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Emotional Walking Pattern Generation for a Biped Humanoid Robot Realizing Human-Like Motion

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Outline

- Introduction
- Background and Related Work
- Mechanical Design
- Simple Models of Bipedal Walking
- Walking Algorithm
- Conclusions and Future Work

Introduction

- First Walking Vehicle from the 18th Century
- Motivation
  - Complexity
  - Wider Operation Region
  - Simulate Activities of Human Being

Introduction

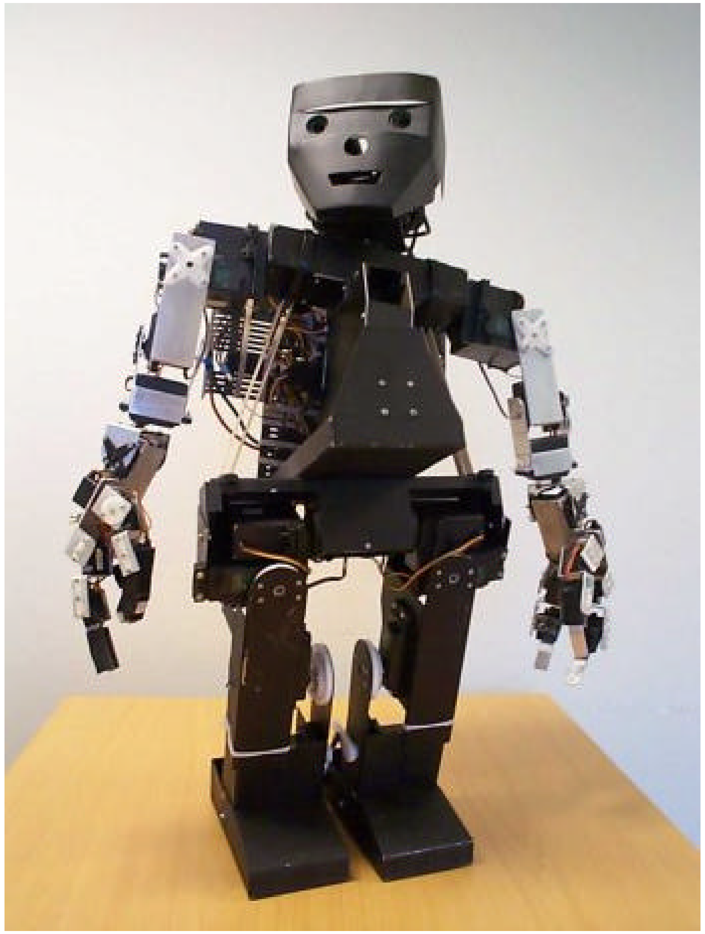
- Objectives
  - Inexpensive Design
  - Naturally Walking Humanoid Robot
  - Library Functions as the Stepping Stone for Intelligent Learning

