Preface

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Preface

The International Symposium on Nanoscience & Nanotechnology in Life Sciences 2017 (ISNNLS 2017) took place between 28-29 November 2017 at Hotel Santika Premiere, Surabaya, Indonesia. The symposium was organized by the Research Center for Quantum Engineering Design and Faculty of Science and Technology, Universitas Airlangga, Indonesia. ISNNLS 2017 was the fourth annual symposium that initiated and previously held by Research Center for Nanosciences and Nanotechnology (RCNN), Institut Teknologi Bandung, Indonesia.

In the last decade, nanotechnology has advanced, and nanoscale materials are used in everything from chemical catalyst to antibacterial agents. The scientific program of the symposium included many topics in the field of nanotechnology and its role in life sciences. The symposium presented keynote speakers from notable experts of nanoscience and nanotechnology, i.e., Kyle E. Cordova from University of California, USA, Prof. Yoshitada Morikawa from Osaka University, Japan, Prof. Heni Rachmawati from Institut Teknologi Bandung, Indonesia, Dr. Tommy Julianto Bustami Effendi from Universiti Teknologi MARA, Malaysia, and Mochamad Zakki Fahmi, Ph.D. from Universitas Airlangga, Indonesia. ISNNLS 2017 facilitated researchers, scientists, and engineers to exchange ideas and discuss progress in four main tracks, chapter of modeling, chapter of synthesis, chapter of treatment and chapter of supporting.

More than 100 participants took part in the symposium. We received 46 submissions to all main tracks. Papers were evaluated to the high standard. Two reviewers from Program Committee and additional reviewers were assigned to review each article. After the completion of the peer review process, 29 papers were selected for publication in the Journal of Physics: Conference Series (JPCS).

We would like to thank all authors, program committee members, reviewers, and fellow members of the symposium committee for their contribution to the symposium. We also greatly appreciated the publication support from Center for Journals Development and Scientific Publications, Universitas Airlangga, Indonesia.

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Abbreviation list for Institution

ITB	Institut Teknologi Bandung, Indonesia
UA	Universitas Airlangga, Indonesia
OU	Osaka University, Japan
UM	Universiti Malaya, Malaysia
UiTM	Universiti Teknologi Mara, Malaysia
ITATS	Institut Teknologi Adhi Tama Surabaya, Indonesia

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Numerical Simulation of Spear Motion as Game Items

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Numerical Simulation of Spear Motion as Game Items

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Abstract. Game development in 3D is mostly done by characters, items and the environment. Game items such as character weapons modeled in 3D will be the attraction of a game. In this paper, spear motion as a game items is modeled in 3D. Nonlinear Equations Six Degrees of Freedom (6 DOF) are used for mathematical models of spear motion. The parameters studied in the motion model are: geometry, mass and aerodynamics. Spear aerodynamic parameters were analyzed using the Datcom method. Numerical simulation of mathematical models of spear motion with variations in the initial velocity of the throw and the direction of the throw. From the results of numerical simulation, the maximum range R = 131.7 m at the initial velocity V_0 = 40 m/s, the direction of throw (angle θ_0 = 35 deg, angle φ_0 = 10 deg, ψ_0= 0 deg). And the maximum height H_{max} = 12.18 m is achieved at the initial velocity V_0= 20 m/s, direction of throw (angle θ_0 = 35 deg, angle φ_0 = 40 deg, angle ψ_0 = 0 deg).

Keywords: spear motion, 6 DOF, aerodynamics, numerical simulation, 3D

1. Introduction

Since the 2000s the development of games has been very rapid [1]. Starting from a simple game, it turns into a complex 2D to 3D. 3D games are preferred over 2D games. Even in the world of education, 3D educational games have a better level of effectiveness than 2D [2]. 3D game development is mostly done. Reconstruction 2D image display becomes 3D to improve game quality [3,4].

