentage.

weak links between actors, the network structure), and the content to be broadcast are the three elements of the diffusion. This distribution is described as the collective behavior of a group of social actors interacting on social networks [11]. Technology transfer is a kind of diffusion in a social network, which has inspired our model of linkages between actors. In the case of a competition for a market, two types of diffusion models are identified [16], [17]: the threshold models where agents adopt if enough neighbors have, and cascade models where the probability of adoption increases with the number of neighbors who have adopted. In our case, the cascade model was implemented. The closest work to ours is that of Ning and Quing [4] which presents a multi agent model for technology transfer. Their model has two kinds of agents (universities and industry), and 4 states, 'doing nothing' to 'active part in a collaboration'. The transfer is modeled between 0 and 100 for each agent. Their results show that the key to a good transfer cost is to seek information (distance between agents) and the probability of finding a partner. The study is limited, omitting financing and turnover to influence direction.

7 Conclusion

In this paper we analyzed the positive or negative influence of the TTO on the individual objectives of other actors in the technology transfer. We shown that they have a positive role in helping to create contacts between the actors. The ultimate goal of this work is to give a tool to understand the springs of technology transfer in Green IT. Note in passing that the methodology and models developed can be extended to other areas. The next step will be to modify the model so that the actors' behaviors is influenced by their SPI value.

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