Spring Loaded Inverted Pendulum Single Legged Hopping Robot

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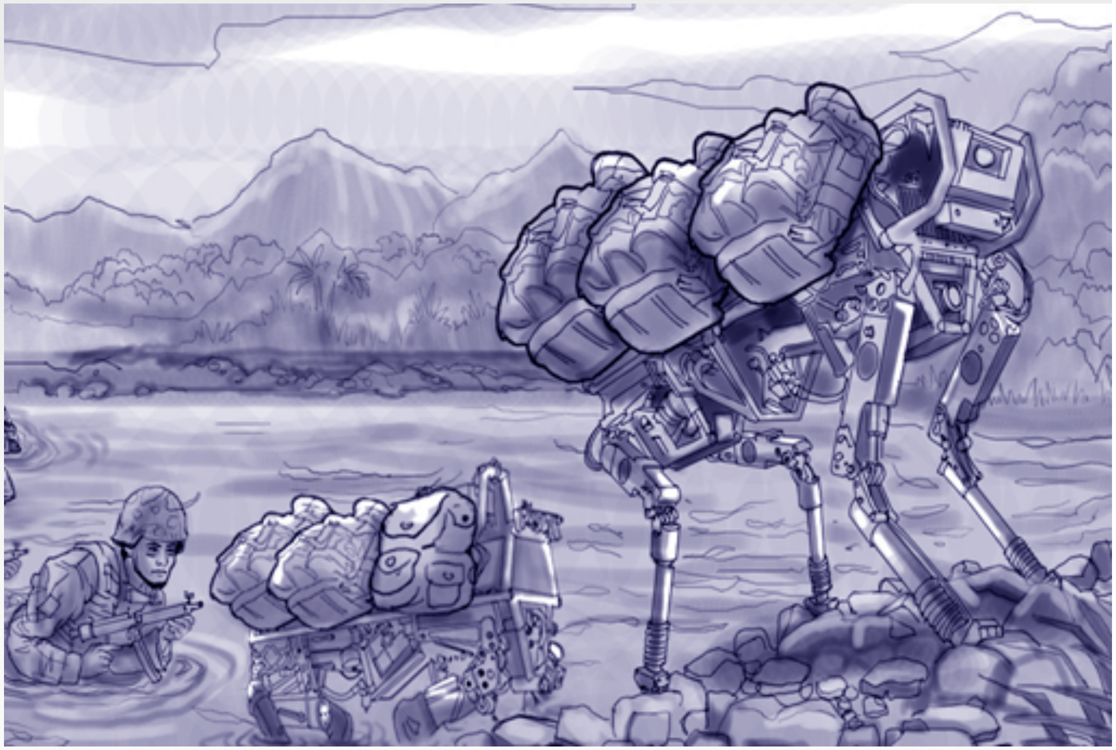
robotics.ece.ucsb.edu

A New Generation of Robots

M3 Program(DARPA)

- Maximum Mobility & Manipulation
- Creation & Enhancement
- Jointed & Legged bots
- Natural Environments
  - ➢ **Focus on Rough Terrain**



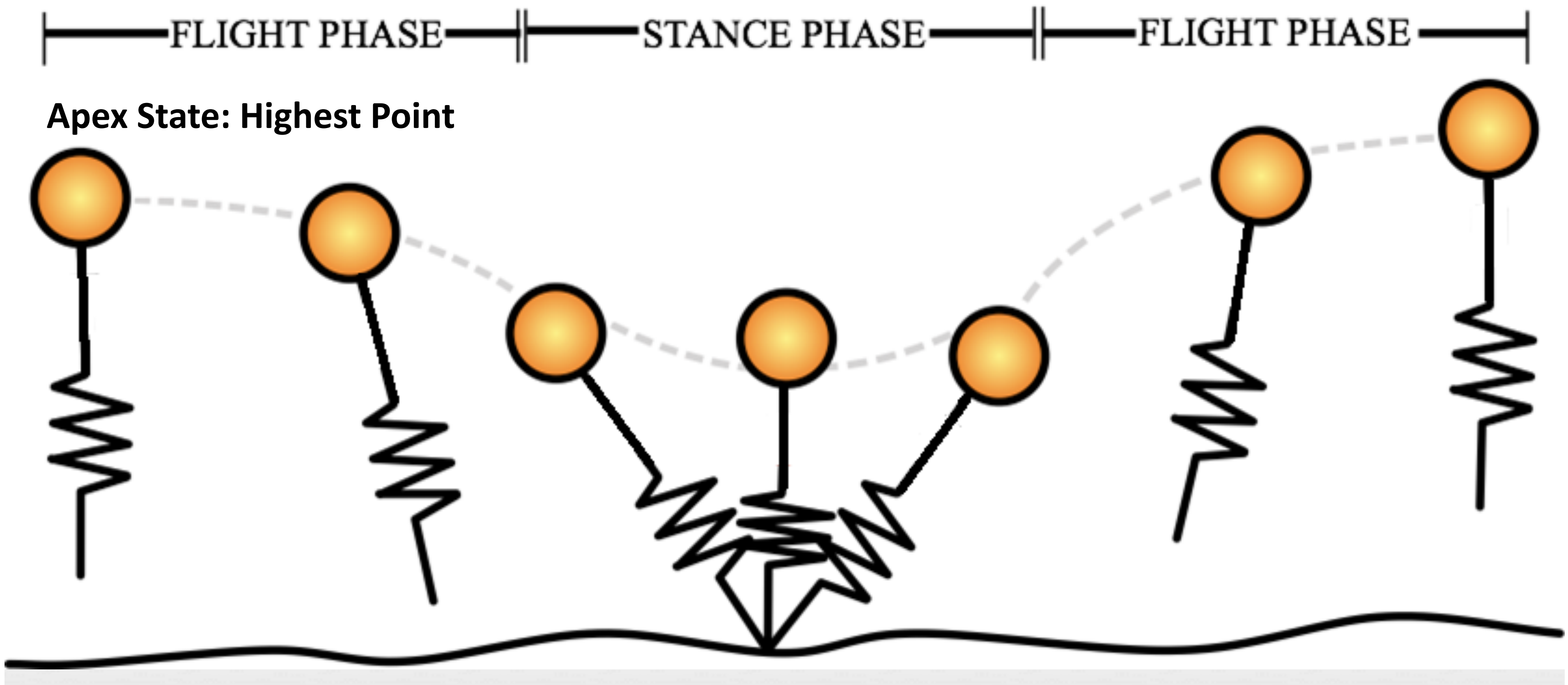
(Image from http://www.bostondynamics.com/)

