Avatar Movement in World of Warcraft Battlegrounds

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ABSTRACT
Evaluating DVE topology management and message propagation schemes requires avatar movement models. Most models are based on reasoned assumptions rather than measured data, potentially biasing evaluation. We measured player movement in World of Warcraft battlegrounds, and compared our observations against common assumptions about player avatar movement and navigation. We found that when modeling a highly interactive DVE such as a battleground, a waypoint model is not sufficient to describe most avatar movement. We were surprised to find that despite game incentives for grouping, the majority of avatar movement between objectives is individual, not grouped. Finally, we found that a hotspot-based model for avatar movement is consistent with our traces.

Categories and Subject Descriptors
C.4 [**Computer Systems Organization**]: Performance of Systems – *Performance attributes.*

General Terms
Measurement.

Keywords
World of Warcraft; Avatar Measurement;

1. INTRODUCTION
Evaluating research into Distributed Virtual Environment / Network Game systems and associated technology requires making assumptions about game and player avatar behavior. These assumptions are based on the way players are expected to behave in these games. We are unaware of any experimental evidence supporting these assumptions in the research we've reviewed.

This paper provides data and analysis based on traces from World of Warcraft battlegrounds, and an interpretation of that data in terms of avatar movement within battlegrounds. World of Warcraft is by far the world's most popular DVE, and so is a good choice for gathering data about actual player avatar behaviors.

We decided to instrument a relatively small part of the WoW experience to focus our findings. Battlegrounds were chosen because of a combination of tractability, and applicability to DVE performance modeling. We examined three common assumptions people make about DVE performance when evaluating their DVE-related research, all related to the way avatars move. We investigated whether a waypoint model is a good fit to describe DVE traffic, whether player avatars organize into coherent groups, and whether movement patterns result in significant hotspots.

We found that a waypoint model can describe some battleground activity, but is inadequate to explain most movement behaviors. We also found that player avatars moved in groups less often than we expected, given the team nature of the battleground. Finally, we found significant evidence of hotspots, with 5% of visited territory accounting for 30% of all time spent in a typical battleground.

The remainder of this paper provides supporting information and evidence for these findings. We start by describing World of Warcraft for those not familiar with the game, and provide particulars about the battleground we evaluated, Arathi Basin. We provide details on our methods for gathering data on player avatar movement within battlegrounds, and accuracy and completeness of that data. Finally, we provide data relevant to waypoint, hotspot, and group movement models for DVE player avatar movement.

2. BACKGROUND
2.1 World of Warcraft
World of Warcraft (WoW) is the most popular DVE in history. With more than 11 million subscribers[1] worldwide, World of Warcraft has 62% of the total market share for all massively multiplayer online games combined[2]. Because of its ubiquity, WoW is especially relevant as a DVE user study test bed. Assumptions and observations made against WoW automatically apply to the majority of all DVE users.

2.1.1 Types of Experiences
WoW experiences can be divided into four main categories: world PvE / PvP, capital cities, instances, and battlegrounds. This paper focuses on battlegrounds, but we provide a basic overview of the other behaviors to support this decision.

World PvE ('player vs. environment') *and PvP* ('player vs. player') are activities where player avatars wander the game world individually or in small groups. This game world is large and detailed – requiring more than an hour to walk across one of its four continents - and player avatars are relatively sparse. Indeed, player avatars are usually out of interaction range of each other, unless they explicitly seek each other out. The world requires significant resources to simulate and to communicate with DVE clients. The game scales by running many simultaneous world copies called *shards*, with each avatar belonging to exactly one shard. A typical shard has between a few hundred and a few thousand active players online at any given time[3], out of a population of tens of thousands assigned to that shard.

Each shard contains ten large cities called *capital cities*. These offer a plethora of facilities, and are densely populated relative to

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the rest of the shard. For example Dalaran, the current end-game capital in World of Warcraft, can have a quarter of the active population on the shard concentrated in less than 0.1% of the world's geography. While densely populated, capital city interactions tend to be infrequently and lightweight, with most avatars sitting still and performing social or character maintenance activities.