One of the game elements according to Rouse [5] is game items. Game items can be purchased, collected, used and manipulated in various ways by the player in carrying out his mission. For example, the type of weapon, the type of fighter begins with property and behavior that is simple to complex. One weapon item in the Reog Ponorogo game scenario especially level 2 [6] is a spear. Not only modeling the shape of the spear in 3D, the model of spear motion in 3D space makes the game more interesting because of its movements like real.

Modeling spear motion or such as spear has been done. The movement of spears in the air has been formulated by examining the elasticity of the spear and its dynamic motion [7]. The spear motion model that is modeled is still in 2D space, namely the x axis and z axis. Maryniak et al. [8] modeled javelin thrown in 2D space. The javelin movement model in 2D is also done using the 3 DOF equation [9]. The spear motion model as a game item in this paper is modeled in 3D by examining the parameters of geometry, mass and aerodynamics.

The aerodynamic parameters of a test object are very important in the field of aerodynamic application science [9]. Moniuszko et al. [10] and Maryniak et al. [8] have modeled the dynamic motion of objects

when in the air and performed aerodynamic tests. Research on the calculation and analysis of aerodynamic characteristics on flat plates and endwall areas was carried out using CFD [12]. CFD software has high accuracy in the calculation and analysis of aerodynamic characteristics, but takes a long time in the calculation process. The Datcom method is used to calculate and analyze the RX 250 LAPAN aerodynamic characteristics [12]. The accuracy of the Datcom method using Digital Datcom Software is lower than that of CFD but the time needed in the calculation process is faster and easier with accurate results. The spear aerodynamic characteristics in this paper were calculated using the Datcom method.
The spear motion model designed is numerically simulated as an analysis of mathematical spear motion. The simulation is carried out with variations in the spear throwing angle and the initial speed of the spear thrown so that the maximum range *R* and the maximum height of the spear *H* can be known. The spear motion model is then implemented in a 3D model in a game using the Unity game engine.

2. Reference frame and kinematics of spear motion

The coordinate system of spear $Ox_by_bz_b$ of the earth reference frame $Ox_hy_hz_h$ is ilustrated in figure 1. Relationship of kinematics between linear elements velocity V_x,V_y,V_z in the earth's reference frame system with linear elements velocity u,v,w in the spear coordinate system described in equation (1).Please follow these instructions as carefully as possible so all articles within a conference have the same style to the title page. This paragraph follows a section title so it should not be indented.

$$\begin{bmatrix} V_x \\ V_y \\ V_z \end{bmatrix} = \begin{bmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{bmatrix} = \begin{bmatrix} \cos\psi\cos\theta & \cos\psi\sin\theta\sin\varphi - \cos\varphi\cos\psi & \cos\psi\sin\theta\sin\varphi + \sin\varphi\cos\psi \\ \sin\psi\sin\theta & \sin\psi\sin\theta\sin\varphi - \sin\varphi\cos\psi & \sin\psi\sin\theta\cos\varphi - \sin\varphi\cos\psi \\ -\sin\theta & \sin\varphi\cos\theta & \cos\varphi\cos\theta \end{bmatrix} \begin{bmatrix} u \\ v \\ w \end{bmatrix}$$

$$\begin{bmatrix} V_x \\ V_y \\ V_z \end{bmatrix} = \begin{bmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{bmatrix} = C_b^h \begin{bmatrix} u \\ v \\ w \end{bmatrix} \quad (1)$$

