Abstract - There is a number of researches on detecting falling human which is no doubt that those researches are very helpful for saving human’s life from falling down accidentally. The results from the researches are not only benefit to medical field, but also profit to robotic field. From the decade of fast development on robot, it can be seen that various types of robot have been produced, from low to hi-technology. From that amount, there is plenty of them that were made by imitated human body and postures. That type of robot called Humanoid, the robot that looks similar to human being. The number of Humanoid robot is increasing significantly due to the fast development on technology over the last few decades. Not only in the human size, there has been trying to build much bigger size humanoid robots which mostly to fulfil people’s dream from cartoon or sci-fi movies. For example, 18 meters walking robot from Gundam Global Challenge. Everyone knows the idiom “the bigger they are, the harder they fall” which is from the true common physical principle, from the reason, bigger size robot will cause more damage than smaller size when fallen down. These are the reasons for this research to investigate on equations, postures and activity patterns that suit to fall detection for big size robot which will make all the big size robot in the near future to be more security when the fallen down.

Keywords - Fall Detection, Big Size Robot, Acceleration, Fall Equation

I. INTRODUCTION

There has been trying to make a two-legged walking robots since around 1970 [1]. In the same decade R. McGhee made the first computer-controlled walking robot, it was later developed to be a stable running robot by M. Raibert who launched LagLab at MIT [1]. In 1990s, McGeer applied his concept on natural cyclic behaviour which was later called passive dynamic [1].

After 2000, from the rapid technology development and industrial breakthroughs, humanoids have been developed in this epoch significantly [1]. The first true humanoid from this era was exhibited by Honda in 1996, it was named P2. The most popular real humanoid robot nowadays is ASIMO, an acronym for Advanced Step in Innovation Mobility [2]. ASIMO has ability to walk and run on its two feet at the max speed of 6 kilometres per hour [2]. ASIMO is the first robot that has predicted movement control system which make it walk similarly to human [3]. Even it came with high technology for walking in that time, ASIMO once fell down in 2006 when it tried to to clime stairs in a presentation in Tokyo [4].
From the fall of the ASIMO in 2009, it shown that even high technology with tons of
digital sensors can be fallen down. It was an
only accident for people’s chitchat from the
human size as ASIMO, however, the result
will be different when it comes with bigger
size robots. The fall of bigger robots may
cause to fatal accidents. From the concern, this
research aim to find how to detect fall from
big size robot by finding what equation and
activity patterns that are suitable to detect big
size robots when fall down accidentally, in
order to prevent loss to humans and properties.

II. METHOD

A. Legged Robot
There are two main concepts on making the
moving robot, Leg and Wheel. The legged
robots have been designed from natural
terrestrial creatures, while the wheeled robots
have been virtualised from human-made
vehicles. The advantages of using wheel(s) to
move are much easier to construct and control.
Economically, it normally cheaper than legged
robots. While the legged robots have
counterpart on transversability, they also have
ability to avoid damage from ground banes, to
control their stability, and consume less energy
(and more efficiency) [14].

B. Two Legged Robot
Two legged robot have been the type of
robot that was financially invested for develop
the most at all times. Humanoid was in the
robot field since the beginning. Even they look
different, legged robots has been developed
from wheeled robots from the concept of
wheel and spokes. Knee joints was later
developed for allowing one leg to bend and
swing while the other is straight. Ankle joint
was added afterwards for more energy
efficiently [15].

From the concepts above, the robots are not
only able to walk, but also able to run. The
first robot that could achieve the running
ability was RunBot, the robot developed in
Germany and Scotland. It could run and the
speed of 3.5 steps per second in 2006 [16].

The most successful robot at present is
ASIMO from Honda, it is a humanoid that has
the ability to climb stairs, adjust walking speed
by itself, and run at four miles per hour. With
iWalk technology from Honda, the robot can
control its stability (maintain its balance)
smoothly while walking and running [17].

C. Stable Walking Steps Technique
Human can balance his body by moving
body weight in different directions naturally
when standing and moving. If the balance
technique is not able to prevent from fall
down, human will move his left or right foot to
the new spot. This fall-defence mechanism
was adapted to use with robot, especially in
humanoid.

D. ZMP (Zero Moment Point)
When robot move it foot forward for walk,
there are inertia which is the resistance of
physical object to any change in its stage of
motion such as speed and direction [7], and
Gravity which is a natural phenomenon by
which all things with every are brought
toward, in this research we focused on earth’s
gravity.