Instances are small, self-contained adventures which groups of players play together. Just as a shard is one of many copies of the game world, an instance is one of many copies of that adventure on a given shard. Instances are shared by a self-selected set of avatars – typically 5, though up to 40 are allowed in certain 'raid' instances – and together they solve puzzles and fight particularly difficult AI-controlled avatars. An instance can be thought of as a private PvE experience requiring a group of players to complete.

Battlegrounds are a special type of instance. Like PVE instances, there can be many identical battlegrounds active and reachable from a given shard. Unlike instances, a single battleground instance can be populated by player avatars from multiple shards, known collectively as a battle group. Battlegrounds are characterized by scenarios which reward PvP, usually to achieve an objective or dominate a resource. Battlegrounds have intense continuous activity with between 20 and 240 mutually interacting participants split into two opposing sides called factions. For comparison, we measured traffic in a capital city with more than 250 people at 40kbps for a given client, while traffic in the Wintergrasp battleground with 200 people often reaches 250 kbps sustained, and can jump over 500 kbps.

Battlegrounds with their high traffic requirements, interaction, and frequent movement characteristics make an ideal test environment for DVE research related to player avatar movement. We chose the Arathi Basin battleground to measure these behaviors. While it isn't the largest battleground, it's big enough to be interesting, and small enough to be tractable to measure and perfect our tools.

2.2 The Arathi Basin Battleground

There are five different battlegrounds in World of Warcraft. Battlegrounds are organized around inter-faction – Alliance and Horde – competition. Arathi Basin is a 30-person battleground where teams compete for control of five stationary flags. Gaining control of a flag requires a team member to use the flag without interruption for ten seconds, and to prevent any enemy faction team members from using the flag for an additional minute. Each team receives points every few seconds based on the number of flags they control. The first team to reach 1600 points wins the battleground. Both teams are rewarded, but the winners received better rewards, incenting each team to win.

The battleground is approximately 600 yards by 600 yards in size, with flags evenly spaced around the center of the map as shown by the circled huts in Figure 1. The circled houses at either end of the battleground are the starting point for each faction, alliance at the northwest, and horde at the southeast. In terms of movement, some terrain slows down avatars, or is impassable. For example, water slows most avatars down to approximately four yard per second, two thirds of their normal movement speed. Most cliffs and steep hills cannot be traversed, and falling off them can injure or kill an avatar.

Figure 1 - Arathi Basin map

Traversing the map requires about one minute mounted, or two minutes on foot, assuming no enemy engagements. Avatars typically must be within either melee range (5 yards) or ranged combat range (30 yards, up to 45 in some cases) to interact. The nearest neighbor to each flag is between 170 and 250 yards as the crow flies, which is effectively several interaction intervals apart. This distance enables avatars to fight between flags without involving avatars at any of the flags.

Players are rewarded for controlling flags and for killing avatars from the enemy faction. When an avatar is killed, it is turned to a ghost and teleported to a graveyard near the closest controlled flag, or to the faction base if no flags are controlled. Every 30 seconds all ghosts at a graveyard are resurrected, and granted full health and mana.

Battles are usually less than a half hour long, with some turnover in participants. Real life or network problems force some players to drop out, and they are replaced by others waiting to battle. As a result, a given player avatar may be in a battleground for as long as the entire match, or as little as a few seconds.

2.3 Avatar Behavior and Traffic Classification

Little research has been done on avatar movement patterns.

Pittman and GauthierDickey studied World of Warcraft shard populations using WoW's built-in extensibility [3]. They found that the workloads used in simulations to evaluate DVE infrastructure were unrealistic. User sessions in WoW are on average less than half an hour, but can reach 24 hours. Peak populations on a shard are typically five times their minimum population.