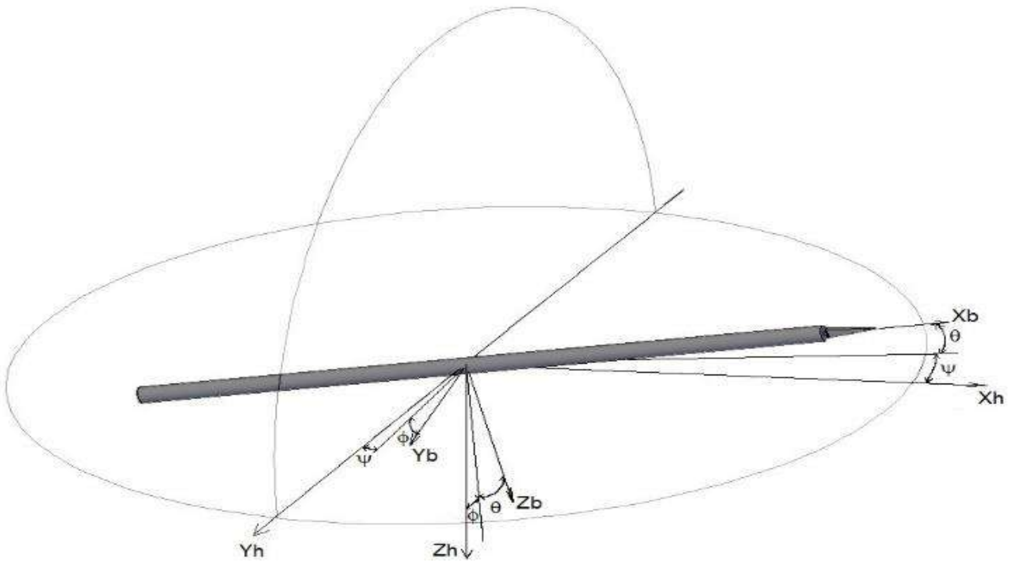

Figure 1. Spear coordinate system for the reference frame (earth coordinate system)

2.1. Wind Coordinate System

The axis of the wind coordinate system determines the direction of the lance's flight path while in the air. The wind coordinate system is shown in Figure 2. The positive x_w axis is the same as the spear speed vector. The spear translation speed in the wind coordinate system is transformed into the spear coordinate system according to equation *(2)*.

$$\begin{Bmatrix} u \\ v \\ w \end{Bmatrix} = \begin{Bmatrix} V\cos\alpha\cos\beta \\ V\sin\beta \\ V\sin\alpha\cos\beta \end{Bmatrix} \quad (2)$$

- $V = \sqrt{u^2 + v^2 + w^2}$ *(3)*
- Attack angle $\alpha = arctan\left(\frac{w}{u}\right)$ *(4)*
- Sideslip angle $\beta = arcsin\left(\frac{v}{V}\right)$ *(5)*

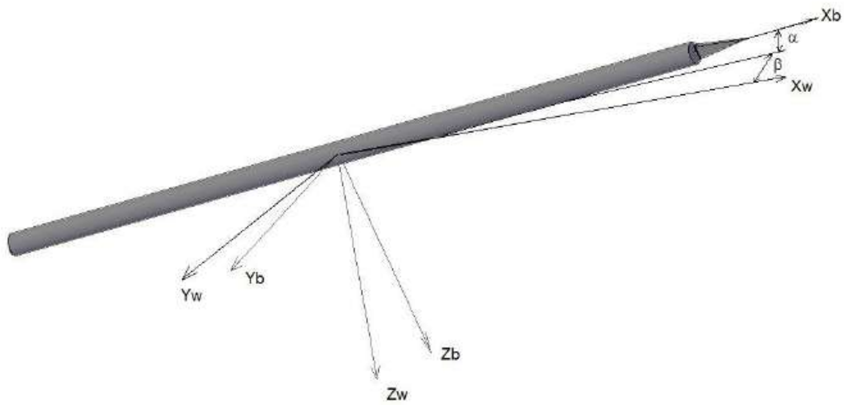

Figure 2. Relationship of wind coordinate system and spear coordinate system

3. Equation of Spear motion

This mathematical equation of spear motion is the equation of the six degrees of freedom (6 DOF). This equation is based on Newton's Second Law and was derived by Euler. Equation The Newton equation follow equation (6) and (7).

$$\sum \Delta F = \frac{d(mV)}{dt} = m\left(\frac{dV_b}{dt} + \omega_b \times V_b\right) + \dot{m}V_b \quad (6)$$

$$\sum \Delta M = I\dot{\omega}_b + \omega_b \times (I\omega_b) + \dot{I}\omega_b \quad (7)$$