Background

- Powered Walk and Passive Walk
- Static Balance and Dynamic Balance

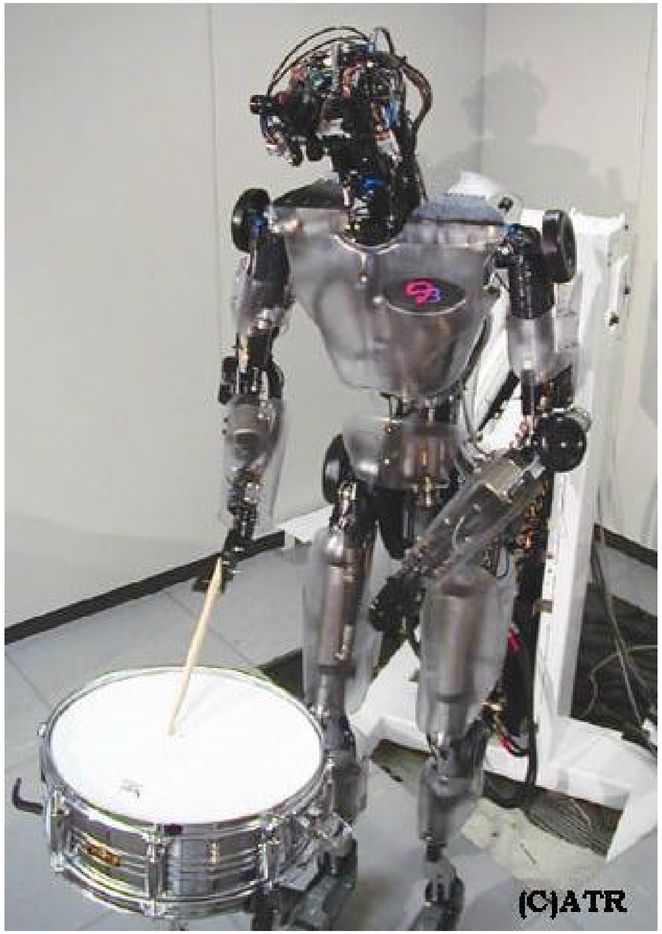
Related Work

- "Elvis"
- Prototype 1, 1998
- 23 Degrees of Freedom



Related Work

- “Robot DB”
- 185cm / 80kg
- 30 Degrees of Freedom
- Cost: ~$1 million US



Japan Science and Technology Corporation

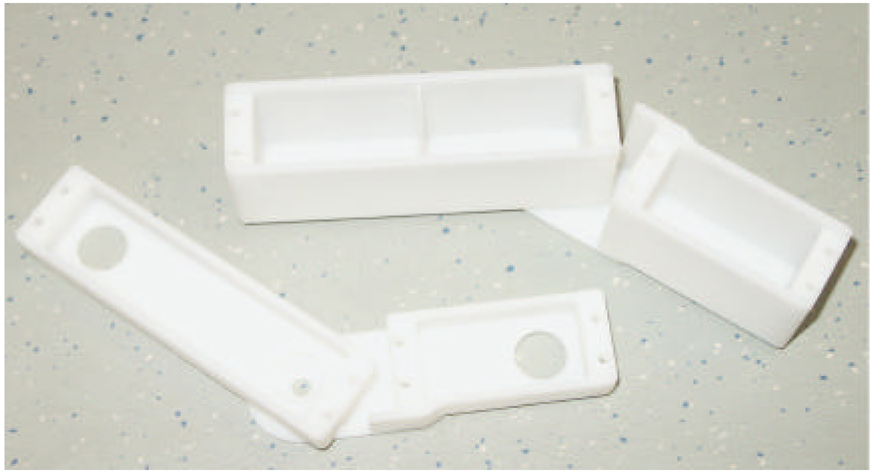
Related Work

- "ASIMO"
- 120cm / 43kg
- 26 Degrees of Freedom
- Walking 0-1.6m/s

Honda Motor Corporation, Ltd.

Humanoid Design

- Hardware Design
  - Microcontroller
  - Sensors
  - Digital Camera
  - Actuators
- Mechanical Design
  - Biped Structure
  - CAD Design
  - Rapid Prototyping



EyeCon Microcontroller

- 32bit Motorola 68332, 16-33MHz
  - TPU, ¼ clock speed
  - 1 Mb of RAM
  - 512 kb of ROM
- GUI, 128x64
- Real-Time OS, RoBIOS
  - 12 Servos
  - 2 DC Motors with Encoders
  - 6 IR Sensors & 6 A/D Inputs

