Dealing with the Effect of Path Curvature on Consistency of Dead Reckoned Paths in Networked Virtual Environments

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1. INTRODUCTION

Collaboration and competition are important factors of Networked Virtual Environments (NVE). Both require a certain level of consistency in order for the interaction to be fruitful and compelling. However, finite network bandwidth and communication delay are key factors affecting this aspect of interactivity. A popular method in their mitigation for dynamic entities is the IEEE DIS standard dead reckoning mechanism [1]. In previous work, it was demonstrated that the conventional approach of using a purely spatial threshold for dead reckoning can lead to bounded spatial inconsistency but unbounded absolute inconsistency [2]. This measure of absolute inconsistency, Ω_l is provided by Zhou et al [3], and is given by (1).

$$\Omega = \begin{cases} 0, & \text{if } |\Delta(t)| < \varepsilon \\ \int_{t_0}^{t_0+\tau} |\Delta(t)|\, dt, & \text{if } |\Delta(t)| \geq \varepsilon \end{cases} \quad (1)$$

where

- Δ is the difference between the position of a local object and its remote replication;
- $\Delta(t)$ is the above difference over a duration t;
- t_o is the start time of the inconsistency and τ is the duration;
- ε is the minimum perceivable distance.

Previously, it was shown that a dead reckoning threshold based on the local absolute inconsistency measure, Ω, results in bounded local absolute inconsistency. However, the use of this threshold can result in poor spatial inconsistency. To combat this, a novel hybrid threshold was introduced, which evaluates both metrics simultaneously. When one reaches the error threshold, an update packet is transmitted, and both metrics are reset.

In this work, the inconsistency arising from the use of both thresholds is explored both in an analytical and an experimental manner.

2. PATH CURVATURE AND INCONSISTENCY

Under the dead reckoning approach, each participant transmits position and velocity data in an update packet. All other participants then use this data to model the behaviour of each entity. A further update is not transmitted until the actual and modelled position deviate by a certain threshold – see Figure 1.

At t_0, a dead reckoning update is transmitted. As velocity, v, is constant, the distance l travelled by both the modelled and the actual entity in each time interval is equivalent. The curvature of the actual entity path, k, is also constant. The actual position and model position are given by $P_A\left(\frac{\cos(\theta)}{k}, \frac{\sin(\theta)}{k}\right)$ and $P_M\left(\frac{1}{k}, vt\right)$ respectively.

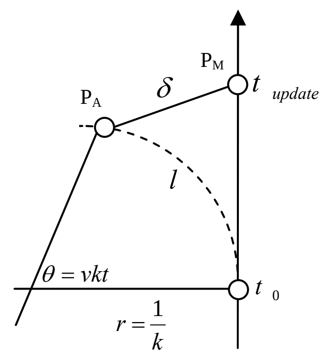

Figure 1. Actual and dead reckoning model position

Using the standard arc length formula, the angle θ is found to be vkt. At each time step, the distance between P_A and P_M can be calculated using the two-dimensional Euclidean distance formula (2).

$$d = \sqrt{\left(\frac{\cos(vkt)}{k} - \frac{1}{k}\right)^2 + \left(\frac{\sin(vkt)}{k} - vt\right)^2} \quad (2)$$

By simplifying (2) using Taylor approximations, the time taken to reach this distance can be calculated. This can then be used to calculate the time taken, t_{update}, to reach the spatial threshold, δ; see (3).

$$d = 0.5v^2kt^2 \Rightarrow t = \sqrt{\left(\frac{2d}{v^2k}\right)} \Rightarrow t_{update} = \sqrt{\left(\frac{2\delta}{v^2k}\right)} \quad (3)$$

According to (1), given absolute inconsistency can then be calculated using (4).

$$\Omega = \int_{t_0}^{t_0+t_{update}} d(dt) = \int_{t_0}^{t_0+t_{update}} 0.5v^2kt^2 = \frac{1}{6}v^2kt^3 \Big]_{t_0}^{t_{update}} \quad (4)$$

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3. RESULTS

Using (3) and (4), the inconsistency arising for varying spatial and time-space thresholds and curvatures were calculated. Figures 2 and 3 detail the results of these calculations. These figures illustrate that the two threshold types are suited to opposite ends of the spectrum of curvature values. This supports the solution proposed in our previous work, which combined the spatial threshold and the absolute inconsistency threshold in the form of a novel hybrid threshold metric.

