XX IASP WORLD CONFERENCE ON SCIENCE AND TECHNOLOGY PARKS
June 1-4, 2003 - Lisboa, Portugal

INTERSECTIONS: A MANAGEMENT TOOL FOR SCIENCE & TECHNOLOGY PARKS

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Abstract:

INTERSECTIONS is a tool to support science and technology park management. The tool can be used to create a virtual world with the aim to help management explore would-be scenarios for the park. Essentially the tool is an agent-based computer simulation model of innovation as adaptation. The model relies on two basic mechanisms: plasticity (i.e. in-park firms can react to outside pressure to innovate by interacting with others) and variety. In our virtual world there is also social interaction. In the paper we present a simple model built with INTERSECTIONS based on a case study. We discuss simulation results that relate to one question relevant to the case study: what can be achieved by stimulating interaction between in-park firms?

INTRODUCTION

This paper describes a tool, INTERSECTIONS[1], to support science and technology park management. We are trying to create a virtual world where park managers could safely test hunches, run what-if scenarios, and preview the impact of big and small decisions - all without major investments, public embarrassments, and competitive backfires. Our aim is that the computer simulation model will help management to explore possible new realities for the park by offering an unconventional point of view on a broad range of issues and questions.

In the first part of the paper we briefly outline the simulation model and the basic mechanisms that it relies on. We then focus on the kind of questions that can be answered with support of the tool. In the third and final part of the paper we discuss simulation results pertaining to one of these questions: what can be achieved by stimulating the interaction between in-park firms?

THE MODEL

Innovation as Adaptation

INTERSECTIONS is an *agent-based* simulation model, which means that our virtual world is made up of a diversity of virtual "agents" (firms, universities, research labs, etc., both in-park and off-park) that interact driven by a pressure to innovate. Although the model allows for large numbers of agents and a great deal of diversity, in this paper we present a simpler version of the model having 15 agents, all firms. The firms are spread over different geographical locations (all in-park). Each firm has a second attribute next to location: a "kene" [2]. With a kene (think of a genetic string) we represent the skills and technologies that a firm has accumulated over time. Figure 1 illustrates our implementation of kenes.

The accumulation of all kenes constitutes a "variety pool". The variety pool is a valuable resource for the firms to respond to (exogenous) pressure to innovate. This is because firms can interact with other firms and *adapt* some of the skills and technologies from the other. If the variety pool is rich, there are many possibilities for firms to interact and adapt. The rules for adaptation in our model are such that 1. firms only interact with other firms that are "compatible" (i.e. not too similar and not too different) and 2. firms that interact become more similar. These rules are illustrated in Figure 2.

Moving past the details of kenes and rules, we wish to stress at this point that what we have essentially created is a model of innovation as adaptation that relies on two mechanisms. The first mechanism is *plasticity*, which means that firms can react to outside pressure by interacting with others. Secondly, there is the mechanism of *variety*, which increases the capability of firms to react.

