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The Game of Science

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My first impression of the AI-Lab of Luc Steels at the Flemish Free University in Brussels (VUB) in 1996 was a little bit surprised but very positive. The place was different from the typical German or US institutes I was mainly used to, with their long corridors of classical offices and some separate lab-rooms here and there. The AI-lab was something that already included many elements, which were to become fashionable in the years to come, e.g., in the context of what is known as *living labs*. The AI-lab featured many open spaces, no strict boundaries between working desks and larger experiment set-ups, open meeting areas, a kind of chill-out zone with a couch and arm chairs in front of a little library, and a bunch of interesting robots and design elements that gave the whole place a scientific and nevertheless playful atmosphere.

The official purpose of my visit back then was to give a presentation about my research for my PhD that I had just finished. I was at that time still very early in my academic career and I was – as it is often the case right after a PhD – not really sure yet what to do next. My talk went well; I had some very interesting conversations with the people in the lab including a longer conversation with Luc Steels about my research and my (vague) future plans; and it ended with a job offer that I was just very glad to take.

In the little lab library was a book that Luc recommended to me: *The Game of Science*. The book included some good recommendations about proper scientific work, how to plan for an academic career, etc. It was definitely useful for a young postdoc and I enjoyed reading it. The aspect I liked most about it was the metaphor of science as a game. It is a metaphor that I still love to use when giving students – from BSc to PhD level – an introduction to proper scientific work in terms of problem formulation, literature search, citations, impact, experiment set-up, data analysis, etc. Like any game, there are rules, you can score, and there are ways to lose or to get even disqualified when you are violating essential rules. But there is clearly also a playful element; you play the game because it is fun – and there is a good chance to enjoy it more if you do it right. It may not be so clear who your opponents are; it can be the universe hiding its big secrets or more often just smaller open research questions waiting for an answer. But it should for sure be something you want to tackle because it is fun – and never because you have to, unless it is a stepping stone toward another bigger research question. This does unfortunately not imply that an academic career is just pure fun and that sometimes not also administrative, financial or political opponents have to be tackled. But that is a different story. And the secondary opponents are only worth tackling if there is sufficient scientific fun in the game to be worth the hassle.

Though a few colleagues may disagree, I strongly believe that the game of science is a team sport. Like in soccer or other team sports, there is of course competition among players to get onto a team and to be nominated to play a match. And there is of course also competition between teams, e.g., for funding. But the ultimate driver is the enthusiasm for the game, to find new strategies and tactics, and to score in the end, i.e., to beat the prime opponents of nescience and ignorance. There are sometimes individuals who might get a lot of attention – like highly successful strikers in professional soccer – but there is always a team behind them; even if it is "only" the general academic environment in which they grew up or operate in. This academic environment is the playground of the game. It is essential for carrying out the game and also for training, which should never be underestimated as an essential element, too. The VUB AI-lab set up and run by Luc Steels was an excellent playground for me when I was there to become a professional player in the game of science under Luc as role model of an excellent player and as coach.

The AI-lab and the whole environment around it – including social events, retreats and private invitations to Luc – was an excellent playground for many reasons. The most important one was that the whole atmosphere was filled with an intellectual spirit. The game of science despite its rules and regularities requires a significant amount of creativity. To play well, you have to come up with new strategies, tactics and ideas – co-evolving with the progress in the field and sometimes even being a game-changer. One great aspect of this playground was that Luc Steels had managed to get a very international, very motivated crowd of young researchers to work in the lab. He also managed to have excellent visitors coming by for talks and sometimes even longer research visits who brought in additional new ideas and views. And of course Luc himself, with his broad interests and activities, was and still is a great role model providing interesting food for thought.

The atmosphere of a playground is a tremendously important element. But also its infrastructure, i.e., the toys you can play with, is really important, too. One approach in the academic world is to simply think big and to get the largest, most expensive toys money can buy. Some open questions may only be tackled with incredible amounts of research infrastructure. But large and expensive alone does not guarantee success. And sometimes, the small and beautiful, well-designed set-up can prove to be much more effective. The VUB robot ecosystem with which I worked was exactly this kind of experimental playground. The idea of the ecosystem originated from Luc Steels working with David McFarland, an ethologist from Oxford. The ecosystem featured mobile robots that could recharge themselves in a charging station. The robot had simple sensors, e.g., mechanical bump detectors and infrared obstacle sensors. The charging station was marked with a bright white light that the robots could detect with photo-sensors. By using two sensors, a robot can get a differential signal that indicates the direction in which the station is in plus some rough sense of its distance to it. A voltage and a current sensor on each robot provided the basis to measure the amount of charge left in its batteries; they can also be used as indication when charging takes place. This core part of the ecosystem is something that goes back to the earliest days of robotics when the British neuroscientist and cybernetics researcher William Grey Walter built two artificial "tortoises" with a similar set-up in the late 1940's and early 1950's. An interesting aspect is that Walter did not have any computer technology as we know it at hand and that he hence had to use analog circuits based on vacuum tubes to implement his robots.