Evaluation of proposed DVE systems often uses a synthetic workload based on previous research, or on a model generated by the evaluators. For example, Krause [4] compares three different categories of DVE infrastructure using a synthetic workload based upon an average session time of 100 minutes. Avatars in his evaluation are simulated using a combination group and waypoint model, where groups of simulated avatars agree on a next point to visit, and move there together. Several other frameworks [5][6][7][8] assume movement and arrival / departure properties of participants without any obvious experimental basis. The assumptions are reasonable, but without firm experimental grounding. We believe using a model based on actual DVE participant behavior can provide valuable insight into actual system performance under load.

Player avatar migration patterns are of critical importance for evaluating geometric routing schemes. For example, VAST [9][10] and Delaunay triangulation [11] organize themselves based upon the position of player avatars, and their overhead and efficacy depend heavily upon the density, distribution, and dynamics of those avatars. Likewise, region-based DVE architectures [12] [13][14] organize region clients by their avatar location, and are affected by the frequency of avatar transitions between zones, and any tendency of avatars to cluster in hotspots.

Understanding the movement of avatars is of paramount importance for evaluating region-based and geometric-mesh based DVE schemes. The remainder of this paper provides information about avatar behavior in a real-world DVE which can be used to inform future DVE framework evaluations.

3. METHODOLOGY

Our goal is to capture all movement events for a set of battleground sessions for comparison against proposed movement models. To do this, we need an exhaustive trace of all movement during the battleground session. Unfortunately, Wow clients only receive avatar movement data which is immediately relevant to them. In practical terms, this means movement data for avatars which are within avatar visual range – approximately 250 yards – and which are not blocked by large obstructions such as cliffs.

Each WoW client transmits its own avatar movement updates to the server, which the server redistributes to other relevant clients. Updates are absolute, consisting of a client identifier, 3-D Cartesian position, and facing information, as well as additional information we don't decode. The server does not send position information for avatars the client can't perceive, such as very distant or stealthed (invisible) avatars.

Experimentation confirmed two well-placed observers receive movement updates for most of the Arathi Basin map. Getting into those positions takes between 1 and 2 minutes from the start of a battle, depending upon enemy activity. Battles in our sample set ranged from 4 to 23 minutes in duration.

Figure 2 - Arathi Basin from the Lumbermill Plateau

Figure 3 - Placement of observers in Arathi Basin

We used Microsoft Network Monitor 3.3 to capture network traffic, and FRAPS to capture video from a game client's rendered view. FRAPS videos enabled the game client view to be replayed to answer questions about activity in the game associated with specific times in the network traces.

Overall the movement data we captured is correct, but incomplete. The two leading causes of missing data are an observer being out of position, and stealthed non-observer avatars. Observers went out of position as a result of enemy attack, typically resulting in the observer's death. Death teleports the observer's ghost to the nearest owned graveyard. Resurrection introduces a 15 second delay on average, and returning to post takes another 0.5 to 2 minutes. We used observers with stealth capabilities to reduce the chance of detection, and therefore of being targeted by the enemy. Our observers' positions in the map are marked with white X's in Figure 3. One was at the north edge of the lumbermill plateau, the other on top of a waterfall at the south end of the mine valley to the East.

Our observers avoided combat, and so effectively filled two of the 15 slots in the Alliance team with non-contributors. This biased the results of the battles, but not significantly. Our sample set has a good mix of battle results, with Alliance winning nearly half the observed games, in one case by a score of 1600-0. We were able to capture battles with scores ranging from 1600-1590 (the closest a battle can be) to 1600-0.

4. ANALYSIS

We captured a few dozen traces of Arathi Basin battles, and retained 13 where our observers were mostly at their assigned posts. We analyzed our data to verify its correctness, and to provide information for others to evaluate suitability of avatar movement models used for evaluating DVE's. The three main phenomena we wanted to investigate were: appropriateness of waypoint models for guiding movement, existence of hotspots for hotspot-based movement models, and grouping/flocking.

- **Waypoints**. We expected flags and graveyards to be strong candidates for waypoints for movement models.
- **Hotspots**. The map has natural hotspots in the form of avatar starting locations and flags. We were curious if other hotspots would show up, and if hotspots were consistent across battles.