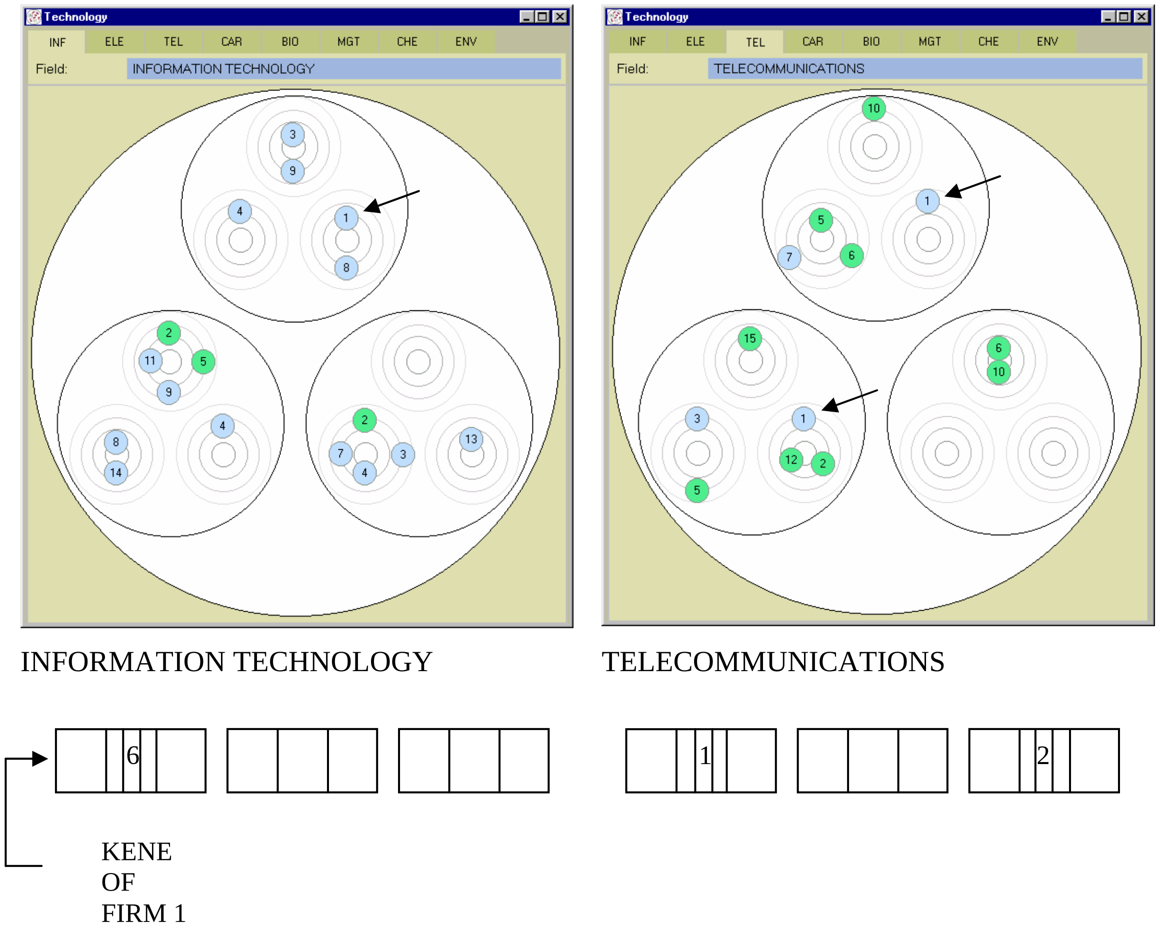
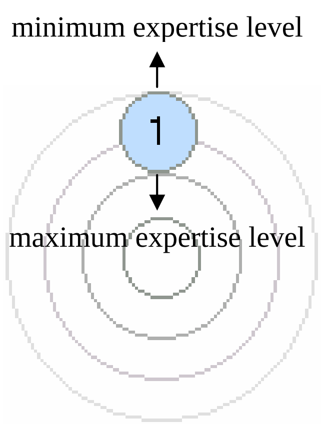


Figure 1. Implementation of kenes

Explanation. In the example firm 1 has acquired an expertise level of 6 in a particular niche in Information Technology. It has also acquired some expertise in Telecommunications. Because its expertise in Information Technology dominates its kene, it is given the color light blue. Firms specialized in Telecommunications are colored green. Below is explained how the expertise levels can be read from the figure.



