14.1 Path Planning: Unconventional Computing Approaches

Path planning (or motion planning) is a common application of computer science and robotics where a path has to be found between points (typically two points, source and destination point) within an arena. The representation of the arena may already be known or may be discovered by localisation and mapping methods (in this chapter we consider examples where the arena layout is known in advance). The resultant path should be short, minimising distance between the points. Other constraints may also apply, such as requiring paths of sufficient width, avoiding walls, avoiding obstacles, or minimising the number of turns.

Unconventional computing seeks to utilise the computing potential of natural physical systems to solve useful problems. Since these systems are localised in space, they typically use different mechanisms to classical approaches. In recent years physical propagation through space in chemical substrates has been used as a search strategy. Babloyantz first suggested that travelling wave-fronts from chemical reactions in excitable media could be used to approximate spatial problems \[262\]. Wave propagation in the Belousov-Zhabotinsky (BZ) chemical reaction was subsequently used to discover the path through a maze \[72\]. In this research a trigger wave was initiated at the bottom left corner of a maze and its propagating wave front recorded by time-lapse photography. Direction of wave propagation was calculated from the collective time-lapse information to give vectors which indicated the direction of the travelling wave. The path from any point on the maze to the
exit (the source of the diffusion) was followed by tracking backwards (using the vector information) to the source.

Wave-front propagation generates a solution from any (and indeed every) point in the arena. Branching paths (for example around obstacles) are searched in parallel and the solution time is dependent on the spatial size (in terms of maximum path length) of the arena and the wave-front propagation speed. Although computationally efficient, a direct spatial encoding of the problem (arena, desired start and end points) must be stored, as opposed to a more compact graph or grid encoding in classical approaches.

Reading the output of the parallel calculations is not a simple approach using chemical substrates. Although the propagating wave solves the shortest path for all points in the arena, finding and tracking the desired path from start to end point requires separate processes. Different approaches have been attempted including image processing [263], using two wave-fronts in both directions [264], and hybrid chemical and cellular automata approaches [171]. More recently, a direct visual solution to path planning was devised in which an oil droplet (exploiting convection currents and surface tension effects) migrated along a pH gradient formed within a maze to track the shortest path through the maze [71].

In this chapter we continue the exploration of material computation by morphological adaptation seen in [216] and [243] and examine its application to path planning. Taking inspiration from the behaviour of slime mould, we use a large sheet, or ‘blob’ of virtual slime mould which is located within an arena in which a path between two points (represented by attractants) must be found. By shrinking this blob over time, it withdraws from the confines of the arena boundary and adapts its shape to connect the start and end points of the path. Examples of the shrinkage method are given in Section 14.2 along with more challenging additions to the problem such as multiple-path options, collision-free paths and obstacle avoidance. We conclude in Section 14.3 by summarising the approach and its contribution to unconventional computing methods of path planning in terms of its simplicity.

### 14.2 Morphological Adaptation in the Model Slime Mould

We placed a large population of particles within the confines of a 2D arena (Fig. 14.2a), so that the virtual plasmodium completely filled the arena (Fig. 14.2b). Start and end points of the path were represented by projection of attractant into the arena at their respective locations. The virtual plasmodium was attracted to these start and end points. The population size was reduced by adjusting the parameters governing the growth and shrinkage in favour of shrinkage. The collective ‘blob’ began to shrink and, as it did so, adapted its shape to maintain connectivity to the start and end points and conform to to the borders of the arena (Fig. 14.2c-e). Any extraneous