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Potential Flow for Unit Positioning During Combat in StarCraft

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***Abstract*—This paper presents a method for improving the quality of unit micro management by applying potential flow to unit positioning in the popular RTS game StarCraft. We believe that it is the first time an application of potential flow has been seen in this domain. Experimental results are provided at the end of this paper, which show a promising potential of integrating the method into a StarCraft AI bot and playing it in actual games.**

Keywords—RTS games; StarCraft; micro management; unit positioning; potential flow

I. Introduction

A. Unit Micro Management

In StarCraft, unit micro management, or in other words, low-level unit control, is the key to winning a battle. This paper focuses on unit positioning, which is one of the most common unit micro management techniques. In real battles which often contain a lot of units, to control every single unit is impossible even for top players. Therefore, the way units are positioned can help players to gain strategic advantages over the enemy and even change the result of the whole game.

Although there have been several AI studies on this domain, bots whose unit behaviors are defined via static scripts still predominate in AI competitions. However, most of them only focus on actions of individual units and do not take into account squad-level tactics like unit positioning. Some examples of commonly used scripts are listed as follows:

- *AttackClosest*: The unit will attack the closest enemy unit within its attack range, but will take no actions while reloading. If there are no enemy units within the attack range, it will move towards the closest enemy unit.
- *Kiting*: This script is similar to Attack-Closest, except the unit will move away from the closest enemy unit when it is unable to fire.
- *Attack-Value*: This script is similar to Attack-Closest, except the unit will attack the enemy unit with the highest damage per frame / HP value within its attack range when possible.
- *No Over Kill Attack-Value (NOK-AV)*: This script is similar to Attack-Value, except the unit will not attack the enemy unit which has already been labeled “lethal damage” this round. It will instead choose the next priority target, or wait if one does not exist [1].

B. Potential Flow

Potential flow is a concept originating from fluid dynamics and is defined as inviscid, irrotational flow of ideal fluid. A two-dimensional flow is often represented by complex potential w, which is a complex function composed of velocity potential φ and stream function ψ.

$$w = \varphi(x, y) + i\psi(x, y) = f(z),$$

where $z = x + iy$ is a complex number associated with point (x, y) in complex plane. Lines of constant ψ are known as streamlines, and lines of constant φ are known as equipotential lines. The velocity v of a potential flow can be obtained by taking partial derivatives of either the velocity potential or the stream function:

$$v_x = \frac{\partial\varphi}{\partial x} = \frac{\partial\psi}{\partial y}, \qquad v_y = \frac{\partial\varphi}{\partial y} = -\frac{\partial\psi}{\partial x}$$

A property of potential flow is that it satisfies the principle of superposition, which means various potential flows can be added together to generate new complicated potential flows. Below are some basic potential flows and the corresponding complex potentials.

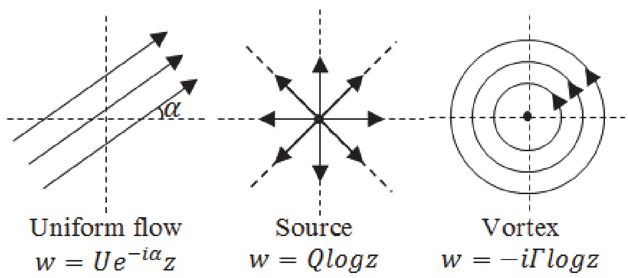


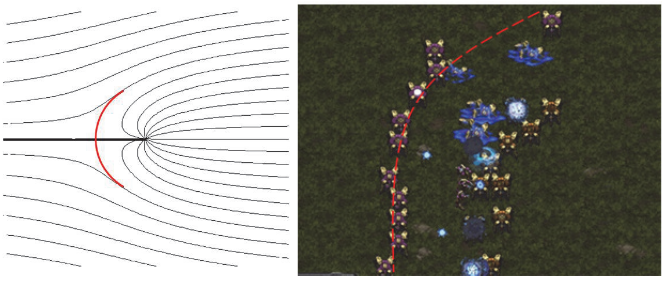
Fig. 1. Examples of basic potential flows.