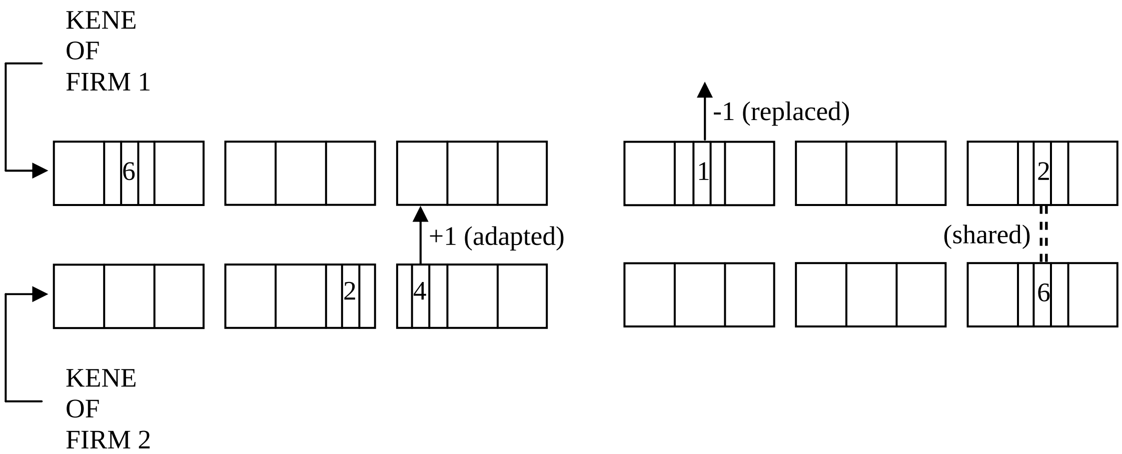


Figure 2. Innovation as adaptation

Explanation. In the example firm 1 and firm 2 are compatible because they have acquired expertise in the same niche in Telecommunications. If firm 1 decides to interact with firm 2, it will adapt some skills and technology from firm 2 (not necessarily from the niche that they share). These new skills and technology replace some older ones. A consequence of these operations is that firm 1 and firm 2 will become more similar.

Social Interaction

In our virtual world there is also social interaction. We represent the outcome of these interactions with a network of "social ties" between firms. With our notion of social ties we try to capture a myriad of relations between two firms that influence the likelihood of interaction for innovation in case they are compatible. The rules in our model for social interaction are such that social ties are most likely to be established between firms that are 1. compatible or 2. geographically proximate (or both).

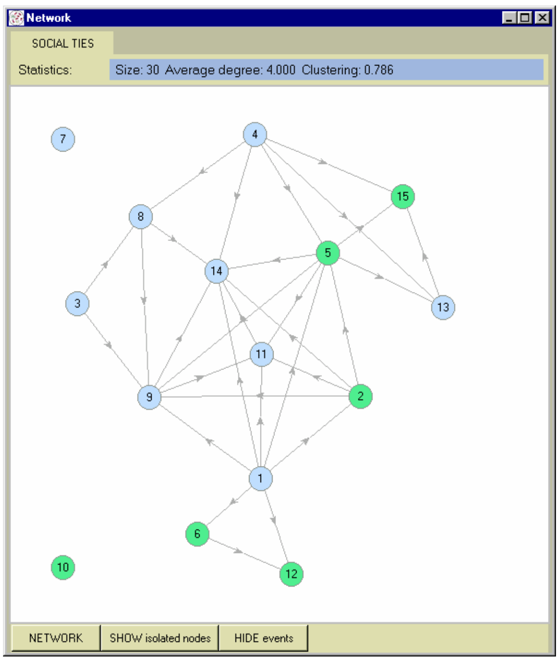


Figure 3. The network of social ties between firms is represented by a graph

The configuration of the social network has an impact on the interaction for innovation. This is because the rules for interaction in our model take into account whether or not there are social ties between firms. If ties exist, even firms that are different (but not too different) can interact. The question to which degree the social network increases the capability to innovate (to adapt) of in-park firms is non-trivial. We think that the impact of the social network on the mechanisms of plasticity and variety depends on the kind of *connectivity* that governs the evolution of the network. We will come back to this question when we discuss simulation results.

Climate for Innovation

Our main interest when we work with INTERSECTIONS is to discover mechanisms that exist only on the level of the park (i.e. the whole population of in-park firms) and that cannot be traced back to the level of the individual firm. More specifically, we hope that we can identify a number of mechanisms that contribute to the emergence of a "climate for innovation" in the park.

Methodological Framework

There are a couple of things to be said about the methodological framework that we used with INTERSECTIONS. First of all, we combined computer simulation with other methodologies, predominantly a case study of a science and technology park in Portugal. Secondly, our framework accomodated the role of modelling as we see particular to agent-based modelling. In short, we think of the simulation model functioning as "a halfway house between data and theory". Thirdly, our methodology engaged people in a particular use of the model that differs from uses commonly associated with simulation (e.g. prediction). In short, we used the INTERSECTIONS model to generate "would-be scenarios" that allowed us to switch from intuition to reality and back.