Unmanned Military Operations

- Transportation of Supplies & Equipment
- Evacuation of Injured personnel
- Exploration of remote and hazardous areas
- Search and rescue
- Advanced Scouting

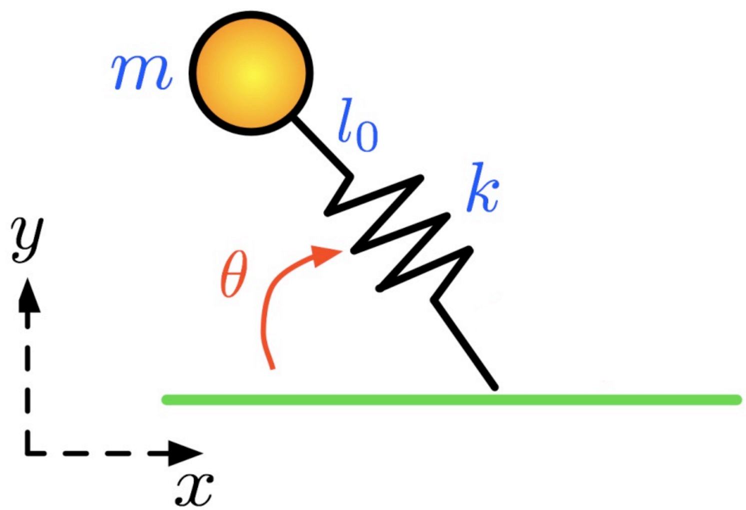
Spring-Loaded Inverted Pendulum(SLIP) Model

Goal: To simulate a real & successful trajectory on rough terrain of the model using Matlab.



Defining the SLIP Model Equations

$X = [x, y, \dot{x}, \dot{y}]$



Fixed Variables

m=1 kg

L0= 1 m

k= 106 N/m

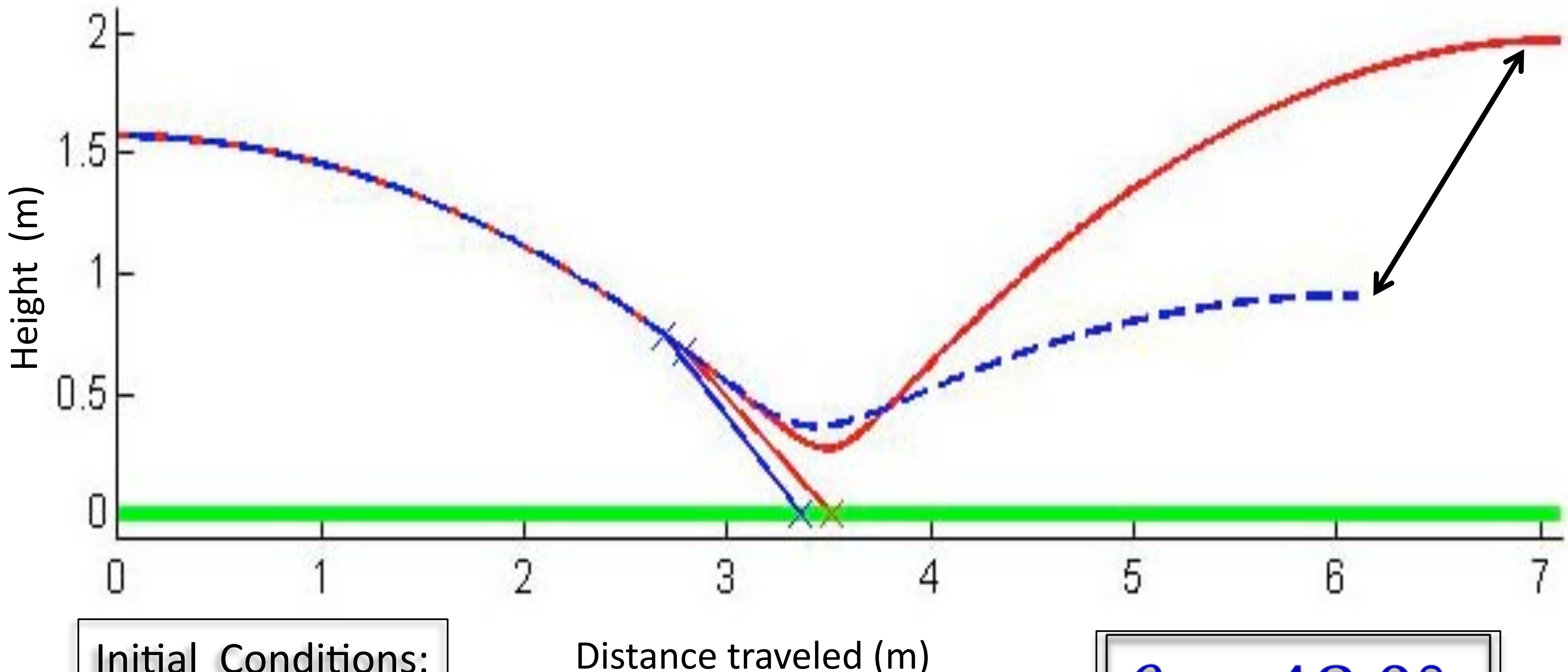
Vary (dx, y)