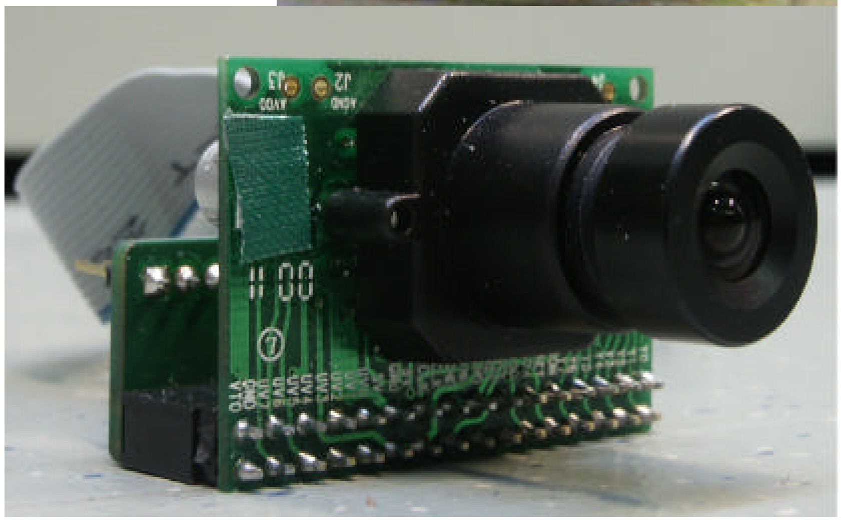
Sensors

- Digital Camera
- Accelerometers
  - VTI Technologies
  - Body Movements

Digital Camera

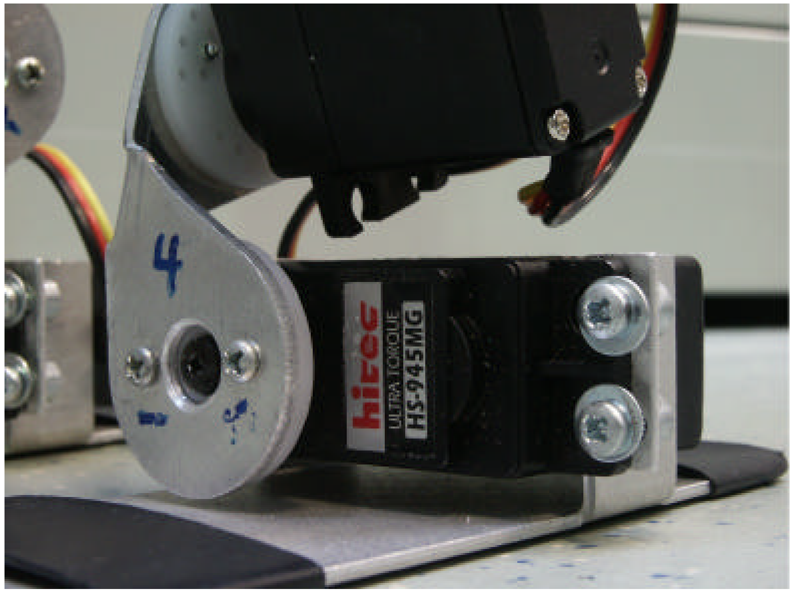
- CMOS Technology
- Full Color, 24bits
- 80x60 pix/frame

- CCD Technology
- Full Color, 32bits
- 160x120 pix/frame



Actuators

- Standard Servo Motors
  - Hitec HS-945MG
  - High Torque
    - 10.6 kg/cm @ 6V
- Servo Control
  - Internal PD Controller
  - PWM Signals from TPU

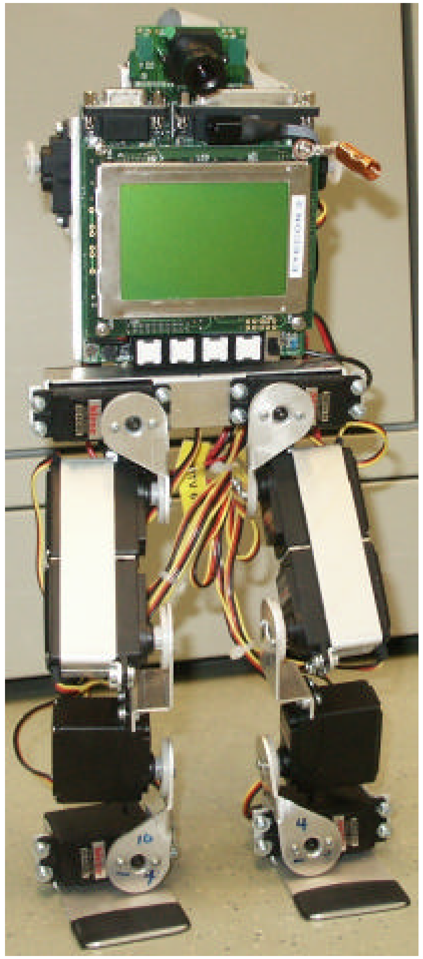


Servo Problems

- Calibration
- Jitter
  - Noticeable as Vibrations
  - No Position Sensor – Unbalanced System
- Insufficient Torque
  - Mostly with the Ankle Servos

Biped Structure

- Aluminium Structure
- Totally 12 Degrees of Freedom
  - Upper Body – 2 DOF
  - Lower Body – 10 DOF
- Low Cost



Simple Models of Bipedal Walking

- Inverted Pendulum Model
- Influence of the Dynamics
- Center of Mass
- Center of Pressure

Center of Mass

- Distance-Weighted Average Location of the Individual Mass Particles

$$COM = \frac{\sum P_{mi} \cdot M_i}{\sum M_i}$$

(where Pmi is the location of the mass particle i, and Mi is the mass of particle i)

Center of Pressure

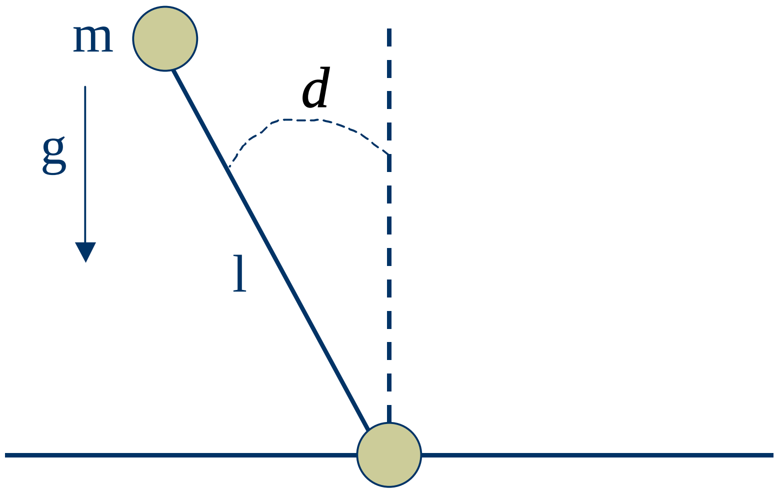
- the center point of the convex hull of the foot where it supports the most pressure

$$COP = \frac{\sum P_{pi} \cdot P_i}{P_i}$$

(where Ppi is the location of the pressure particle i, and Pi is the pressure of particle i)