$\sum \Delta F = [F_x \quad F_y \quad F_z]^T$ is the total force vector on the spear coordinate system, $V_b = [u \quad v \quad w]^T$ is vector of velocity on the spear coordinate system and $\omega_b = [p \quad q \quad r]^T$ is vector of angular velocity from a spear. $\sum \Delta M = [M_x \quad M_y \quad M_z]^T$ is vector of the total force moment in the spear coordinate system and *I* is the inertial tensor. The spear mass is fixed, so that $\dot{m} = 0$. Equation (6) is described as equation (8) and equation (7) is described as equation (9). Equation (8) is the equation of translational motion and equation (9) is an equation of rotational motion.

$$\dot{u} = \frac{F_{ax} + F_{gx}}{m} - qw + rv$$

$$\dot{v} = \frac{F_{ax} + F_{gx}}{m} - pw + ru$$

$$\dot{w} = \frac{F_{ay} + F_{gy}}{m} - pv + qu$$

(8)

$$\dot{p} = \frac{M_x I_{zz}}{\Delta} - \frac{[I_{zz}(I_{zz} - I_{yy}]qr}{\Delta}$$

$$\dot{q} = \frac{M_{yy}}{I_{yy}} - \frac{(I_{zz} - I_{xx})pr}{I_{yy}}$$

$$\dot{r} = \frac{M_z I_{xx}}{\Delta} - \frac{[I_{xx}(I_{xx} - I_{yy})]}{\Delta}$$

(9)

Gravitational force on the spear coordinate system:

$$\begin{bmatrix} F_{gx} \\ F_{gy} \\ F_{gz} \end{bmatrix} = C_b^{\square} \begin{bmatrix} 0 \\ 0 \\ mg \end{bmatrix}$$

(10)

Aerodynamics forces:

$$F_{ax} = \frac{1}{2}\rho l d V^2 (C_x + C_{xq} q)$$
$$F_{ay} = \frac{1}{2}\rho l d V^2 (C_y + C_{yb} \beta)$$
$$F_{az} = \frac{1}{2}\rho l d V^2 (C_z + C_{zq} q)$$

(11)

And aerodynamics moment is follow equation [14]

$$M_x = \frac{1}{2}\rho S V^2 l C_l$$
$$M_y = \frac{1}{2}\rho S V^2 c (C_m + C_{mq} q)$$
$$M_z = \frac{1}{2}\rho S V^2 l C_n$$

(12)

ρ : air density
l : length of the spear
d : maximum spear diameter
V : spear velocity
c : spear diameter
$\Delta = I_{xx}.I_{yy}.I_{zz}$
I_{xx}, I_{yy}, I_{zz} : inertial tensor
C_x, C_y, C_z : aerodynamic coefficient on the spear coordinate system
C_{xq}, C_{Yb}, C_{zq} : aerodynamic coefficients obtained from the calculation of the datcom method
C_l, C_m, C_n : rolling moment, pitching momen and yawing moment

4. Calculation of Spear Aerodynamic Parameters

The calculation of the spear aerodynamic parameter is obtained from Digital Datcom results by entering the geometry of spear. In addition to calculating aerodynamic parameters. spear mass geometry is needed to determine the center of mass and the moment of spear inertia. The location of the spear mass center is determined by the equation *(13)*

$$x_c = \frac{\sum_{i=1}^{3} m_i x_i}{\sum_{i=1}^{3} m_i}; \quad y_c = \frac{\sum_{i=1}^{3} m_i y_i}{\sum_{i=1}^{3} m_i}; \quad z_c = \frac{\sum_{i=1}^{3} m_i z_i}{\sum_{i=1}^{3} m_i}$$

(13)