Equations of motion

Flight Phase: Ballistic Trajectory

Stance Phase: $\ddot{l}\ ,\ \ddot{\theta}$ → Matlab ODE45 → $l(t),\ \theta(t)$

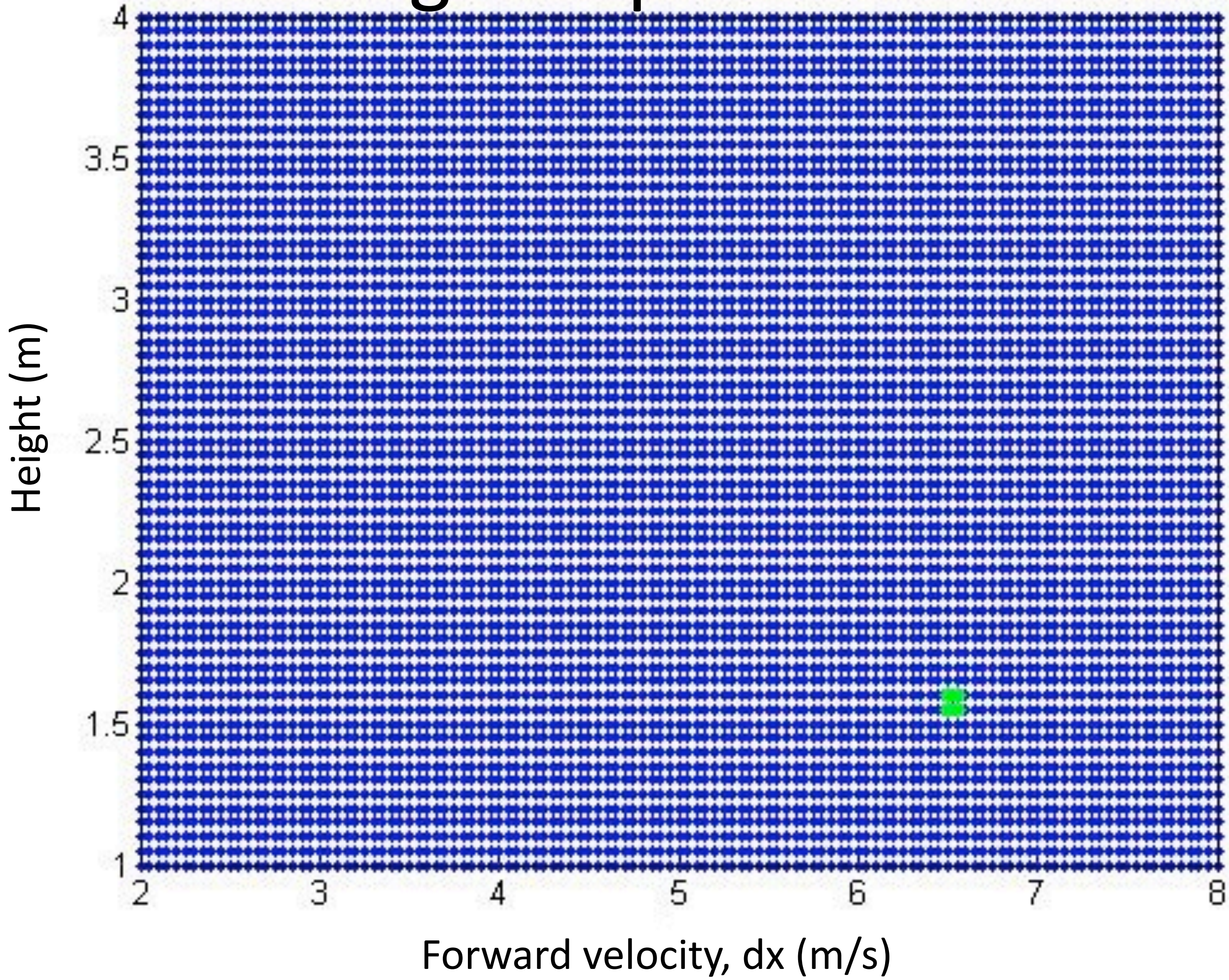
We must control the angle θ at which the leg touches the ground



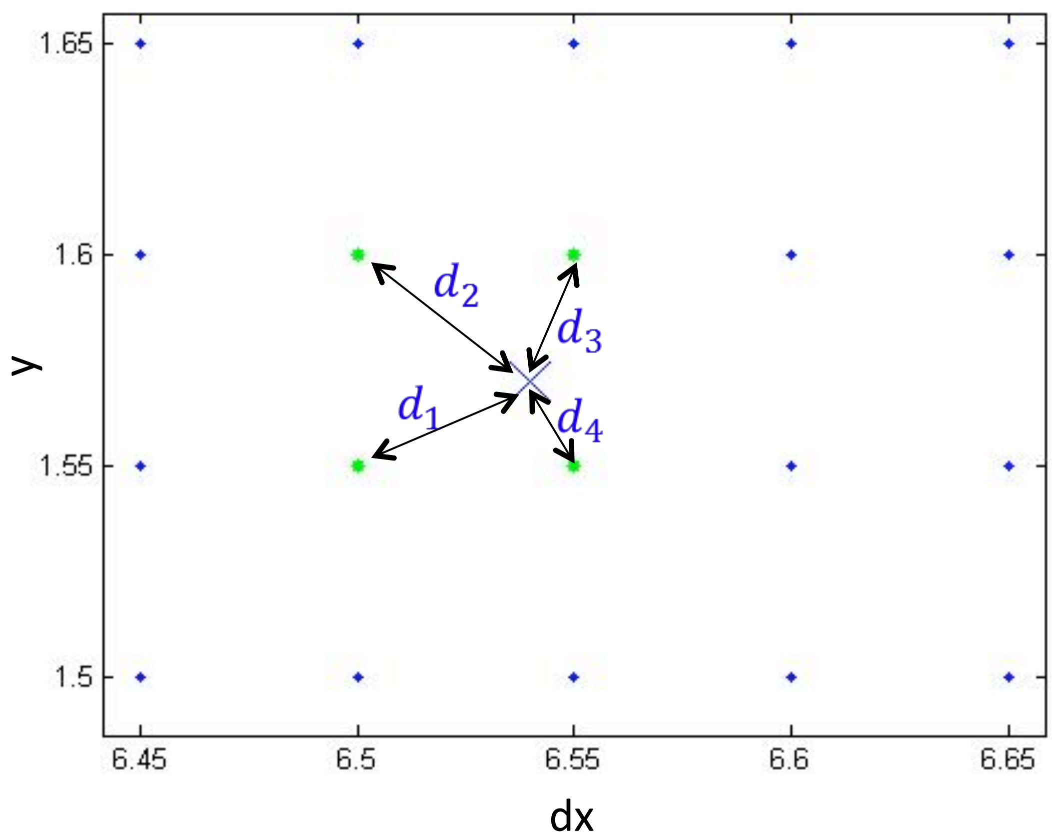
Initial Conditions:
x = 0
y = 1.57 m
dx = 6.57 m/s

