The Development of a Three-Dimensional Material Point Method Computer Simulation Algorithm for Bullet Impact Studies

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ABSTRACT

The two-dimensional Material Point Method (MPM) algorithm outlined by Chen and Brannon has been extended to three dimensions. The development of the code is discussed as well as applications for simulating bullet impact on biological and non-biological systems.

I. INTRODUCTION

The study of bullet impacts on various systems is a currently active research field whose results have important meaning for the health and safety of people. Due especially to the destructive nature of bullet insult, computer simulations prove to be very useful in understanding and predicting the behavior of systems involved in such impacts. It is of particular importance to study systems whose components are elastic and can fail. This involves the bullet and target being composed of either a finite element grid or actual particles. In order to study material deformation and failure, we chose the latter scenario.

One significant challenge in simulating impact with systems composed of particles is that internal forces need to be communicated throughout the object when it deforms. In order to achieve such communication it is normally thought that a collision algorithm between the particles constituting the system is required which, in three dimensions is quite time consuming. There exists, however a two-dimensional (2D) Material Point Method (MPM) algorithm evaluated by Chan and Brannon [1] which allows modeling of elastic behavior and failure with no contact algorithm, as discussed later. The purpose of this work is to develop a three-dimensional (3D) MPM algorithm and to demonstrate its utility for impact simulations.

II. THE MATERIAL POINT METHOD

We began with the 2D Material Point Method (MPM) algorithm outlined and evaluated by Z. Chen and R. Brannon [1]. MPM is advantageous because it doesn't require a complex time consuming algorithm to simulate collisions or material failure. Instead, MPM maps the mass and momentum of groups of particles in the simulation to a background grid and utilizes the conservation equation of mass as well as conservation of momentum to ultimately advance the system through time. The use of the background grid also avoids entanglement associated with other contact – based algorithms.

To begin with, the initial conditions for the simulation include a collection of particles with initial positions $\{\vec{x}_p^{\,0}\}$, velocities $\{\vec{v}_p^{\,0}\}$ and boundary conditions chosen so as to reflect the important physics of the actual system as much as possible. Next, the background grid is defined, where computational space is separated into a defined number of grid cells in which nodes are placed in each corner of each cell. The mass M_p of each particle p at time t is