The inertia moment of spear :

$$I_{xx} = \sum_{i=1}^{3} m_i(y_i^2 + z_i^2) \qquad J_{xy} = J_{yx} = \sum_{i=1}^{3} m_i x_i y_i$$

$$I_{yy} = \sum_{i=1}^{3} m_i(x_i^2 + z_i^2) \qquad J_{xz} = J_{zx} = \sum_{i=1}^{3} m_i x_i z_i$$

$$I_{zz} = \sum_{i=1}^{3} m_i(x_i^2 + y_i^2) \qquad J_{zy} = J_{yz} = \sum_{i=1}^{3} m_i z_i y_i$$

(14)

Spear material is iron, and spear wood material is areca nut. The shape of the spear follows the size of the spear in Table.1

Table 1. Spear Geometry[1]

Spear geometry	
Spear total length	330 cm
Head spear length	21 cm
length of the transition section	7 cm
the length of the wooden spear	302 cm
diameter of wood spear	4 cm
thick head spear	23 mm
maximum spear width	5 cm
total spear mass	4,55 kg
head spear mass	644 g
mass of the spear transition section	170 g
spear mass center (measured from head spear)	149.87 cm

From the Datcom calculation the coefficient value is obtained C_{xq}, C_{Yb}, C_{zq} ,C_l ,C_m ,C_n, C_D, C_L used in the equation *(11)* and *(12)*. C_D, C_L used to determine the value of the aerodynamic coefficient on the spear coordinate system with the equation *(15)*.

$$\begin{Bmatrix} C_x \\ C_y \\ C_z \end{Bmatrix} = \begin{Bmatrix} C_L \sin\alpha - C_D \cos\alpha\cos\beta \\ -C_D \sin\beta \\ -C_D \sin\alpha\cos\beta - C_L \cos\alpha \end{Bmatrix}$$

(15)

5. Numerical Simulation of Spear Motion

The numerical solution of equations *(8)* and *(9)* with Euler integration are described equations (*16)* and *(17)*.

$$u(t) = u_0 + \int_{t_0}^{t} \dot{u}\, dt$$

$$v(t) = v_0 + \int_{t_0}^{t} \dot{v}\, dt$$

$$w(t) = w_0 + \int_{t_0}^{t} \dot{w}\, dt$$

(16)

[1] The Results of interviews with Batoro Katong Heritage Guard

$$p(t) = p_0 + \int_{t_0}^{t} \dot{p}\, dt$$
$$q(t) = q_0 + \int_{t_0}^{t} \dot{q}\, dt$$
$$r(t) = r_0 + \int_{t_0}^{t} \dot{r}\, dt$$

(17)

Initial value p_0,q_0,r_0 at t = 0 is zero, also the initial value α and β is zero. Initial value u_0,v_0, w_0 at t =0 according to the eq. *(2)*

$$\begin{Bmatrix} u_0 \\ v_0 \\ w_0 \end{Bmatrix} = \begin{Bmatrix} V_0 \cos\alpha \cos\beta \\ V_0 \sin\beta \\ V_0 \sin\alpha \cos\beta \end{Bmatrix}$$

(18)

V_0 is initial throw speed. From the results of numerical solutions, equations *(16)* and *(17)*, the value of V_x, V_y, V_z is obtained. Numerical solutions of eq. *(1)* is:

$$X(t) = X_0 + \int_{t_0}^{t} V_x dt$$
$$Y(t) = Y_0 + \int_{t_0}^{t} V_y dt$$
$$Z(t) = Z_0 + \int_{t_0}^{t} V_z dt$$

(19)

$X_0 = 0, Y_0 = 0, Z_0$ =1,8. Nilai Z_0 =1,8 is obtained from the average height of the person plus the length of the arm.

Figures 3,4,5 is a graph of the spear aerodynamic coefficient on the angle of attack at various Mach values. The value of C_D in figure 3 tends to decrease for the increase in Mach numbers. Minimum value of C_D at the angle of attack α = 0 deg. The C_L value shown in Figure 4 tends not to change for the increase in Mach numbers. This is because the range of Mach numbers taken is not too significant. Taking Mach number is based on the presence of spears. The value of C_m shown in figure 5 does not change for various Mach values. The value of Cm is negative in the range of -7 deg < α < 0 deg and α > 7 deg indicating that the attack angle is the state of the spear in a static stable state according to longitudinal static stability.