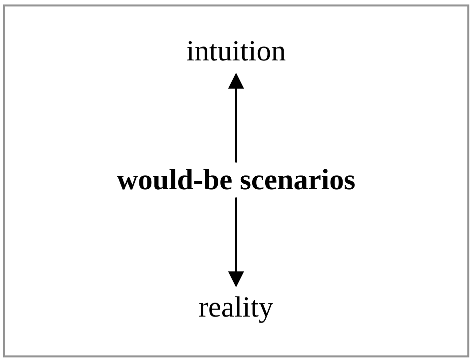


Figure 4. Switching from intuition to reality and back

QUESTIONS

Now we turn to the kind of questions that can be answered with support from the INTERSECTIONS tool. Before doing so, we stress two important differences with standard economic models:

Bottom-up change. Most economic models assume right away that the behaviour of firms is to a large extent determined by aggregate functions like industries or markets. With INTERSECTIONS we shift interest to the possibility that micro-level interactions between firms produce "bottom-up" change in terms of aggregate outcomes like the emergence of a climate for innovation.

Contingencies. In reality, interaction for innovation and social interaction are odd mixtures of goal-seeking and contingencies. Firms formulate hypotheses about successful innovations, but also stumble on new ideas through interaction with others. They think strategically about promoting their social linkages, but important new chains of connections may just as well start with accidental encounters. In our model, instead of merely accomodating for contingencies to happen - e.g. by treating them as noise - we place them central in the dynamics.

Case Study

In our case study we applied the INTERSECTIONS tool to explore: *What can be improved to stimulate the interaction between in-park firms?*

Furthermore, we intend to use the model in the near future to deal with some other questions that are relevant in our case study, including:

- How can we measure success of a science and technology park?
- Considering different kinds of actors (anchor entities, a public operator, service firms) what is the optimal mix for the park?
- How can microfirms make the step from reactive to pro-active innovation behaviour?

The paper continues with a presentation of simulation results that relate to the first question - stimulating interaction.

SIMULATION RESULTS

The simulation results that we present here were obtained with a simple model that was built with INTERSECTIONS, having no more than 15 firms. The firms are spread over 9 possible locations, either randomly or according to a plan for articulation of the microgeography of the park (see Would-be Scenarios). We configured the model so that in the starting situation firms are randomly endowed with kenes that are limited to two technological fields - Information Technology and Telecommunications. No social ties exist between firms in the starting situation.

The dynamics of the model can be described as a series of events. In the case of social interaction, (social) events also have a formal definition. We give two examples.

The first example of a social event is a conference. Firms will participate in the event if their kenes are "compatible" with the theme or topics of the event (also represented by a kene). The location of the conference is irrelevant. Consequently, the impact of the event on the social network is that social ties are established between firms that are compatible, but not necessarily geographically proximate.

The second example is an accidental encounter in a restaurant. Firms frequent the restaurant only if it is located sufficiently closeby. Consequently, the impact of the event (i.e. the accidental encounter) on the social network is that social ties are established between firms that are geographically proximate, but not necessarily compatible.

Here, then, is the formal statement of the entire dynamics of the model:

Repeat the following steps for as many events as desired.

Interaction for innovation:

Step 1. At random, pick a firm to be active, and pick the firm with which it is most likely to interact for innovation (considering their compatibility and the existence of social ties between them).
Step 2. If there is a good enough match, the active firm adapts some skills and technologies from the other firm (as is illustrated in Figure 2).

Social interaction:

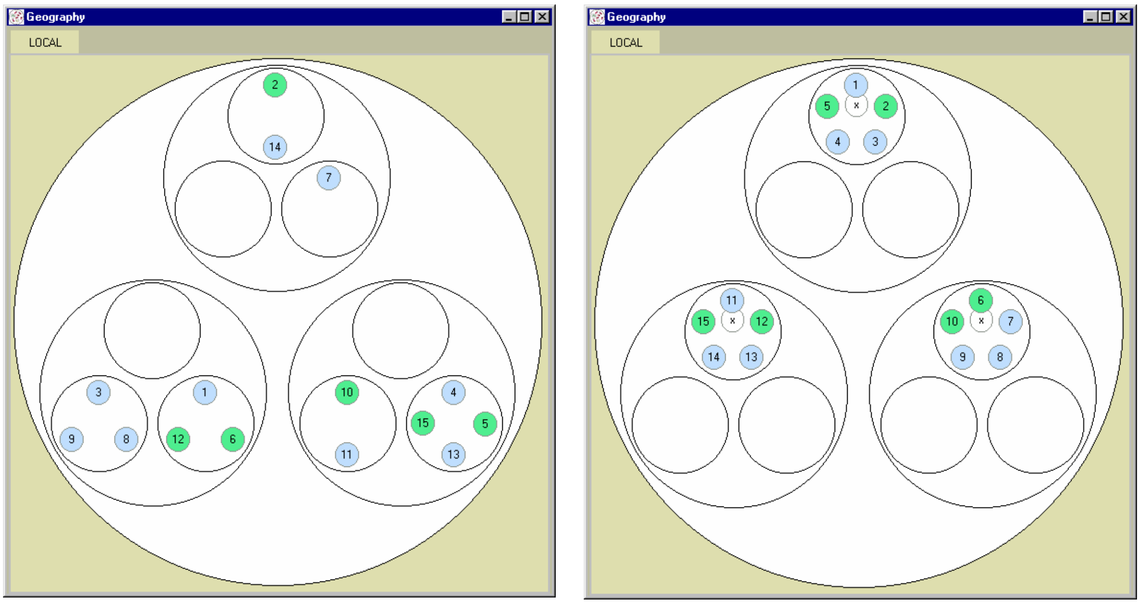
Step 3. At random, pick a (social) event, and pick a small group of firms that participate in the event (considering their compatibility with the event's theme or topics or their proximity to the event's location).
Step 4. If there are enough participants, with a small chance new social ties are established between pairs of participants.

Each simulation was repeated 40 times, so that we learned about the "average" behaviour of the model.

Would-be Scenarios

For the first question: *What can be improved to stimulate the interaction between in-park firms?* we compared two scenarios.
Scenario 1. The situation in the park as we see it now.
Scenario 2. Same, but with articulation of the microgeography of the park and other measures that aim to stimulate the interaction between in-park firms.

In general, measures in Scenario 2 cover some ideas that correspond to the integration of (a) the planning of “clusters” of firms that respect some diversity with (b) the planning of “centers” that attract people to spend some time there, taking into account:
- the quality of a location (ecology, comfort, ...)
- the diversity in a cluster (technological fields)
- the polarity of a center (combinations like restaurant & services, library & place for reading & place for having coffee, ...)



SCENARIO 1. RANDOM SCENARIO 2. ARTICULATION

Figure 5. Articulation of microgeography in the park

Explanation. In the image on the right, the nodes labelled with "x" indicate centers where people can spend some time and encounter each other like restaurants, a library, etc.

The differences between the two scenarios are in the growth of the social network and the type of connectivity that governs its growth. In Scenario 1 firms rarily establish social ties with other firms in the park. Moreover, if we concentrate on the locations of these connected firms, we find that these links lie arbitrarily. In Scenario 2 the articulation of the microgeography facilitates the growth of a denser social network governed by *small-world* connectivity. Concentrating again on the locations of connected firms, what we have is a would-be scenario in which 1. firms are likely to establish social ties with their closest neighbours and 2. firms that are more distant are likely to establish social ties only if they are compatible. An example of such a small world is depicted in Figure 6.

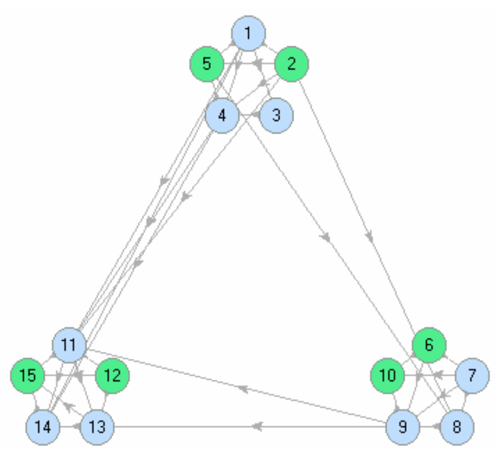


Figure 6. Small-world connectivity

We call it a "small world" because now each firm is linked to every other firm in the park only through a small number of connections. In combination with the planning of clusters that respect some diversity, this scenario might produce a positive impact on the mechanisms of plasticity and variety. Indeed this is the basic idea behind Scenario 2.