- **Flocking and grouping**. Logic dictates there should be significant grouping in movement. All avatars for each team begin at the same point, their faction base, and are released simultaneously. Resurrection is synchronized, with all waiting ghosts at each graveyard resurrected every thirty seconds. Battle dynamics incent avatars to group as well, to maintain numeric superiority.

Before describing our findings, it's worth discussing overall battleground and avatar participation characteristics.

4.1 Avatar Participation Characteristics

We had a series of qualitative questions. First, we wanted to provide an estimate of turnover in the battleground population. In other words, were there joiners and leavers? If so, how long was a typical session? Also, we knew we were missing movement for some avatars some of the time, and wanted to quantify the missing data.

Table 1 summarizes this information for each of the thirteen battles we analyzed, excluding our two observers. 'Lost by' shows the score difference between the winning and losing teams. 'Avatars' shows the number of unique avatars recorded during the battle. The battleground allows in a maximum of 30 avatars, 28 factoring out our observers, but departures can be replaced. 'Duration' gives the total time of each battle in seconds, from when avatars are released from their base to when one team wins and the battle concludes. 'Average play' gives the percentage of the total duration an average participant played. This number is biased downwards by the time it takes observers to first encounter all of the enemy avatars, on the order of 120 seconds. 'Average recorded' shows the percentage of avatar participation time successfully recorded for that battle. Average recorded was calculated by summing the total seconds played by all avatars, and subtracting out gaps in the traces for each avatar.

Our data set includes a good sampling of battle scores, ranging from the largest to smallest possible difference, with an average difference of 910. The average battle had 35 unique participants, each present for an average of 69% of the battle. Participant turnover was on average 25% during the course of a battle. We recorded a total of 392 unique avatars. We successfully recorded movement and position for avatars 73% of their participation time. As mentioned earlier, gaps were caused primarily by avatars becoming invisible and therefore undetectable, and observers being killed and temporarily out of range of some avatars.

Table 1 – Avatar Participation Summary

Lost By (points)	Avatars	Dur (s)	Avg Play	Avg Rec.
10	36	1423	72%	81%
300	38	1296	67%	75%
420	46	1208	52%	62%
720	36	1015	69%	75%
870	36	957	63%	62%
950	33	671	71%	69%
960	37	951	69%	76%
980	36	891	70%	78%
1050	33	885	79%	78%
1180	37	658	61%	60%
1370	36	765	66%	65%
1490	32	583	78%	83%
1600	20	266	76%	82%
AVERAGE	35	890	69%	73*%

The remainder of this section describes relevance of waypoint, hotspot, and grouping models to DVE player avatar movement.

4.2 Waypoints

Waypoints are fixed points in the environment used as intermediate or final destinations for linear navigation. Drawn graphically, the path for an avatar following waypoints would resemble a series of straight line segments connecting the waypoints visited in the sequence they're visited.

Obvious waypoint candidates for the battleground are graveyards, flags, and points on the optimal (non-water, non-cliff) routes between graveyards and flags. We inspected a number of our traces, and found we could characterize most avatars as belonging to one of three movement categories, with examples shown in Figure 4. Graveyards are diamonds and flags are circled.

1. **Wanderers**. The paths of these avatars may pass through flags, but don't use a fixed route in navigating between points of interest. In a single battle they may visit the same flag many times, using a different route each trip. The grey dashed path is a wanderer.
2. **Patrollers**. These avatars move from point to point using efficient routes, and tend to follow the same route fairly closely for trips between the same two points. The green solid line is a patroller.
3. **Guards**. These avatars prefer to operate in a specific part of the battlefield, guarding it from the enemy. Waypoints are largely irrelevant for these avatars. The yellow dashed path in the lower right is a guard.

Based upon this example, only patrollers are a good fit for waypoint navigation. Patrollers made up 16% of the total population, varying from 6% to 33% of a given battleground's participants. Guards were on average 12% of the battleground population, and wanderers 49%. The remaining population's movement traces were too short to classify.