Figures 6 and 7 are the results of several experimental examples. Figure 6 is one of the results of the study by throwing the direction of direction φ_0 at the initial velocity V_0 = 20 m/s, θ_0 =35 deg, ψ_0 =0. These results indicate that the greater angle φ_0 causes the H_{max} value be higher. The value of φ_0 also affects the range (flight distance) value R. Increasing value of φ_0, the value of R also increases. Exceptions at φ_0 > 30 deg, the range gets smaller even though the H_{max} is greater. This shows that φ_0 = 30 deg is φ_0 optimum for flight distance R of spear. Figure 7 is a simulation result with variations in initial velocity V_0 at θ_0 =35 deg, φ_0 = 10 deg, ψ_0 = 0 deg. The results show that the initial velocity affects the magnitude of the R.

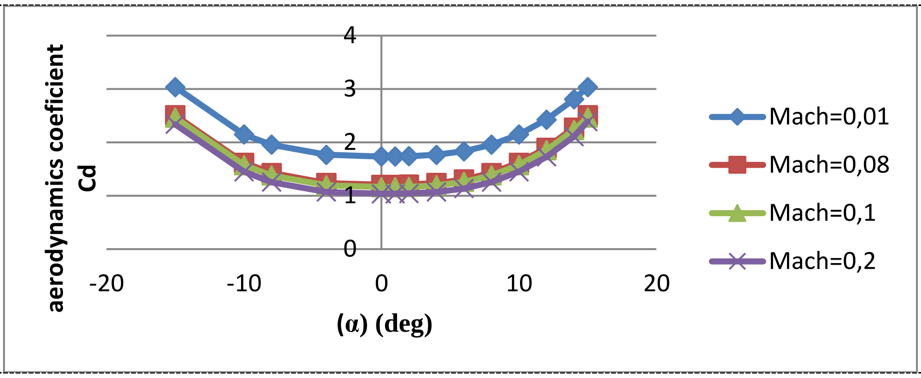

Figure 3. C_D graph of angle of attack for various Mach numbers

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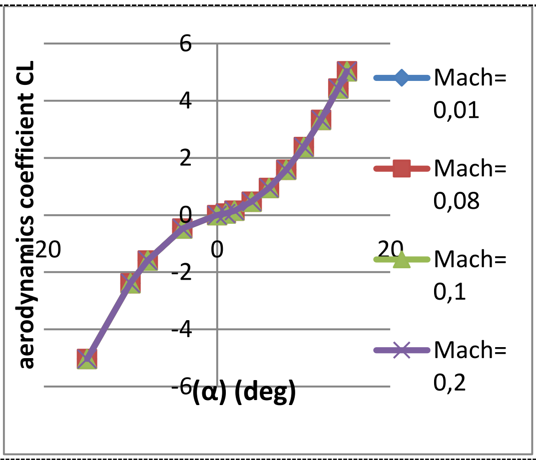

Figure 4. C_L graph of angle of attack for various Mach numbers

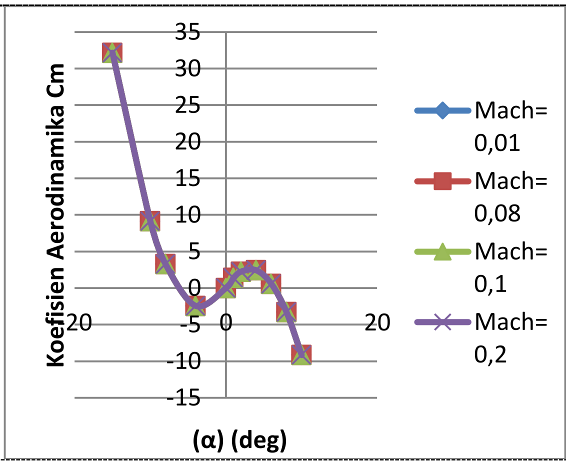

Figure 5. C_m graph of angle of attack for various Mach numbers.

