Moving Cells: Being a cloud of particles

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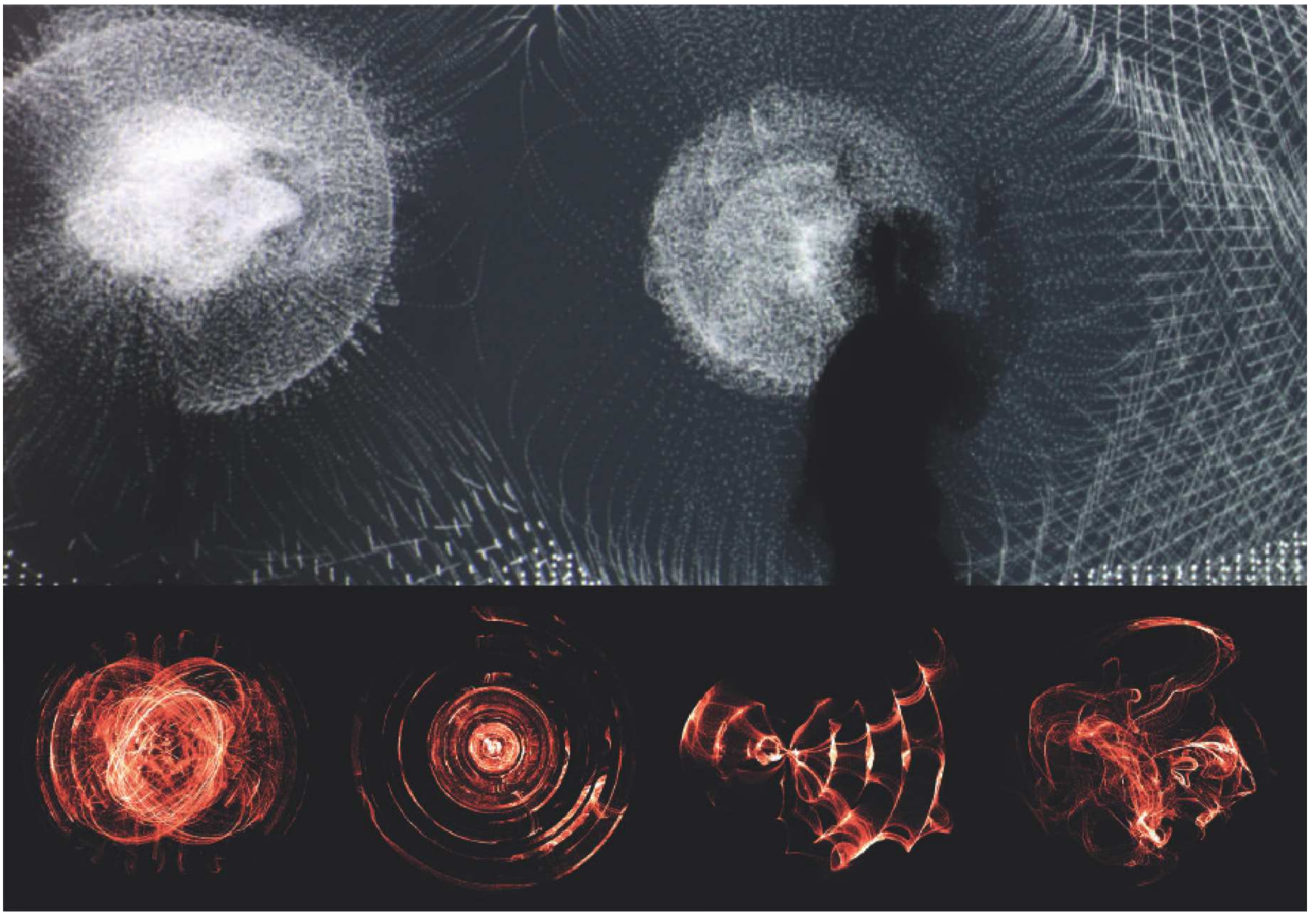
Few things have inspired and intrigued humankind as much as stars. The night sky is, indeed, beautiful with its collection of twinkling dots. Throughout the history of science, it took quite some time to figure out the dynamical mechanism that govern their motions but today we have a reasonably good understanding of it. Unfortunately, one cannot observe in real time the spiralling motions of stars within their galaxies due to the long timescales involved, except in computer simulations that run equations able to reproduce their dynamics. Such equations describe how each object moves given the so-called "gravitational potentials" generated by big masses in their surroundings such as planets, stars, or black holes. The larger and closer the mass, the bigger its effect on other objects.