$\theta = 48.0°$
$\theta = 43.0°$

For each set of points (dx, y), we know the degree span we can use



Locating point on known grid



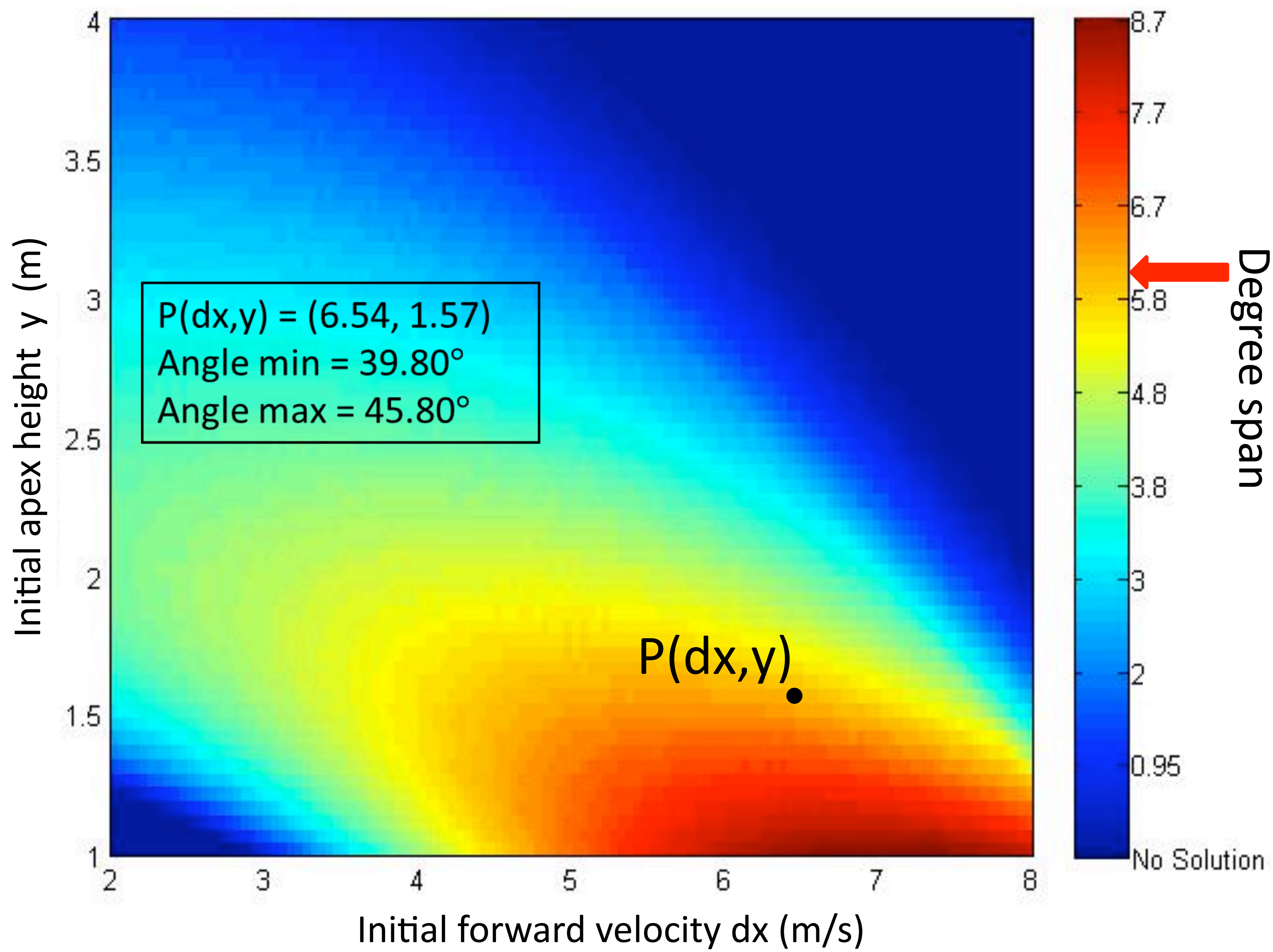
- **Locate random point** between 4 known points for which we know the angle range for (.05 intervals)
- **Obtain a weighted average** in order to predict an angle range

$$W_{avg} = \sum_{i}^{4} W_i d_i$$

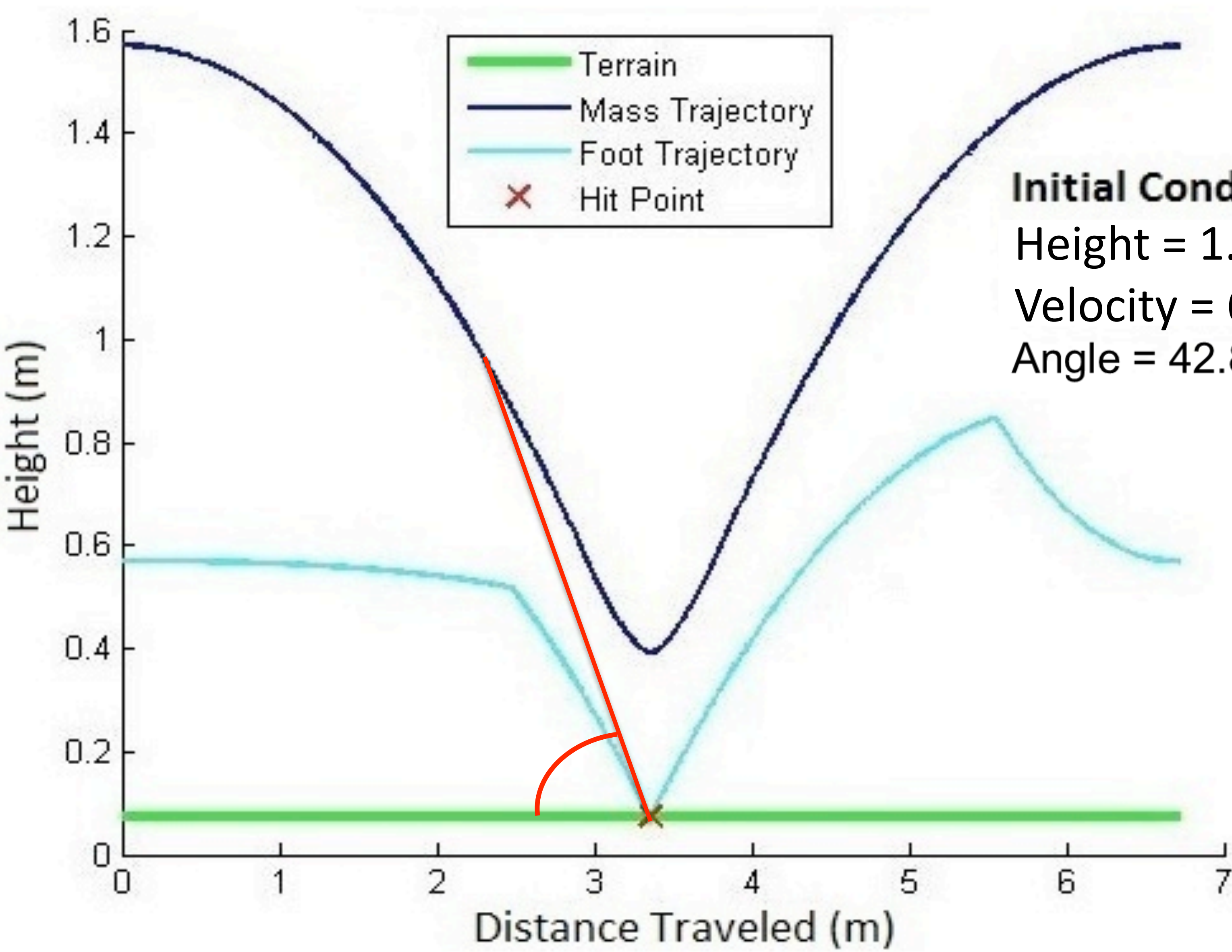
- **Choose the middle point** of the range in order to have an angle that will allow a successful jump.