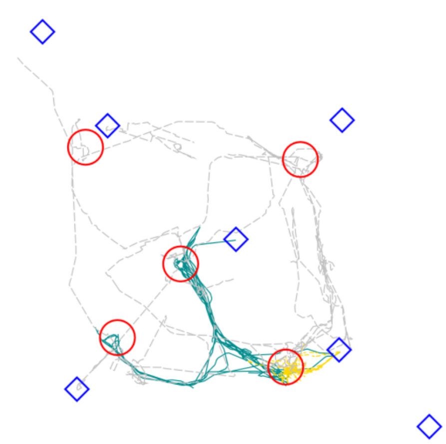

Figure 4 - Movement of Guard, Wanderer, and Patroller

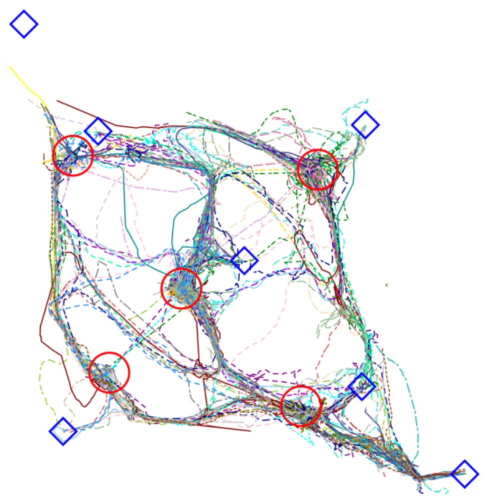

Figure 5 - Battle 980 movement paths

The terrain between some points of interest strongly constrains movement, making them more appropriate than other paths for waypoint navigation. For example, travel between the stables, and the lumbermill, or the lumbermill and the farm has only a narrow corridor to travel, flanked by a cliff wall on one side, and a cliff drop on the other.

The example in Figure 5 shows movement traces from battle 980. It has a mixture of correlated and variant paths between most pairs of nodes. For scale reference, the radius of the circles is 30 yards, the maximum interaction range for most spells and missiles.

Based on our earlier analysis and traces such as the one rendered above, waypoints may be useful for characterizing movement of a minority of participants, but cannot adequately describe overall movement patterns.

4.3 Hotspots

Hotspots are portions of the battleground where avatars spend the most time. Mathematically, hotspots are determined by dividing the map into cells, summing the number of seconds spent by avatars in each cell, and designating the cells with the highest totals as hotspots. We expected hotspots at flags because they are game objectives, and at graveyards because participants die many times each battle, and await resurrection in the graveyard.

We found most hotspots contained either a flag or graveyard. A subset of the seven graveyards and five flags were in the top ten hotspots in each battle, but the subset selected varied from battle to battle. Additional hotspots were encountered as well, such as terrain choke points in the route between two flags. Inter-flag hotspots were not consistent between battles.

Hotspots are shown in dark grey or black in the player time-density maps in Figure 6, with the five most active hotspots labeled 1 through 5. The trace on the left shows hotspots at the stables, mine, and blacksmith flags. The fourth hotspot is on the path from the alliance base to the stables, and the fifth at the farm flag. The trace on the right shows hotspots at the farm flag and graveyard, the route between the farm and blacksmith, and then the lumbermill flag and blacksmith graveyard.

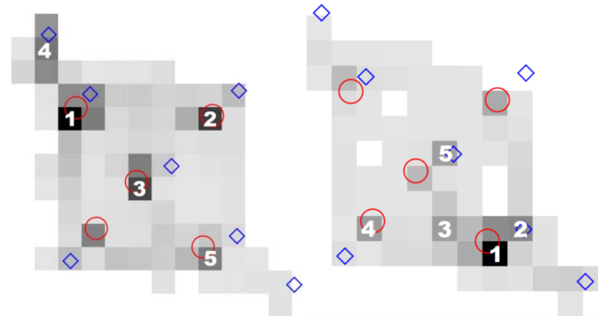

Figure 6 - Activity density maps from two different battles

As we forecast, hotspots were usually located where there was heavy contention over a flag, or a battle which migrated from flags towards arriving combatants. Based on this, we believe an adaptive hotspot-based model, taking into account current populations at hotspots, would be a valid way of modeling avatar movement within battlegrounds.