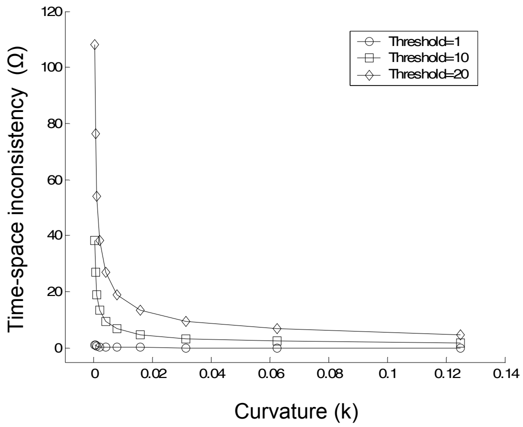

Figure 2 – Time-space inconsistency, Ω, arising from use of a spatial threshold

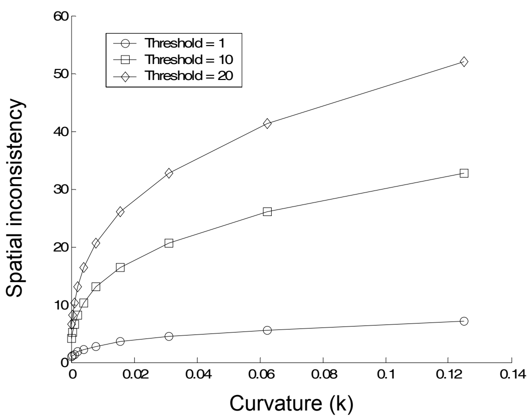

Figure 3 – Spatial inconsistency arising from use of a time-space threshold

The spatial, time-space and hybrid dead reckoning schemes were implemented in the Torque game engine, and a number of live internet trials were conducted. The goal of these trials was to navigate a course with varying curvature characteristics in a race against a single opponent.

Figure 4 details the type of updates transmitted during a live trial, when the hybrid threshold of 10 is employed is plotted. This is superimposed over the participant trajectory.

The type of updates transmitted is related to the curvature of the course. At the beginning of the simulation, when curvature is low, there is a higher frequency of breaches of the time-space threshold. As curvature increases in the middle section, the spatial threshold is primarily reached. Towards the end of the course, the frequency of time-space updates increases once again as the course curvature decreases.

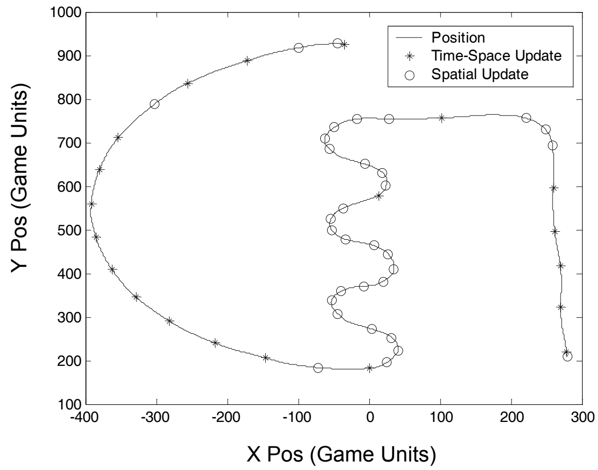

Figure 4 – Varying updates are transmitted as the curvature of the course changes

Future work will examine an adaptable threshold that reacts to network usage and course curvature. In addition, the impact on qualitative aspects of game play will be investigated.

4. ACKNOWLEDGEMENTS

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REFERENCES

[1] IEEE IEEE Standard for Distributed Interactive Simulation - Application Protocols IEEE Std 1278.1-1995. IEEE Std 1278.1-1995 (Revision of IEEE Std 1278-1993), IEEE**:** 1995.

[2] Roberts, D., D. Marshall, S. McLoone, D. Delaney, T. Ward and R. Aspin "Exploring the use of local inconsistency measures as thresholds for dead reckoning update packet generation". *DS-RT*, Montreal, Canada,10 12 October, 2005.

[3] Zhou, S., W. Cai, F. B. S. Lee and S. J. Turner "Time-space Consistency in Large Scale Distributed Virtual Environment." *ACM Transactions on Modeling and Computer Simulation (TOMACS)*, January 2004,2004,31 - 47.