P(dx,y) = (6.54, 1.57) → Angle Range = 39.80°– 45.80° → Angle Chosen = 42.80°

Angle span with respect to an initial height and velocity



Successful Jump



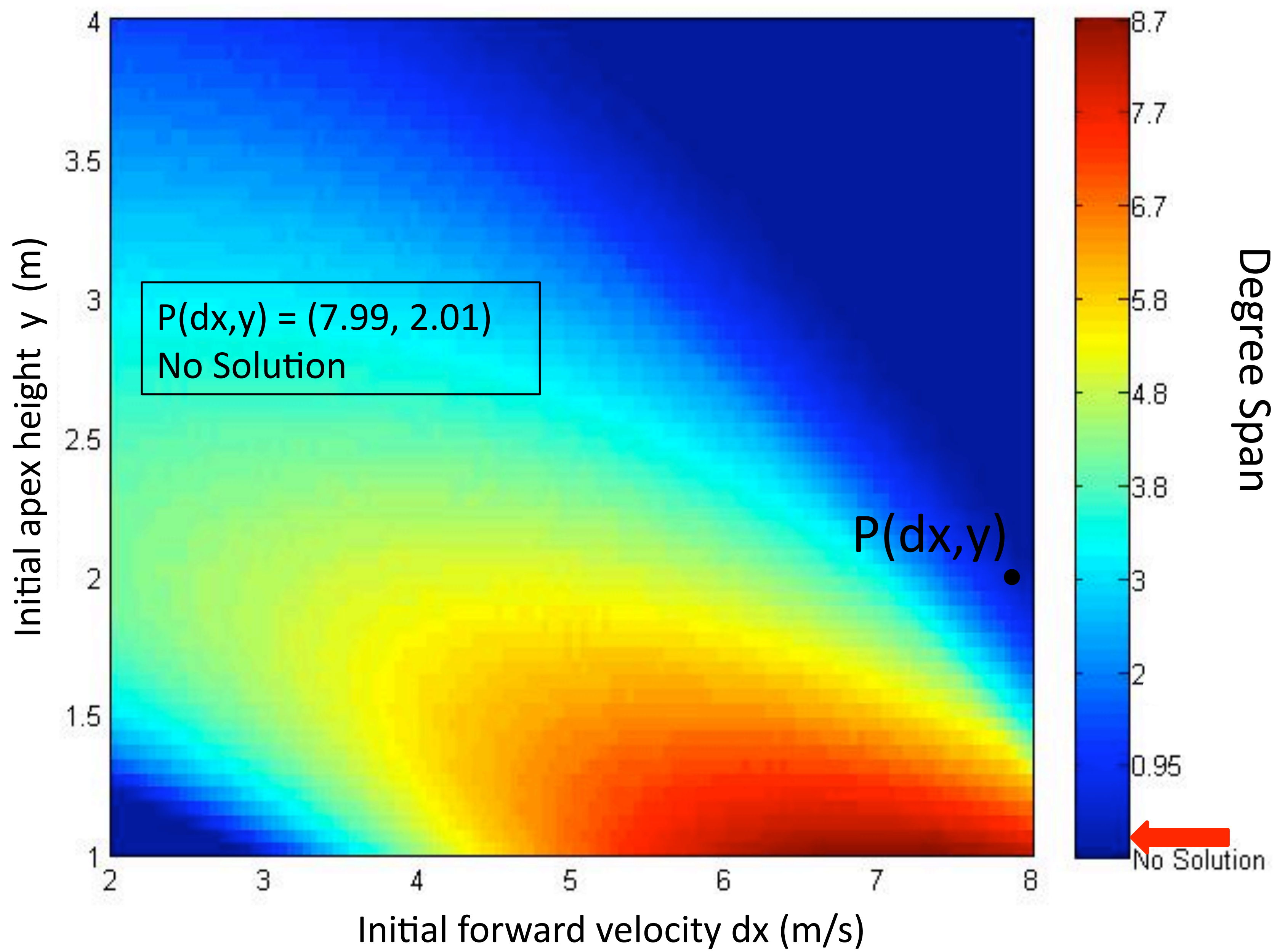
Initial Conditions:

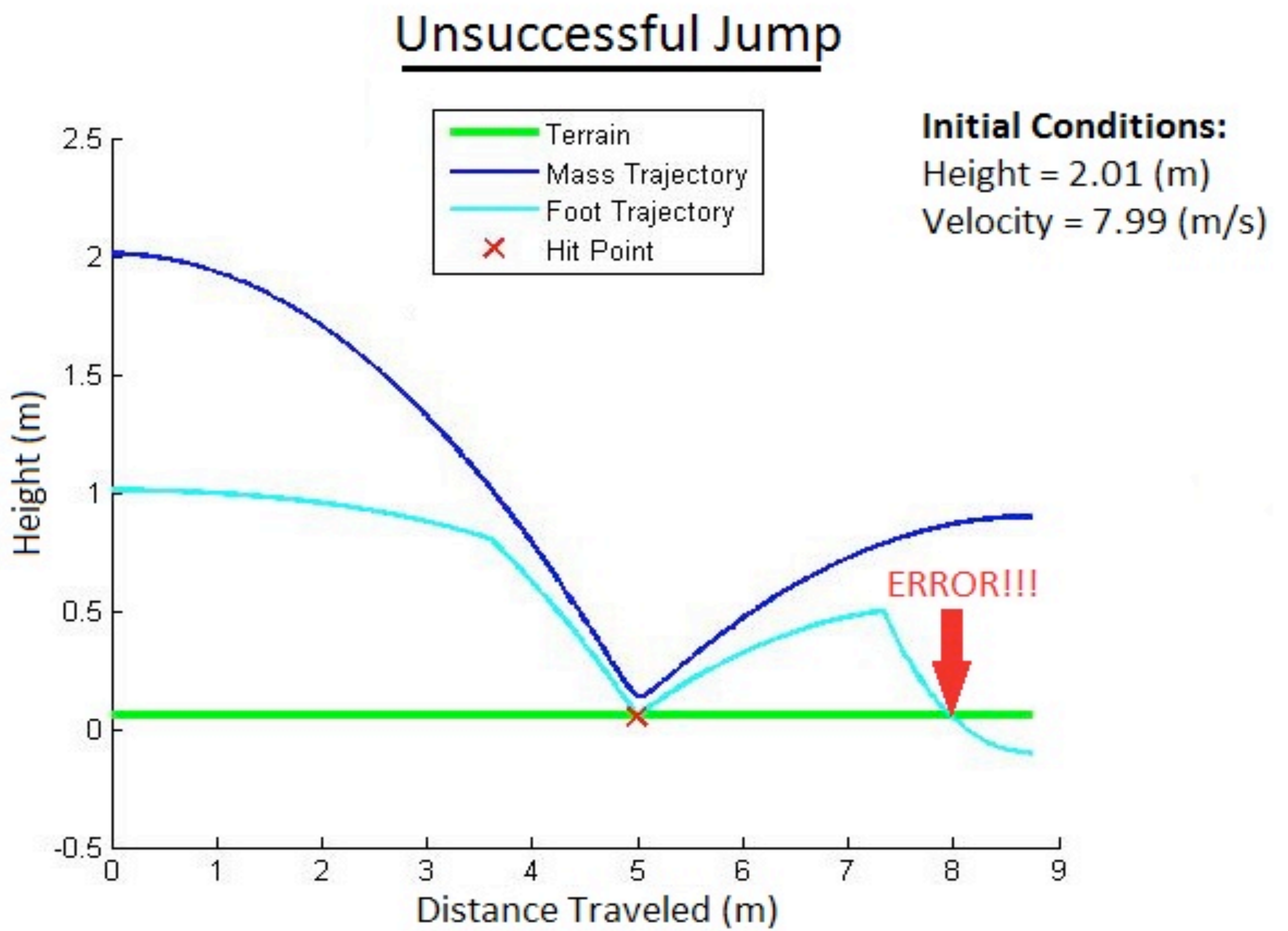
Height = 1.57 (m)

Velocity = 6.54 (m/s)

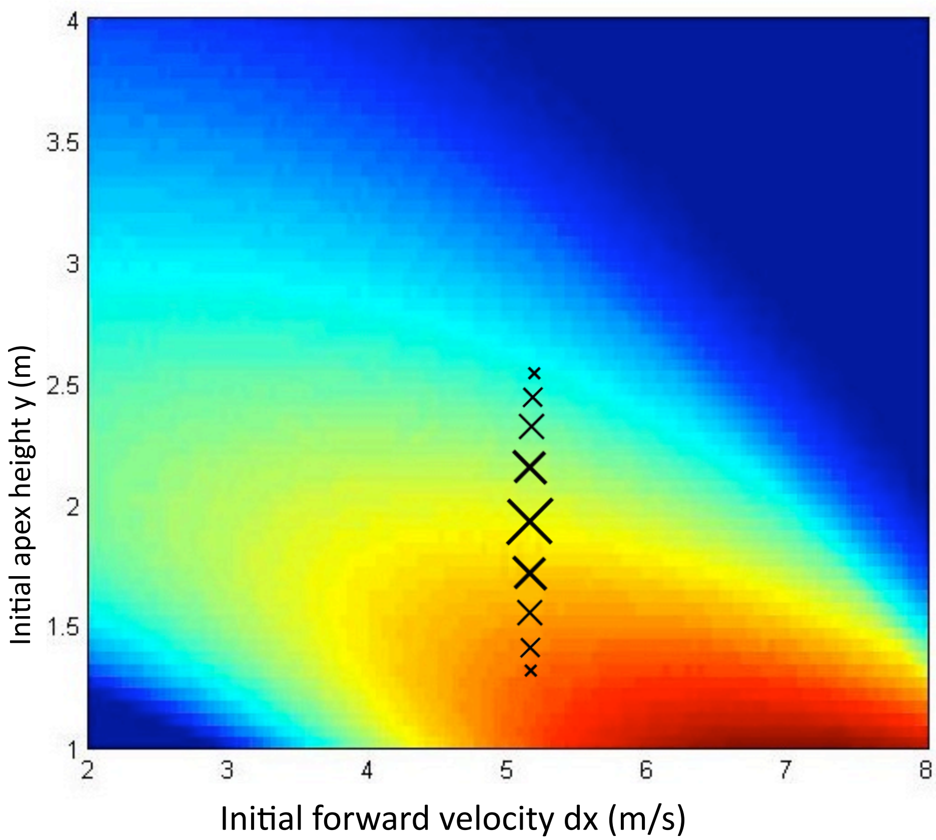
Angle = 42.80°

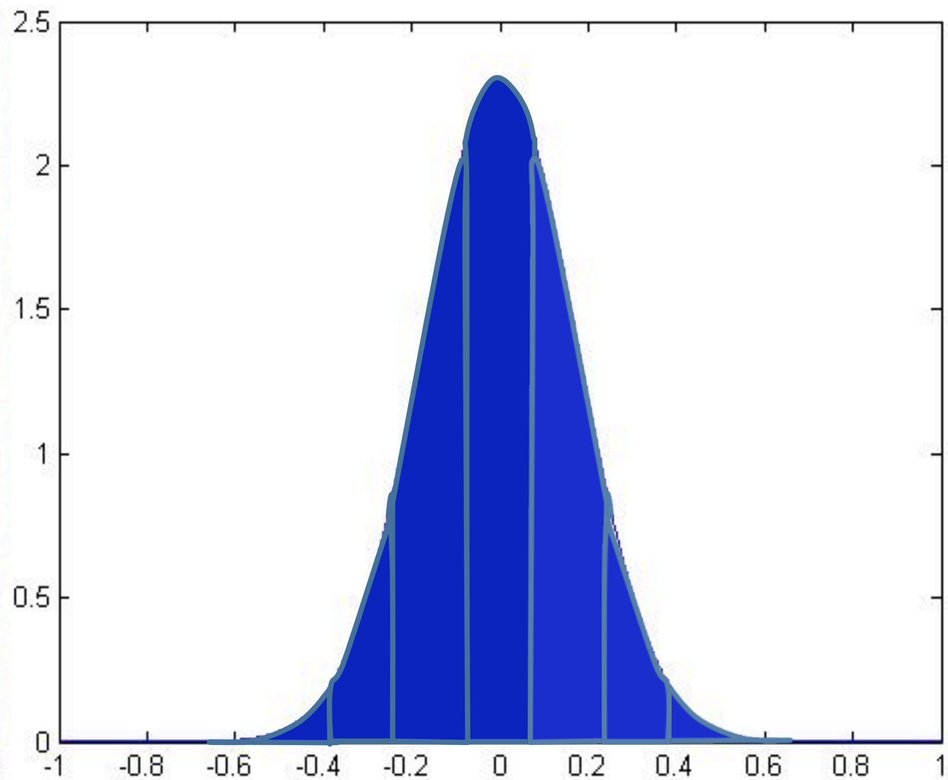
Angle span with respect to an initial height and velocity




