

Forming Nested 3D Structures Based on the Brazil Nut Effect

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This study investigates the formation of nested structures in swarms of intelligent agents that can freely move in three dimensions. The underlying segregation mechanism is inspired by the Brazil nut effect, which occurs when granular mixtures are subjected to vibrations [6,1]. Similar effects were reported for brood items sorted by ants [3]. This sorting behaviour was validated with swarms of mobile robots [7,5]. Different from these studies we are concerned with sorting the agents themselves. In [4], we proposed a controller based on the Brazil nut effect that was capable of segregating groups of simulated e-puck robots reliably in two dimensions. In the present study, we investigate a 3D particle system implemented in NetLogo¹. The agents mimic the behaviour of particles of distinct sizes. The motion of each agent is determined by three types of vectors [4]: (i) a repulsion vector for every agent that intrudes the particle's virtual body, (ii) a random vector simulating vibrations, (iii) and a "gravitational" vector that points to a "centre" location. The agents do not communicate. However, the repulsion behaviour requires them to sense each others' relative positions within their particle range. The segregation quality is measured as the percentage of pairs of particles from different groups that are segregated correctly (based on distance to centre) [4]. A value of 100% corresponds to perfect structures with all large agents surrounding the small agents, 50% corresponds to purely random structures, whereas 0% corresponds to perfect but inverted structures.

The structure formed by 2 groups of 50 agents was investigated for different particle size ratios [see Fig. 1(a)]. For ratio 1.00, all agents behave identical and hence no segregation occurred. For ratios near 0, structures achieved consistently a segregation quality of about 100%. The study was expanded to include a third group with results that matched the ones obtained with two groups [see Fig. 1(b)]. We observed the formation of asymmetric structures when using group specific centres of gravity [see Fig. 1(c)]. Video recordings are available in [2].

The formation of 3D structures could be useful in medical, military and space applications. Future work will have to investigate a physical implementation.

¹ <http://ccl.northwestern.edu/netlogo>

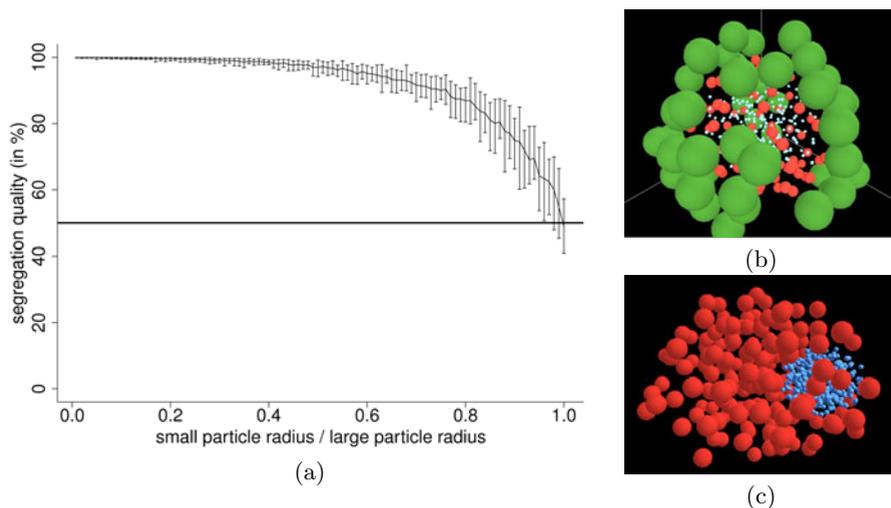


Fig. 1. (a) Mean segregation quality as observed for two groups of particles (30 trials per particle size ratio). Arrows stretch from the smallest to the largest observation. (b) Three groups of particles organise into a nested structure. The smallest particles form a sphere located in the centre. The sphere is surrounded by a layer of medium sized particles, which in turn is surrounded by a layer of large particles. (c) Asymmetric structures formed by two groups of particles with different gravitational centres.

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