Expectations

We knew that in Scenario 1 firms would remain relatively isolated over simulated time. For this reason we expected the impact of the social network on the mechanisms of plasticity and variety to be small. More specifically, we expected that we would obtain outcomes similar to the dynamics produced by a well-known agent-based model developed by Robert Axelrod[3]. In his 1996 study on disseminating culture, Axelrod raised a question much like ours about the impact of interaction (of people) on (cultural) diversity, and convincingly showed that local convergence can coincide with global polarisation. In our simulations, this result would translate to dynamics in which the variety pool becomes a less valuable resource to firms because they are either too similar or too different. In other words, we expected the park to reach a "fixed state" in which no further interaction between firms is possible, as is sketched in Figure 7.

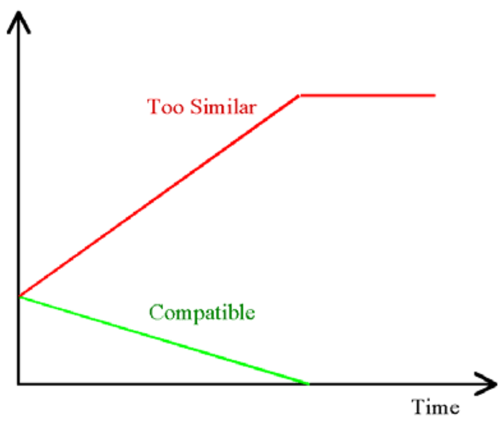


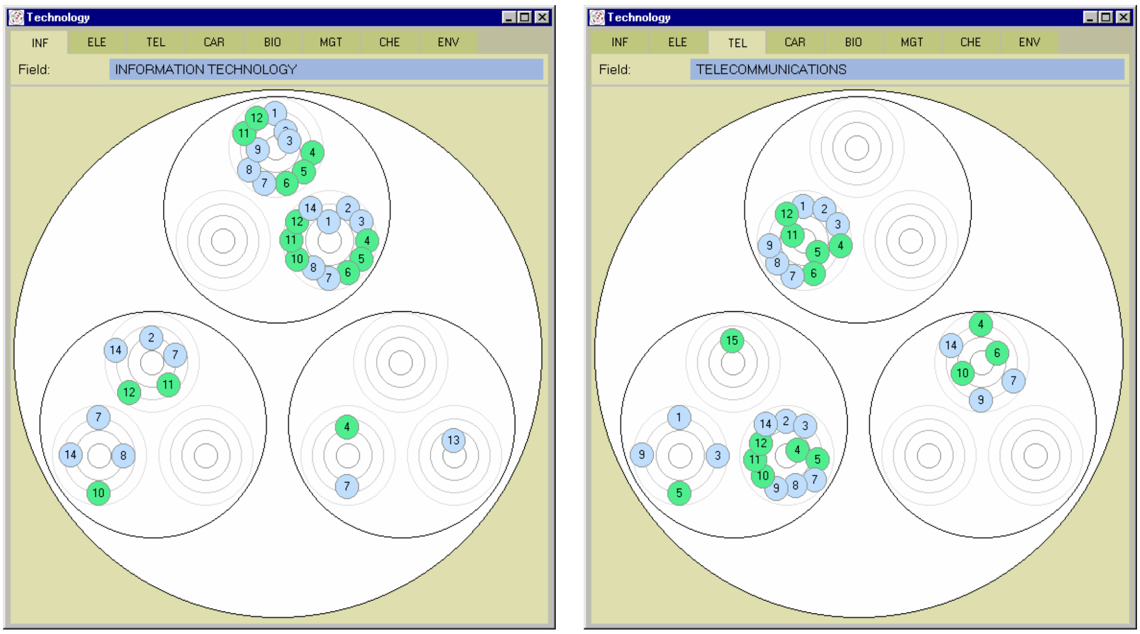
Figure 7. Expected dynamics for Scenario 1

It was beyond our grasp to formulate exact expectations about the dynamics in Scenario 2. Instead, it was left to the simulations to provide insight on whether the impact of small-world connectivity on the dynamics would be strong enough to sustain the mechanisms of plasticity and variety, in a way that the fixed state would not be reached.

