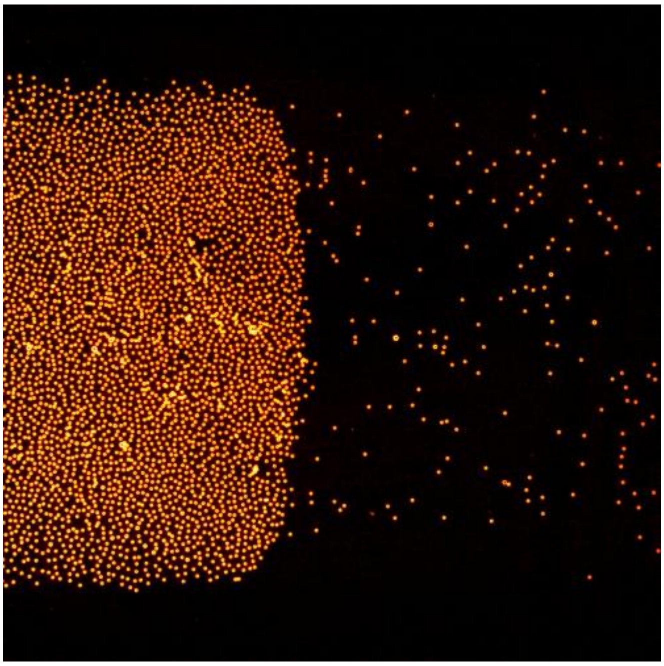
Researchers devise means for creating controlled coordinated swarming (w/ Video)

7 November 2013, by Bob Yirka



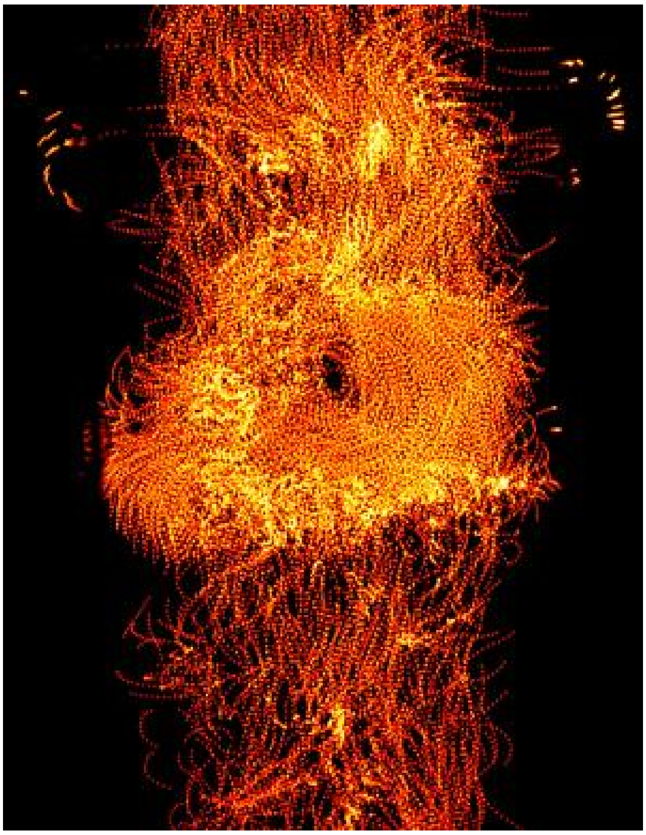
A superimposed picture of the collision between two swarms composed of thousands of colloidal rollers. Credit: Denis Bartolo, Antoine Bricard and Nicolas Desreumaux

(Phys.org) —A team of researchers from several facilities in France has devised a means for modeling coordinated swarming behavior in a controlled environment. In their paper published in the journal *Nature*, the team describes their experiment and how it might impact future research efforts.

Humans have noted coordinated swarming in its natural state for most of history—members of flocks of birds or schools of fish change direction individually, simultaneously without any obvious control mechanism. Scientists have sought to better understand such behavior to learn more about how such systems work in smaller environment such as those made of bacteria. Also, understanding how it works might help engineers build robotic systems able to accomplish the same feats. Holding things up, however, has been an inability to create a replicable model of the behavior in a controlled environment. Now, it appears, the team in France has done just that.

The environment they created was very simple—they added very tiny plastic balls to a water solution, then poured the results into a racetrack shaped (oval) enclosure. A clear lid was then placed on the enclosure to allow for observing what occurred inside. To get the balls moving the researchers applied a small electric charge. Doing so caused chaotic movement at first, but as time passed, the researchers observed that the balls formed a swarm that moved around the track as a single entity. Closer observation revealed that the swarm that developed was also homogeneous; the balls were somehow able to create and maintain rules of swarm behavior that allowed for seamless movement around the racetrack.

The researchers suggest that the individual balls were able to "sense" one another noting not just their distance apart, but their orientation as well. This allows each to maintain a certain distance from the others—they all wind up following the crowd, in what looks on film, very much like the coordinated swarm behavior found in nature.



A superimposed picture of the collision between two swarms composed of thousands of colloidal rollers. Credit: Denis Bartolo, Antoine Bricard and Nicolas Desreumaux

The researchers also suggest their simple set-up might serve as the basis for conducting other experiments regarding coordinated swarm behavior, which might ultimately lead to a better understanding of how such swarms form, how they maintain their form, and ultimately, how some manage to change their collective behavior as if they are actually one large being.

More information: Emergence of macroscopic directed motion in populations of motile colloids, *Nature* 503, 95–98 (07 November 2013) DOI: 10.1038/nature12673

Abstract
From the formation of animal flocks to the emergence of coordinated motion in bacterial swarms, populations of motile organisms at all scales display coherent collective motion. This consistent behaviour strongly contrasts with the difference in communication abilities between the individuals. On the basis of this universal feature, it has been proposed that alignment rules at the individual level could solely account for the emergence of unidirectional motion at the group level. This hypothesis has been supported by agent-based simulations. However, more complex collective behaviours have been systematically found in experiments, including the formation of vortices, fluctuating swarms, clustering and swirling. All these (living and man-made) model systems (bacteria, biofilaments and molecular motors, shaken grains and reactive colloids) predominantly rely on actual collisions to generate collective motion. As a result, the potential local alignment rules are entangled with more complex, and often unknown, interactions. The large-scale behaviour of the populations therefore strongly depends on these uncontrolled microscopic couplings, which are extremely challenging to measure and describe theoretically. Here we report that dilute populations of millions of colloidal rolling particles self-organize to achieve coherent motion in a unique direction, with very few density and velocity fluctuations. Quantitatively identifying the microscopic interactions between the rollers allows a theoretical description of this polar-liquid state. Comparison of the theory with experiment suggests that hydrodynamic interactions promote the emergence of collective motion either in the form of a single macroscopic 'flock', at low densities, or in that of a homogenous polar phase, at higher densities. Furthermore, hydrodynamics protects the polar-liquid state from the giant density fluctuations that were hitherto considered the hallmark of populations of self-propelled particles. Our experiments demonstrate that genuine physical interactions at the individual level are sufficient to set homogeneous active populations into stable directed motion.

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