4.4 Grouping

Grouping is the tendency of avatars to form and maintain groups. There is strong incentive for players to group within a battleground: a lone combatant in WoW has very little chance of defeating multiple enemies. A fight between members of two factions almost always goes to the force with greater numbers. Success in combat implies success at controlling flags, which in turn leads to battleground victory and greater in-game rewards.

Two factors provide a disincentive for forming and maintaining player groups, especially long-term groups. First, the difficulty of coordinating group formation and maintenance. Second, the conflict between group and individual goals: without an accepted group leader, these often diverge.

Even when a group is well coordinated and has an acknowledged leader, maintaining group coherence is difficult. If a group member is slain, they become a ghost, and must resurrect and travel back to the body of the group. Barring enemy interference, this can take up to two minutes, half the battle length in some cases. In the meantime, the group typically continues towards its objective, with subsequent deaths splintering the group further.

We're most interested in grouping as it applies to movement, for example, movement between flags. To evaluate this, we defined a grouping metric called 'affinity.' An ideal affinity metric would measure joint travel of avatars between hotspots. We defined a more generous metric: any avatar within 30 yards of any other avatar in a given second is considered as having affinity for that second. If the majority of avatars don't have affinity between hotspots using this metric, they certainly wouldn't have affinity using a more realistic (and restrictive) affinity metric.

We represent this interpretation of affinity graphically in Figure 7. Two trace maps are shown: An affinity view on the left, and the complement of that view (all movement segments without affinity) on the right. A side effect of this generous affinity selection algorithm is that most movement around the flags – heavy combat areas – is classified as affinity movement, and so most hotspots show as holes in the non-affinity map.

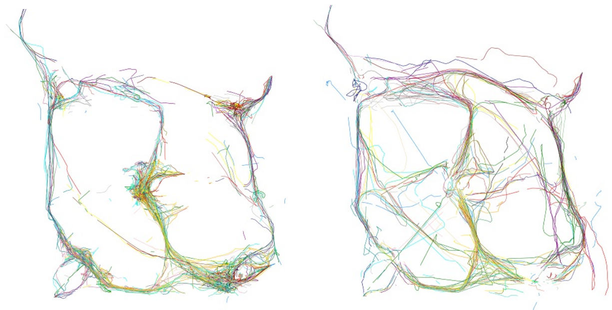

Figure 7 – 30-yard affinity (left) and non-affinity (right) view

We produced affinity and non-affinity movement maps with affinity radius set to 30 yards. As previously mentioned, this is the maximum distance for most avatar interactions. Traversing 30 yards requires about five seconds of running, or about three seconds of riding. As the example maps in Figure 7 illustrates, most inter-flag journeys are in fact made alone, without affinity. This implies traffic models which assume group movement between waypoints are not appropriate for battlegrounds.

5. CONCLUSIONS

There is a large pre-existing body of DVE research which describes mechanisms for migrating DVE operation from client-server models to more distributed architectures. This research is usually evaluated by proposing a set of DVE client movement patterns, and simulating the impact of those movements. These movements are typically based upon logic, rather than real data.

In this paper we present movement data taken from battleground traces of World of Warcraft, the world's most popular DVE. We analyzed this data in terms usually used for generating DVE avatar movement patterns: waypoints, hotspots, and group movement. We showed that typical avatar movement is more varied than a simple waypoint model can provide, and that most navigation movement is not group based, but rather individual. We also showed that the concept of hotspots is supported by battleground data, and we believe it forms a solid basis for navigation simulation models.

For future work we would like to evaluate some of the proposed topology models for DVE's – especially those employing geometric routing based upon avatar position – with our real-world data. We would also be interested in the results of others evaluating existing research with this real-world data.

6. ACKNOWLEDGEMENTS

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