Abstract

Artificial intelligence (A.I.) has been a actively studied area of research, especially in recent years. Among the large number of A.I. methods, procedural content generation (PCG) and agent-based simulations are two topics that have attracted much attention. The goal of PCG algorithms is to automatically generate game content (levels, maps, non-player characters, etc.) to save both time and expenses for human designers and artists. It is essential that a PCG method reliably generates content with the desired properties and qualities. To ensure this, PCG has become the subject of much academic work in recent years, and especially the game industry has been studying PCG methods a lot. Also at the center of much attention are agent-based simulations. Here, many small agents living in a bigger system follow certain rules, and by their individual actions and decisions, properties or structures are formed on the system level. One example of an agent-based simulation method are ant colony optimization (ACO) algorithms. These are optimization methods that are usually applied to find the shortest path through a graph. The ant agents mark the paths they find through the graph, and the shorter a path is, the stronger it is marked. Other ants are more likely to follow a path the more strongly it is marked, and mark it themselves when they then traverse it. As a result, after some time, the shortest path is the strongest marked one and all ants follow it.

Minecraft is a game whose worlds consisting of blocks are generated using PCG algorithms. In these worlds, there are villages, structures consisting of buildings and paths, that are also procedurally generated. However, we find that these villages do not look very natural. We define a village to be natural if it meets the following criteria: It has a clearly identifiable village center, houses are placed in locations that make sense depending on their function, paths adapt to the slope of the terrain, and paths follow a hierarchy. In our opinion, the default villages in Minecraft meet none of these criteria.

To generate more natural-looking villages, we propose using ACO algorithms. The idea behind it is that the life of the villagers is simulated by ant agents. Whenever a villager wants to go from one house in the village to another, it is the ants that find a path for the villager. Ants look for short and flat paths, which they mark with different strengths depending on a path's length and flatness. In the process, a network of ant trails is formed, which in turn is defined to be the path network of the village. However, in order to fulfill this goal, the classical ACO algorithms have to be modified, since they were not designed to find natural solutions, but optimal ones. We must redefine on which basis the ants make pathfinding decisions, and furthermore on which criteria the strength of the path marking depends.

To be more precise, we propose to proceed as follows. First, houses are placed stochastically, where the probability of a location depends on two factors, namely the flatness of the terrain and the proximity to the village center. Paths between houses are generated using ACO algorithms. Each of the villagers is simulated for by ants. These ants find a path through the village whenever the villager wants to move from one house to another. The shorter and flatter the path found by an ant, the more likely it is that other ants will follow this path later. Through repeated search for paths, a network of paths that connects all houses in the village by short and flat paths is formed. Placing houses and finding paths can be repeated to grow the village. When the growth of the village is complete, the houses and paths are placed in the Minecraft world. Houses near the center of the village are assigned different functions than houses farther out, and paths that have been traversed more often

are built wider than paths with less traffic.

Villages generated by this method consist of houses that are closer together in the center of the village than outside, and a network of paths that connects all houses. We analyze how the length and flatness of the paths that the villagers (ants) choose through the village changes over time. The results show that the paths become shorter and flatter as time passes. This means that the network of paths formed by the villagers connects a house of the village to any other house in the village by a short and flat path, as desired.

Furthermore, people with different backgrounds are interviewed and asked to compare the default villages and the villages generated by this algorithm. The results confirm that the generated villages are more natural than the default villages, with especially the course and structure of the paths being perceived as more natural. Overall, 73.3% of participants find the paths generated by our method to be more natural, and the majority of participants with prior playing experience in Minecraft find the placement of houses and the general appearance of the village to be more natural.