Moving Cells (Robin Lamarche-Perrin et Bruno Pace, 2015) is a digital installation that allows people to interact though their movements with a cloud of particles projected onto the wall. Many complex patterns emerge from simple gravity-inspired interactions, and participants experience a strong sensation of cognitive extension.

What if the potential affecting the "stars" inside a simulation were ruled by dancing individuals, simultaneously spectators and (inter) actors? This was the starting point for our installation, in which people dancing or simply moving affect the gravitational potential that govern a cloud of particles following classical gravitational physics' equations. Therefore, every person becomes a central piece inside our installation, gaining the power to control the attracting or repelling forces that dictate the dance of the stars – or light particles – projected onto the wall. Once inside the installation, every individual closes a feedback loop: watching the movement of the particles inspires them to move which, in turn, is captured by a sensor and enters the equations, ultimately changing the potentials that affect the movement of the particles again. This is one fundamental ingredient for complex, emergent behaviour.

Technical description

Moving Cells implements a retroactive information loop, linking the dancer's motion to their visual perception through a simple technical apparatus made up of a sensor, a computer, a projector, and a screen. Information regarding objects within the dancing area flows through this apparatus to be rendered as an abstract picture with which one can interact.

Motion is first captured by an infrared depth sensor,[1] a device allowing to measure the physical distance of the objects it faces. The resulting image, similar to the one of a classical camera, is a black-and-white picture providing tridimensional information about the scene it records: black means far, white means close. Using this device, one can easily distinguish the shapes of the main objects from the scene's background, thus cutting off and extracting information from the dancers' bodies. Several simple measures can be computed on theses shapes to extract postural features of interest. We decided to focus on two very basic features: the bodies' wingspans, both horizontal and vertical, as well as their 2D position within the interaction area.

Theses features serve as inputs for the equations governing the particle cloud[2] that is rendered on the screen. When no one is interacting with the installation, it simply consists of half a million motionless particles. Each one of them emits a bit of light, almost invisible when taken alone, but adding up to form denser regions when they happen to overlap on the screen (that is, within the same pixel).

The dancers create centers of gravity in the projected cloud, mapped from their bodies' locations within the interaction area. These centers of gravity then bring motion to the particles according to a formula analogous to the classical law of gravitation: in the most gravitationally-faithful setting, the amount of motion transferred to the particles is inversely proportional to the square of the distance separating them to each center of gravity, but other functional relations were also explored. The magnitude of attraction or repulsion depends on the body posture: the more spread out, the more repulsive; the more hunched up, the more attractive. One can, hence, modify the particles' trajectories by traversing the interaction area and opening (or closing) one's body to different extents.

The cloud's particles all follow the same basic rules: (1) they are attracted (or repelled) by gravity centers depending on their distances and on the centers' magnitudes; (2) when they hit a border of the screen, they bounce without any velocity loss; (3) their movement is slowed down by a constant friction force. Moreover, the particles do not interact with one another but only with the gravity centers and the screen borders, such that the movement of a given particle does not depend on the movement of the others. These three microscopic principles are summarised by simple formulae, thus fully describing the dynamics of the whole cloud. Yet, despite this apparent simplicity, a large number of macroscopic shapes and behaviours seem to emerge.

Emergence and complexity

At the turn of the XXth century, there were two conflicting ontological stances about the nature of the real world. On the one hand, reductionist *monism* claimed that any phenomenon in nature – however complex – could be explained by the microscopic description of its components. On the other hand, non-reductionist *dualism* stated that some phenomena would be the effect of macroscopic forces that could not be reduced to the microscopic interactions. In particular, when it came to biology, dualism defended that living bodies differ from inert bodies due to some sort of "vital energy" that would operate "beyond" the microscopic laws of chemistry.