Unsuccessful Jump
Initial Conditions:
Height = 2.01 (m)
Velocity = 7.99 (m/s)
Terrain
Mass Trajectory
Foot Trajectory
Hit Point
ERROR!!!
Height (m)
Distance Traveled (m)
2.5
2
1.5
1
0.5
0
-0.5
0
1
2
3
4
5
6
7
8
9

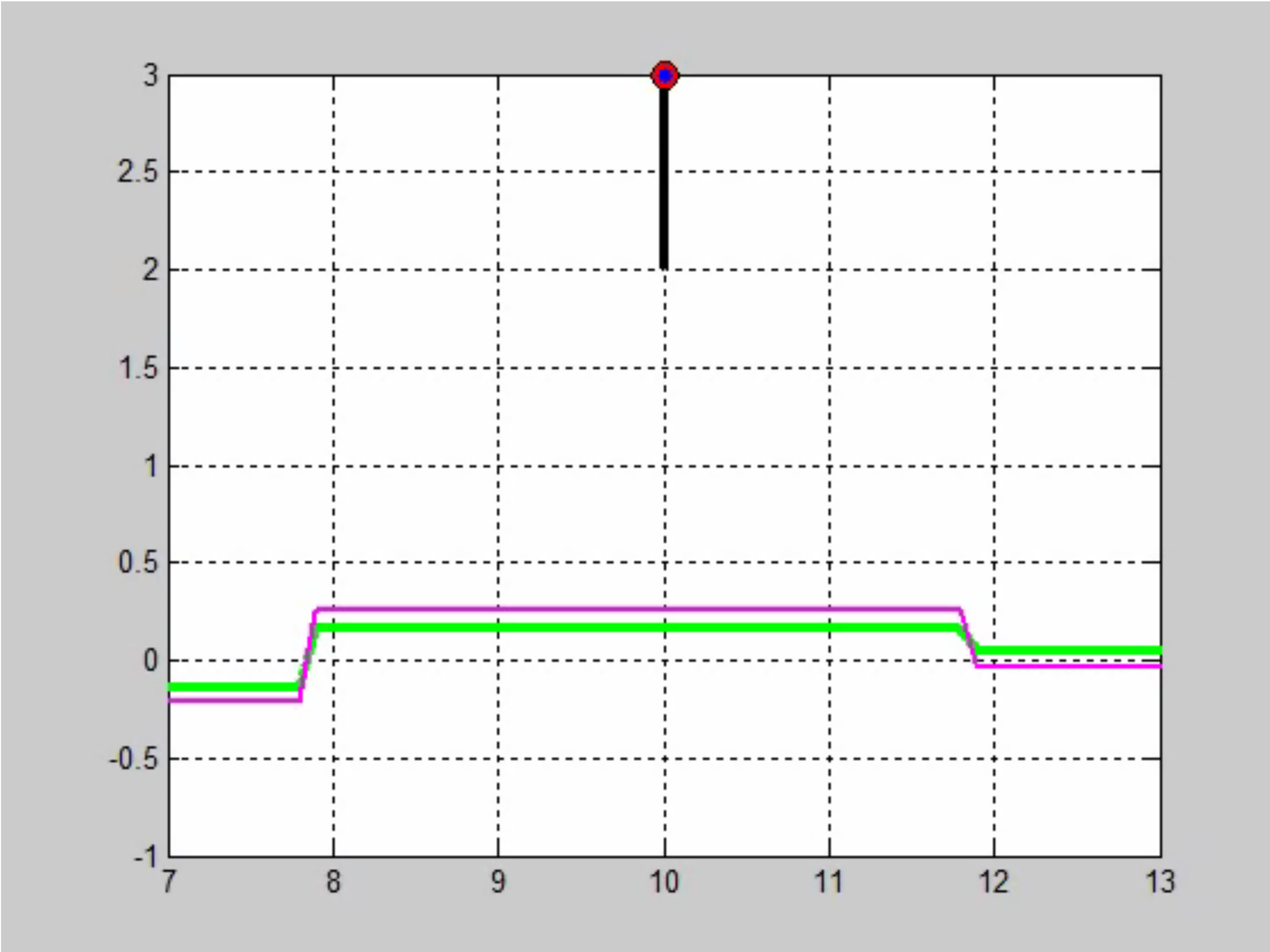
Gaussian normal distribution on sensor error