Simulation Results

The 40 simulations for Scenario 1 confirmed our expectations and Axelrod's result. Figure 8 shows that a fixed state is reached about halfway the simulation time (although in some of the simulation runs this point was reached earlier than in others). Once the fixed state is reached, interaction between firms is no longer possible, because firms have become either too similar or too different. Figure 9 shows that this state corresponds to the formation of clusters in some of the technological niches.

Figure 8. In Scenario 1 the park reaches a fixed state



INFORMATION TECHNOLOGY TELECOMMUNICATIONS

Figure 9. Firms cluster in some of the technological niches

The 40 simulations for Scenario 2 show that again the fixed state is reached, however at a later time (on average it takes about 20% more time). The comparison of the two scenarios is shown in Figure 10.

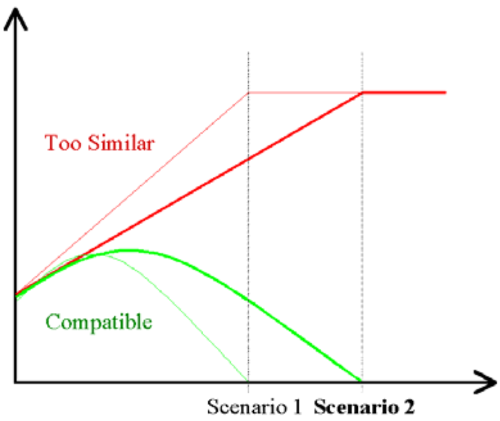


Figure 10. Comparison of the two scenarios

We must be careful in interpreting the observed impact, as it is a combination of 1. the impact of a more dense social network, and 2. the impact of small-world connectivity. The first impact is trivial, because it is implied by the rules used in our model.

Discussion

Are we getting close to discovering mechanisms that contribute to a climate for innovation? From the simulations we have to conclude that the impact of small-world connectivity seems to be rather small. However, we need to recognize that the status of the simulation results is preliminary, pending on more simulations with larger population sizes (which clearly has a big impact on variety) as well as a systematic exploration of different schemes for articulation of microgeography.

At the same time, we wish to proceed in our attempts to provide more insight in the "knots and bolts" of the dynamics. Figures 11 and 12 illustrate a general pattern that underlies the dynamics in all simulations. In these figures we have divided the variety pool into six smaller pools. In the starting situation most variety is concentrated in the pool with the label "too different, no social ties" (bottom right box). Over simulation time, as firms interact, variety gradually flows into the pool "too similar, social ties" (top left box).

This schematization of the dynamics hopefully will provide us with clues that help us to discover self-regulatory mechanisms on the level of the park. If so, we can start designing management options that are capable of changing this general pattern, so that mechanisms of plasticity and variety are sustained, or even self-reenforced.