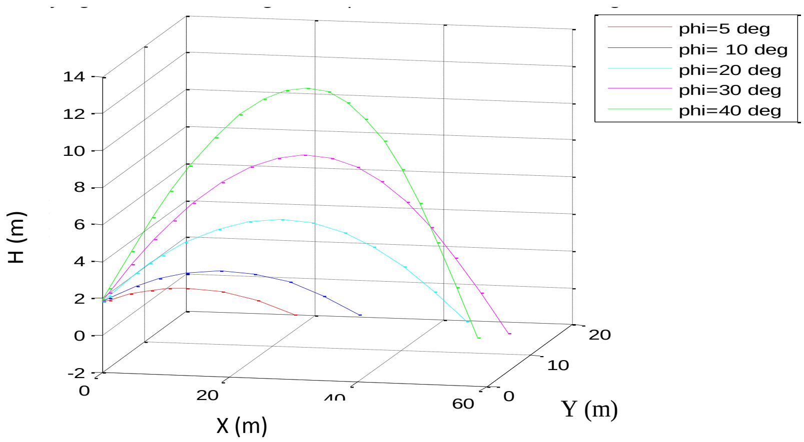

Figure 6. The simulation results of spear with variations in angle φ_0 at the initial velocity 20 m/s, the angle θ_0 35 deg, and the angle ψ_0 = 0 deg

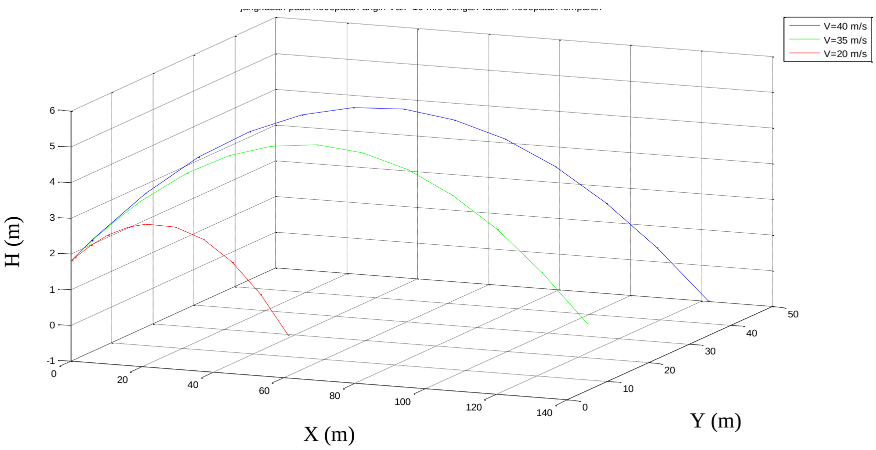

Figure 7. The simulation results of spear with variations in the initial velocity at the angle θ_0 35 deg, the angle ψ_0 = 0 deg and the angle φ_0 = 10 deg

6. Conclusion

The equation of spear motion using 6 DOF can be implemented in spear motion as a game item. The equation of motion used in 3D games with the amount of input entered is the spear mass, the inertia moment of spear, the initial velocity of the throw, the direction of the throw and the output is the position of spear X, Y, Z after being thrown.

The numerical simulation results of the equations of spear motion show the H_{max} of 12.18 m obtained at the initial velocity V_0 = 20 m/s, the direction of throw θ_0 =35 deg, φ_0 = 40 deg, ψ_0 = 0 deg and the maximum range R_{max} is 131.7 m at the initial velocity V_0 = 40 m/s and the throw direction θ_0 =35 deg, φ_0 = 10 deg, ψ_0 = 0 deg

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