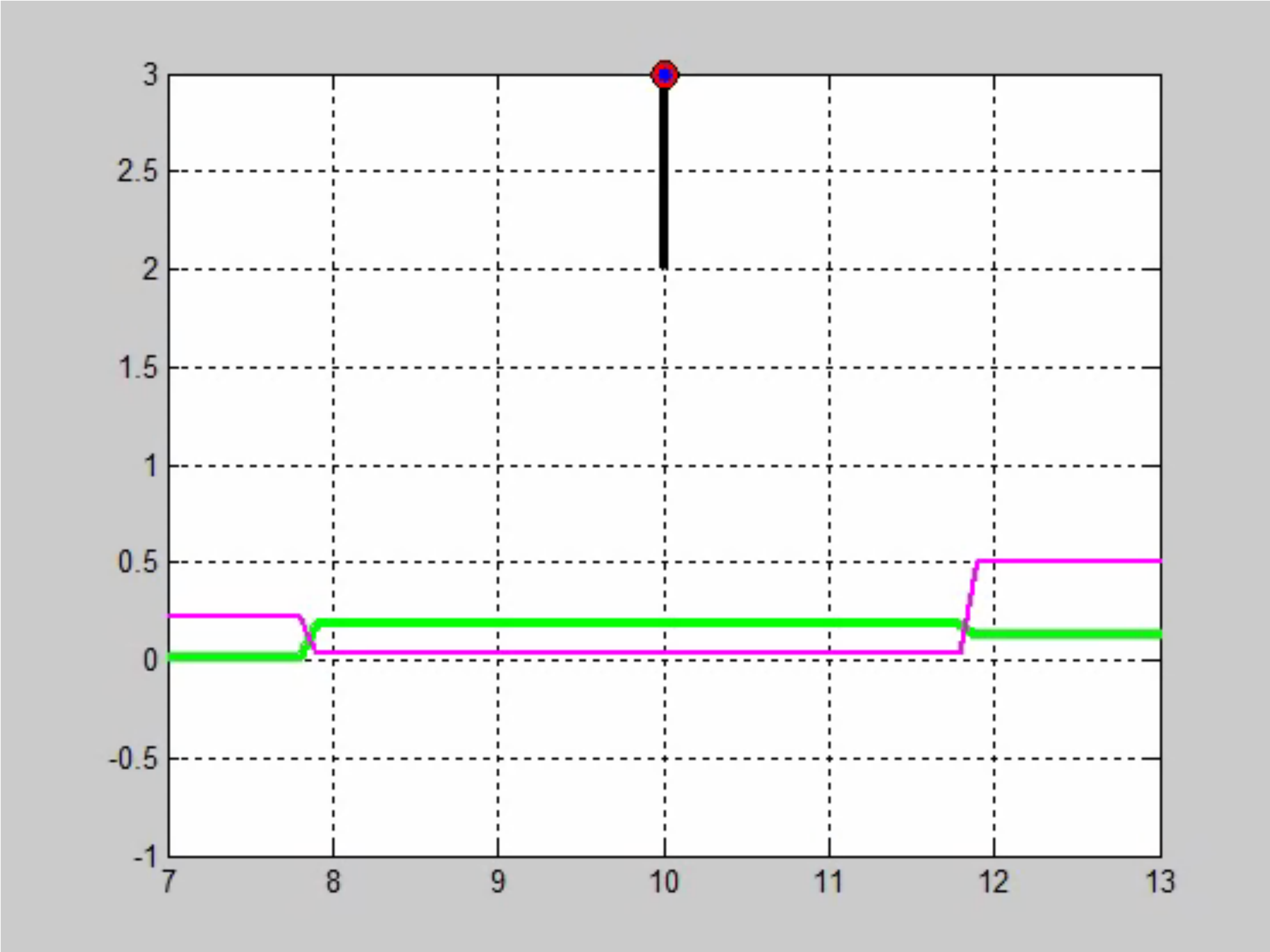


- ❖ The farther the point is, the less consideration we take of that point since it's unlikely to be real.

$\mu = 0$ (mean value)
$\sigma^2 = 0.03$ (standard deviation)

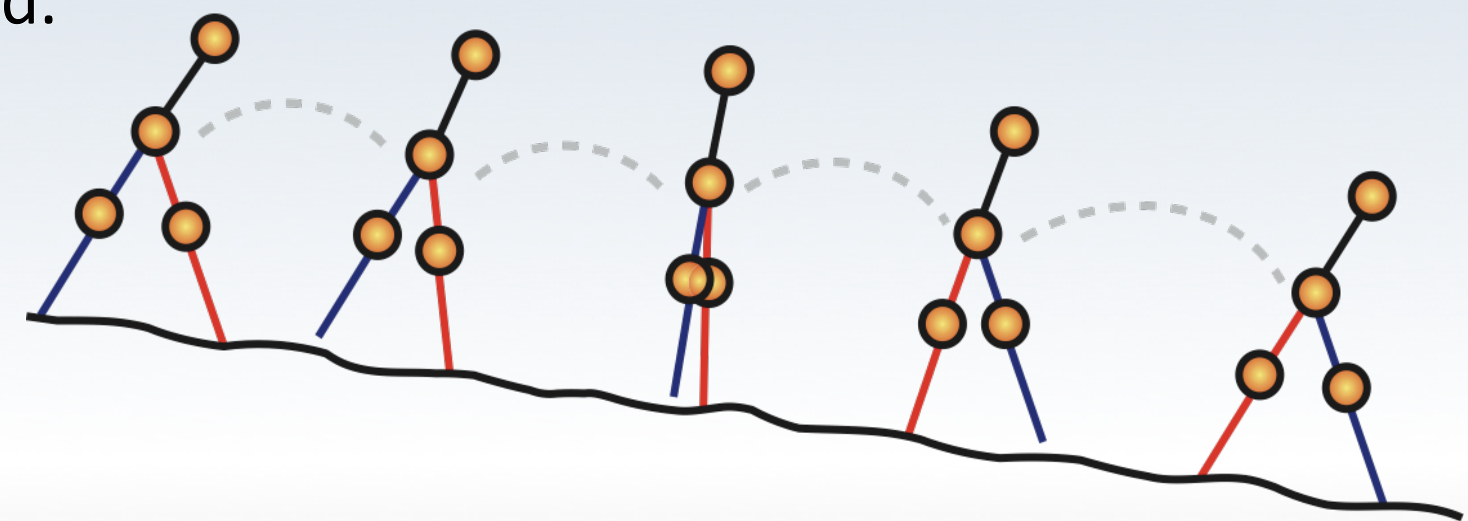


3
2.5
2
1.5
1
0.5
0
-0.5
-1
7
8
9
10
11
12
13


3
2.5
2
1.5
1
0.5
0
-0.5
-1
7
8
9
10
11
12
13

Relative to the Big Picture

- Implement SLIP model to biped and quadruped robots to give ability to run or jump when needed.



Summary

- Defined equations of motion
- Constructed a look up table that shows angle range for specific set of points
- Model successful and unsuccessful jumps
- Used a Gaussian normal distribution to distribute the error percentage that we may encounter
- Video clips of the model

Thank You

INSET: For the opportunity to be part of this great program: Dr. Nick Arnold, Jens Kuhn

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Cristina Luna: For your continuous support, I love you

MESA/SHPE: For coming out and supporting

Virginia Estrella: For all of your great and wise guidance

Future Work:

Implement an actuator to leg in order to add energy to the trajectory so that it can overcome big obstacles.