Simulating Dynamic Time Dilation in Relativistic Virtual Environment

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***Abstract*—This paper critically reviews several Special Relativity simulation applications and proposes a method to dynamically simulate Time Dilation effect. To the authors' knowledge, this has not yet been studied by other researchers. Dynamic in the context of this paper is defined by the ability to persistently simulate Time Dilation effect based on specific parameter that can be controlled by user/viewer in real-time interactive simulation. Said parameter is the value of speed from acceleration and deceleration of moving observer. In relativistic environment, changing the speed's value will also change the Lorentz Factor value thus directly affect the Time Dilation value. One can simply calculate the dilated time by using Time Dilation equation, however if the velocity is not constant (from implying Special Relativity), one must repeatedly calculate the dilated time considering the changing value of displacement/distance and time. This paper discusses the proposed method by dissecting Time Dilation equation and relates it to computational method available nowadays in order to dynamically calculate and ultimately simulate Time Dilation effect in relativistic virtual environment.**

***Index Terms*—Time dilation, simulation, special relativity.**

I. Introduction

An intuitive understanding of Time Dilation effect is hard to develop. One of the problems with current available simulations is that it is not dynamic. Dynamic in this context is defined by the ability to persistently simulate Time Dilation effect in real-time interactive simulation. Real-time interactive simulation is an environment setting whereby user is able to control the input parameter thus simultaneously changing the output simulation in real-time.

This paper will start off with literature on Special Relativity Simulation that focuses on Time Dilation component within the simulation. Fundamental theory of Time Dilation will be discussed next together with its relation to Lorentz Factor specification which is the basis of Special Relativity postulation. The next section will be a detail discussion on a proposed method of how to dynamically simulate Time Dilation in relativistic environment where Length Contraction also being applied to the surrounding space. Time Dilation basic equation will be dissected and several parameters will be modified in order to become relevant with Frame per Second architecture of modern computer nowadays. The discussion will be concluded with a table showing all related activities needed to produce the objective simulation which is a dynamic Time Dilation effect in relativistic virtual environment.

Manuscript received November 28, 2014; revised May 22, 2015. This work was supported in part by the Department of Higher Education, Ministry of Education, Malaysia under the Fundamental Research Grant Scheme (FRGS), RDU130120 through Universiti Malaysia Pahang.

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II. Literature on Time Dilation Simulation

A lot of effort to visualize Special Relativity using graphical computerize simulation have been done throughout recent years [1]-[7]. Most of them focused on visualizing relativistic environment from the effect of Lorentz Transformation. Although it is rare, there is also an attempt to simulate Lorentz Transformation effect in "real world" setting by warping real world camera captured images [8]. Time Dilation however did not get much attention. Even though some simulations include Time Dilation, it is just to visualize the general principle of dilated time over real-world time. Time dilation equation is just used to calculate the total dilated time taken by moving from point A to point B when the speed is near or equal to the speed of light.

Carr and Bossomaier attempted to visualize Time Dilation in their 2D game entitled "Relativity in a rock field". Dilated Time in this game is shown by the countdown timers on a special object that changed relative to the player's speed. This attempt is identified to be not dynamic because the dilated time is only relative to speed, not to time and space which define the value of velocity [1]. Ceperly's Special Relativity-Time Dilation attempt is merely just a 2D simulation to visualize the general concept of Time Dilation with the animation of The Light Clock experiment [2], thus also did not dynamically simulate the Time Dilation effect. Another attempt is by McGrath et al. [5] who simulated a time difference that changed depending on the location of the observer. The location however, is pre-defined by the simulation thus making the dilated time not relative to velocity of a moving observer.

Perhaps the most advanced Special Relativity simulation to date is a game named "A slower speed of light" by MIT Game Lab [4], [9]. Simulation of Time Dilation in this game however is only shown at the end of gameplay where the cumulative time taken to complete the given mission (with observer's speed is equal to the speed of light) is being compared to real world time therefore not dynamic in the sense that it does not persistently simulate Time Dilation as the player accelerate and decelerate in the game environment.

III. Time Dilation

Time Dilation theory was proposed by Albert Einstein in his publication on Special Theory of Relativity [10]. Time Dilation theory indicates that time move slower when