The concept of emergence[3] was originally proposed to offer a middle way between these opposing views by acknowledging the existence of multiple levels of description – or organisation – tied by relations guaranteeing consistency between them.[4] In simple terms, it is thought that the interaction between parts in one level produces either irreducibly novel behaviour (ontological or strong emergence) or unexpected properties (epistemological or weak emergence) in upper levels. If unpredicted macroscopic patterns are in theory the result of the microscopic interactions, they remain in practice objects that can be understood for themselves, thus being "more than the sum of their parts". In other words, complexity arises from simplicity, but it acquires a new meaning when seen through the eye of the observer.[5]
Following the tradition of multi-agent simulations,[6] the objective of our installation was to give birth to different complex structures from simple and repeated interactions. Given half a million particles, combinatorics alone produces a virtually infinite number of microscopic configurations – most of which without any internal structure or apparent correlation. However, because the same three principles are simultaneously applied to each one of these particles, they all become correlated in a way that any observer recognizes as an ordered whole.
The dancer, being the center of gravity, rapidly learns how to build simple macroscopic shapes like concentric circles or light strands. Eventually, after a few minutes of interaction, they will discover many more elaborate patterns, resulting from interactions that are formally allowed by the three principles but that were not initially conceived by design, patterns that seem to emerge.

Embodied cognition and cognitive extension
Moving Cells builds upon emergence to experiment with movement perception and body cognition. So, why do patterns emerge at all? The installation consists of a technical apparatus that is completely inert when left alone. It is the presence of a moving body – especially a cognitive one – that closes the feedback loop and generates all the complex behaviour.
The magic takes place because of a human ability to extend his cognition with elements living outside of their bodies' boundaries. As Chalmers put it in the foreword to Clark's *Supersizing the Mind*, "when parts of the environment are coupled to the brain in the right way, they become parts of the mind."[7] Not only are we able to integrate external devices to our minds, we also count on that on a daily basis. People need their smartphones or search results to think or reason. This is called *cognitive extension*[8] and the reason why, we assume, people dive so deeply into the experience of our installation.
Most interactors would voluntarily stay for a very long time immersed in the interaction area, testing their new extended bodies,[9] discovering new abilities – the sensation of body-boundary dissolution is, in fact, striking. After a first period of adaptation to this extended body, the dancers start to learn how to control the movement of the particle cloud, sometimes resonating with their natural oscillation frequencies, sometimes simply drawing beautiful patterns with their starry bodies.

An additional layer of complexity emerges from the collective experience of the piece. When multiple bodies interact, coordinated movement is required to produce meaningful patterns. Groups that managed to merge their extended bodies coherently – coupled through their shared, cognitively-extended particle cloud – generated the most interesting patterns and reported stronger mind-body-blowing experiences.
Our installation enables bodies to affect the simulation explicitly, in real time; reciprocally, computation extends people's cognitions.

The boundaries between real and virtual are dissolved as the dancers expand the physical borders of their bodies and the simulation exceeds the physical limits of the computer. People recognize themselves as an extended body-galaxy system just as much as the algorithms extend their computation into the people's' bodies.

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[1] We used Microsoft's Kinect: a depth sensor originally conceived for video games that enable users to interact without the need for a controller, commonly used for movement tracking. We used the libfreenect2 open source driver to interface the Kinect with a Linux operating system, see L. XIANG, F. ECHTLER, C. KERL *et al.*, "libfreenect2", *GitHub*, April 2016. https://github.com/OpenKinect/libfreenect2

[2] The simulation and rendering were implemented in C++, see R. LAMARCHE-PERRIN, B. PACE, "Moving Cells", *GitHub*, November 2017. https://github.com/Lamarche-Perrin/moving-cells

[3] J. KIM, "Making Sense of Emergence", *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition* 95 (1/2), 1999, 3-36.

[4] E. P. HOEL, "Agent above, atom below: How agents causally emerge from their underlying microphysics", 2017. https://uberty.org/wp-content/uploads/2017/05/Hoel_FQXi_EPH_wandering_goa.pdf

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[7] A. CLARK, *Supersizing the Mind: Embodiment, Action and Cognitive Extension*, New York, Oxford University Press, 2008.

[8] E. THOMPSON, *Mind in Life: Biology, Phenomenology, and the Sciences of Mind*, Cambridge, Harvard University Press, 2007.

[9] F. J. VARELA, E. T. THOMPSON, E. ROSCH, *The Embodied Mind: Cognitive Science and Human Experience*, Cambridge, MIT Press, 1992.