II. Related Work

So far, navigation of units in StarCraft is mostly handled using pathfinding algorithms such as A*. However, it does not always perform well due to highly dynamic and real-time aspects of the game. For better adaptation to dynamic situations, Johan Hagelback proposed a method using potential fields to deal with unit navigation [2]. A problem of his approach is that such a unit may get stuck at a local minimum and fail to reach the goal. To solve this problem, it is suggested to utilize potential fields that use harmonic functions. A harmonic function, like the complex potential above, is a solution to the Laplace equation and does not have local minima [3].

III. APPLICATION OF POTENTIAL FLOW TO STARCRAFT

In order to position units during combat, we order each of them to move along streamlines of an appropriate potential flow, as described in [4]. When enemy units appear within its attack range, it stops moving and starts attacking. First, the flow is set to be a uniform flow, of which the direction is from the center of our units to the attack position or to the center of enemy units if we can detect any of them. In that case, we also assign a source to each enemy unit. Each source can be thought of as a repulsive force that prevents our unit from going too close to the enemy. In addition, the superposition of a uniform flow and a source is a potential flow around a streamlined body called a half-body as shown in Fig. 2(a). Therefore, moving our units along the streamlines of that flow will result in our units surrounding enemy units. This helps maximize our fire-power because all of our units are able to fire while only part of the enemy units can.



(a) (b)

Fig. 2. (a). The superposition of a uniform and a source. Red line is the positions at which our units are supposed to stop and start attacking. (b). A screenshot of an actual combat. Our units (left) are surrounding enemy units (right).

When many units take part in a battle, they may sometimes block each other from moving to the ordered positions due to collisions. To solve this problem, we propose that a vortex be assigned to every unit that is blocking or will block other units in the very near future. As a result, the blocked unit can go around the blocking units, and unit collisions can be avoided.

IV. EXPERIMENTS AND RESULTS

In order to evaluate the performance of the proposed method, we decided to play our AI against various opponents: StarCraft built-in AI, the aforementioned scripts, and Skynet bot which won the first place in CIG 2012 StarCraft AI competition. For our units, we used AttackClosest script for selecting the target to attack after navigating using the proposed potential flows.

A. Combat Scenario Setup

Each experiment consists of a series of combat scenarios, in which each player controls the same army of N units. In order to mimic battles in real games, N was set to 12, 24, 36, 48; and three different army types were constructed. These armies are *N/2 Protoss Zealots + N/2 Protoss Dragoons*, *N/2 Terran Marines + N/2 Terran Firebats* and *N/2 Zerg Zerglings + N/2 Zerg Hydralisks*. In all games against Skynet bot, because it is designed to play Protoss, only combat scenarios involving the first army type were played. The map we used for experiments contains no obstacles or buildings. At the beginning of every battle, two forces are placed separately but symmetrically around the X-axis of the map.

B. Experimental Results

50 games were played for each combat scenario, giving 600 total games against each opponent (except Skynet bot). The win rates against opponents are presented in Table 1. As can be seen, our proposed method could defeat not only StarCraft built-in AI but also all scripts. The result against Skynet bot is also encouraging, i.e., we were only defeated in large-scale combats. In general, the best results were achieved in middle-scale combats of 24 vs. 24 and up to 36 vs. 36 units, which can normally be seen in any actual StarCraft game.

TABLE I. WIN RATES (%) OF THE POTENTIAL FLOW BASED METHOD AGAINST OPPONENTS.

Opponent	**Number of units**			
	12	***24***	***36***	***48***
Built-in AI	76.0	88.0	100.0	96.7
AttackClosest	58.7	78.7	75.3	52.0
Kiting	72.0	100.0	94.7	86.0
Attack-Value	76.7	100.0	93.3	88.3
NOK-AV	71.3	100.0	85.3	68.0
Skynet bot	64.0	68.0	52.0	26.0

V. CONCLUSIONS

In this paper, we presented a novel approach for unit micro management by proposing a method that utilizes potential flows for positioning combat units in the popular RTS game StarCraft. It was revealed that the proposed method can handle various experimental combat scenarios with superior performance against opponents.

For future work, we intend to incorporate the proposed method into our bot – ICEbot – and take part in StarCraft AI competitions. For that, the method must be able to handle more realistic combat scenarios which may contain many obstacles, buildings and have a complicated terrain.

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