But Steels and McFarland went with their ecosystem idea beyond just using a charging station that kept the robots "alive". They introduced "competitors", i.e., cylindrical objects with lamps inside that were connected to the same global energy supply as the charging station. The competitors hence "eat away" energy from the robots. But the robots can "fight back". When a robot knocks against a competitor, the lamp inside the competitor dims for a little while and there is more energy available in the charging station. The competitors hence introduced a "meaning of life" for the robots: "eat" via energy intake in the charging station, spend energy to find and "fight" competitors, find the charging station and eat, and so on.

The implementation of the ecosystem was simple in some sense but far from trivial. It was simple in the sense that inexpensive material was used wherever possible. The mechanical part of the robots was built from Lego; though a later version also included a more professionally looking robot that a design student from the Hogeschool West-Vlaanderen in Kortrijk made. The surroundings of the ecosystem were simply made from plywood; the charging station as well as the competitors included some plumbing material; and so on. So, a lot of the hardware parts just included inexpensive bits and pieces from a DIY-store. The electronics and onboard computer parts were already much less simple and included quite some engineering and applied research aspects. But the main scientific aspects were in the robots "brains" that controlled them, i.e., the software.

Before he founded the VUB AI-lab, Luc Steels had been at the Massachusetts Institute of Technology (MIT) where he was an influential part in a movement to introduce a new direction of Artificial Intelligence (AI) research. AI has a strong tradition of being concerned with logic and well-defined, often very abstract problems where planning plays an important role. The behavior-oriented movement, where Luc was an important part of, in contrast propagated more of a "here and now" view of intelligence where simple processes of fast sensor motor couplings lead to intelligence. Classical AI builds on actions: well defined operations with clear start and stop moments in time that can be linked to (logical) pre- and post-conditions and that can be chained together to form a plan to reach a (formally expressed) goal. Actions typically are executed one after the other – with no or at most a few non-conflicting actions being executed at the same time. Behavior processes in contrast are executed in parallel by design. They are as mentioned fast sensor motor couplings; they do not have well-defined start and stop moments but they are continuously running, dynamic processes.

An important concept in behavior-orients robotics/AI is *emergence*, i.e., the manifestation of an observed behavior that is the result of the interaction of behavior processes, the system and its environment. One example is the emergence of the "fighting" behavior of the robots in the ecosystem. The competitors emit a special red light that is different from the white light of the charging station. In addition to the red color, it has a frequency modulation that is from an engineering viewpoint easier to detect than different colors – just one example of the many engineering aspects that were also part of the design. Each robot has two sensors that can sense this light. There are two behavior processes that lead to a phototaxis. One process simply turns the robot towards a competitor; if the light from a competitor is stronger on the left sensor, the robot turns to the left – and vice versa for the right sensor. The second process, which is a default process running anyway to keep the robot moving, simply drives the robot straight forward. Both processes are running in parallel in cycles; each cycle starts with reading sensor values, followed by some computations, and ending by writing some output to the motors. The cycles run with a relatively fast frequency – the special onboard computers developed in the lab allowed at least a 100 Hz cycle time for each process with typically some dozen processes working in parallel. The combination of the turning and the forward process then leads to an attraction of the robot to a competitor once its sensors perceive it from some distance.

This phototaxis hence leads the robot to a competitor. Once it comes closer, a process suppresses the Infrared based obstacle avoidance that keeps the robots from crashing into walls. The robot hence hits the competitor. The mechanical bump detectors of the robot trigger a driving back for a short time as part of a bump-detection process. After going a bit back, the robot is attracted to the competitor again, hits it again, and so on until the light in the competitor dims and the attraction is gone and the robot moves on. Similar processes are used to steer the robot toward the charging station and to refill it with energy. An important aspect is that all these processes run in parallel. So, there is no such thing as a central decision unit. The robot may perceive at the same time the charging station as well as a competitor. The signal from one object will be slightly stronger – even if it is just due to sensor noise in that moment – and the robot will make a "decision" and start to move towards this object though the other is still also attracting it – and still pulling it a bit away from the straight course.

Though simple in some sense, the VUB ecosystem is an excellent playground for the game of science. It can be used for a variety of fundamental experiments – I did for example among others some research on the origins of cooperation in it. Its conceptual design also has a strong inherent aesthetic value. This is among others reflected in the fact that it even made it on the big silver screen: it is an essential part of the French movie *Stanwix* by the director Charles de Meaux. The ecosystem serves in this movie both as metaphorical inspiration for the plot, in which a scientist's world is turned upside down as the border between reality and an experiment (using a robot ecosystem) becomes fuzzy, and as part of the physical stage setting in which the movie was filmed. With this inherent conceptual beauty, the VUB ecosystem also very well reflects the character of Luc Steels who is an excellent player in so many different areas in the worlds of science and art.

Images of the VUB Ecosystem