Equation from Theory of Gravitation
(Universe Today)

\[ F = G \frac{m_1 m_2}{r^2} \]

From the intersection within vertical ground
inertias, the moment number at this stage is
zero, the position called Zero Moment Point
(ZMP). The point is the place that has the
reaction which is called reaction at base. When
robot fell down, the theory describes that is
because it balance was out of ZMP [8, 9, 10].
ZMP is a concept related with dynamics and control of legged locomotion, the concept has been widely applied with humanoid robot. In robot, ZMP focuses on the dynamic reaction force at the contact of robot’s foot with the ground does not produce any moment in the horizontal direction which is the point where the total of horizontal inertia and gravity forces equals zero, the concept assumes the contact area is planar and has sufficiently high friction to keep the feet from sliding [11].

ZMP concept was introduced in 1968 by Miomir Vukobratovic at The Third All-Union Congress of Theoretical and Applied Mechanics in Moscow. The word “ZMP” has been well known since 1970 from the papers on them [11]. ZMP became important to biped robot for its motion planning because it have two points of contact with the ground, the plan is for dynamical stability of its whole body [11].

E. ZMP Analysis for Stability
From the concept of ZMP, analysis on mechanical structure of biped robot was conducted by using mathematic simulation for showing ZMP point from each stage which shown below.

1) Balancing State

2) Walking Stage

The stage when the both feet carrying all the body weight and The stage when it has the momentum (the force to move forward)

F. Acceleration of Gravity
The concept was found from Galileo Galilei (1951 - 1642) from let the balls down from the high floor to the ground. From the experiment, he discovered the theory that objects of any weight fell toward the earth at the same rate, it is the uniform of acceleration [12]. The number of acceleration of gravity is 9.81 m/s² at the surface of the earth, this means downward velocity from any object without the factor of air assistance force increase 9.81 meters every second invariably [13].

From the acceleration of gravity theory, this can be adapted with any concept on acceleration from gravity.

G. Fall Equation for Big Size Robot
Fall detection is commonly expected to embedded at waist of a robot, inside a traditional fall sensor is from compose of 3 AXIS Accelerometer, Micro-controller and Wireless Transmitter. It works by sending data from Accelerometer to micro-controller for evaluation. If the result of “g” is more than threshold, or about 2 g, the micro-controller will send its wireless signal to receiver node.

The test on accelerometer for fall detection, applied 3 AXIS accelerometer for X, Y and Z axes for each direction, the range for acceleration is +/- 2g. The sensor was
connected to micro-controller for sending data for calculation. Each axis is from -127 to 127 range, with +/- 2g range with is 2g because the + and - range are equal and the data was set between 0 -127 range, which the result of the 0-2 step size shown below:

\[
x = \frac{g}{\text{length}}
\]
\[
x = \frac{2}{128} = 0.0156
\]

The g number and the acceleration number can be calculated after received data from the 3 Axises Accelerometer for X, Y, and Z Axises. The result was below:

\[
g = \sqrt{(\frac{g}{2})^2 + (\frac{g}{2})^2 + (\frac{g}{2})^2}
\]
\[
g = \frac{\sqrt{3}g}{2}
\]

If \( 1g = 9.81 \text{ m/s}^2 \), a will set to the unit of m/s2. From that \( A = 9.81 \times g \)

\[
A = 9.81 \times g
\]

III. RESULTS

To examine the 3 Axises Accelerometer, the number of g and acceleration were found from the sensor. After that the test for falling was conducted as shown below:

Fig 3. The Graph of Acceleration Numbers Detected from the First Fell Test

Fig 4. The Graph of Acceleration Numbers Detected from the Second Fell Test

Fig 5. The Graph of Acceleration Numbers Detected from the Third Fell Test

Fig 6. The Graph of Acceleration Numbers Detected from the Forth Fell Test

Fig 7. The Graph of Acceleration Numbers Detected from the Fifth Fell Test
From the table above, the 5 times test, average number is 2.09949 which can be set as the threshold range. If found that g number from sensor is higher than the setting threshold number, the system will send the warning data to receiver node.

![Diagram of Warning Data to Receiver Node](image)

**Fig 8. Diagram of Warning Data to Receiver Node**

### IV. CONCLUSION

From this research, the threshold range was found at 2.09949 which is the appropriate number of sensor for fall detection. From the acceleration of gravity theory which objects of any weight fell toward the earth at the same rate, this means that the concept, equation and result from this research can be adapted to fall detection of any size of robot because the idea is based on acceleration detection which is a fixed number to any size of objects.

### REFERENCES

(Arranged in the order of citation in the same fashion as the case of Footnotes.)


[8] [http://www.bs.ac.th/lab2000/physicweb/bal.htm].