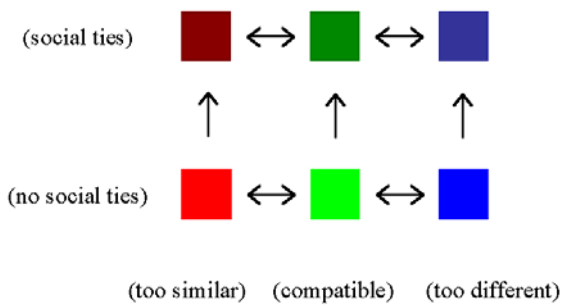


Figure 11. Variety pool divided into six smaller pools

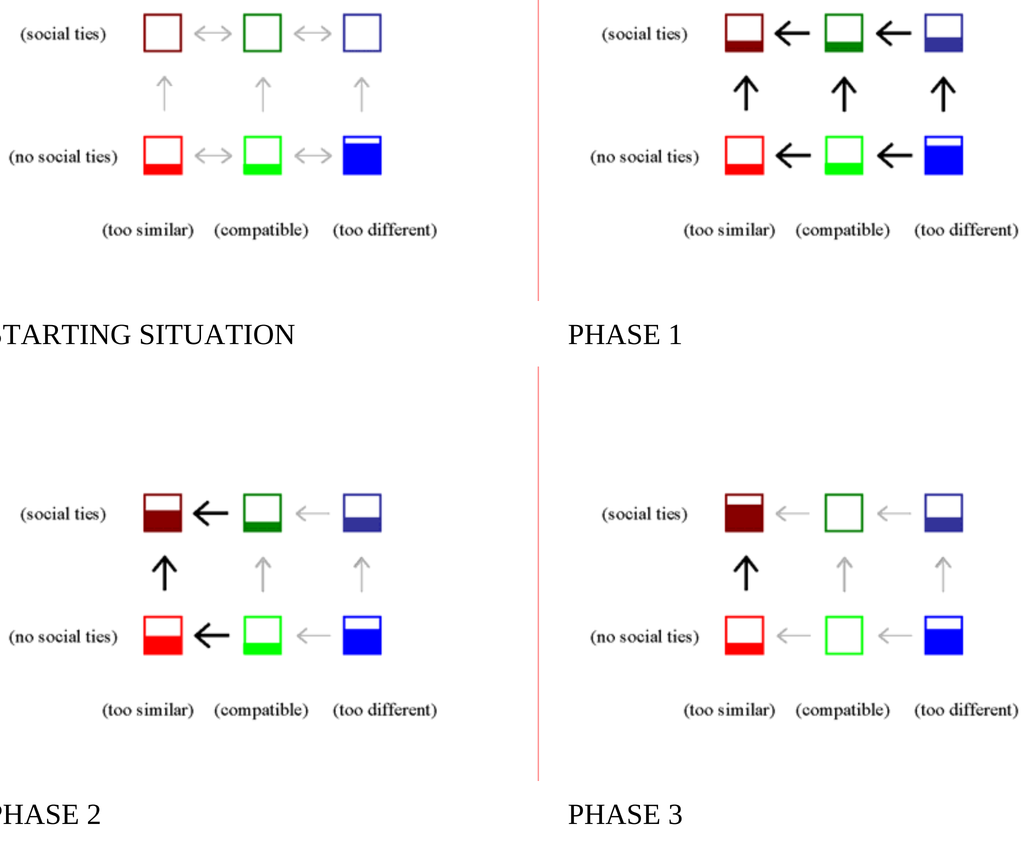


Figure 12. Variety gradually flows from the bottom right box to the top left box

CONCLUSION

In this paper we presented preliminary results with a simple model that we built with the INTERSECTIONS. For application of the tool to support science and technology park management we foresee building more complex models, having a large number of heterogenous agents, and incorporating more features of the park. Yet, the simple model already demonstrates that an important value of the tool lies in the kind of questions that it raises.

To illustrate this point more, we give one final example. In this paper we gave much attention to small-world connectivity. The research on small worlds points to another interesting type of connectivity, called *scale-free*. Networks that are scale-free have "hubs" - highly connected nodes - that make them surprisingly robust to failures. By reasoning from the model's perspective, we automatically focus on the potential impact of anchor entities (the hubs) on sustaining the capability to adapt of in-park firms.

There are many interesting possibilities for extending the model, including:

Strategic behaviour. In our current model agents can only behave reactively. Eventually we will make the step of including the possibility of strategic behaviour involving perception, reasoning, learning, deciding, etc. This might actually make the model easier to study!

Sociality. In the near future we will add more detail in our representation of the relations between agents that influence the likelihood of interaction for innovation.

Immune system perspective. The tool is currently used to build small worlds on notions from biological networks like adaptation and variety. We intend to further exploit notions from evolutionary and developmental biology. One of our future interests is the *immune system perspective* applied to a science and technology park. How can the park deal with infections within or attacks from outside that block innovation?

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[1] The development of INTERSECTIONS involved several research institutions in the Lisbon area. Its start was in the summer of 2001 and it is expected to be completed in the summer of 2004. The research is part of the Complexity in Social Science project (COSI) that is supported by the European Commission's Framework 5 Programme. The project's web-site is http://www.irit.fr/COSI

[2] The idea of using kenes for the research on innovation was introduced in:
Gilbert N., Pyka A. and Ahrweiler P. (2001). Innovation Networks - A Simulation Approach. Journal of Artificial Societies and Social Simulation vol. 4, no. 3. http://www.soc.surrey.ac.uk/JASSS/4/3/8.html

[3] The model on disseminating culture is described in:
Axelrod, R. M. (1997). The Complexity of Cooperation: Agent-based Models of Competition and Collaboration. Princeton, Princeton University Press.