Inverted Pendulum Model

- The Pendulum Pivot Point is Placed Approximately at the Center of Pressure on the Foot



Inverted Pendulum Model

The initial kinetic energy is: $E_k = \frac{1}{2}mv^2$

The change to potential energy is: $\Delta E_p = mgl(1 - \cos d)$

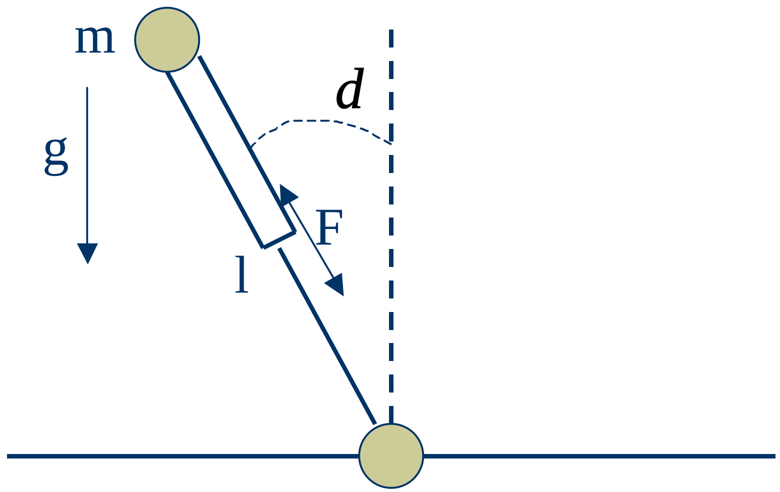
By setting the change of potential energy equal kinetic energy:

$$\cos d = 1 - \frac{v^2}{2 \cdot gl}$$

For small angle approximation, we get $d = \frac{v}{\sqrt{gl}}$

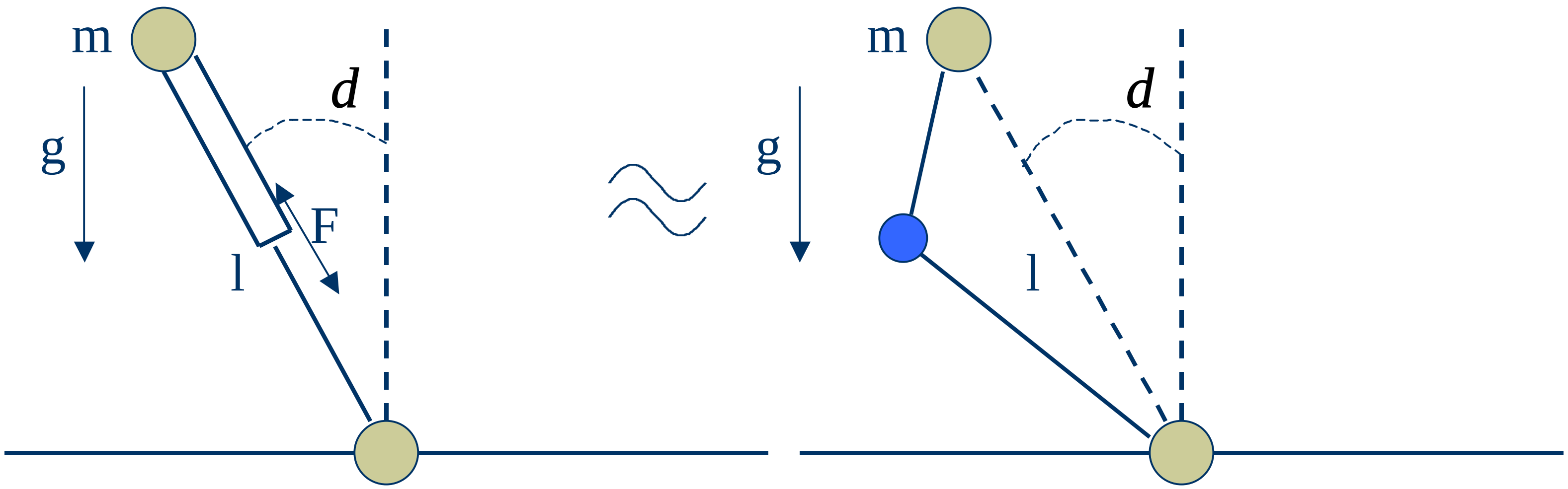
Linear Actuator Pendulum Model

- Linear Actuator Along the Length of the Pendulum



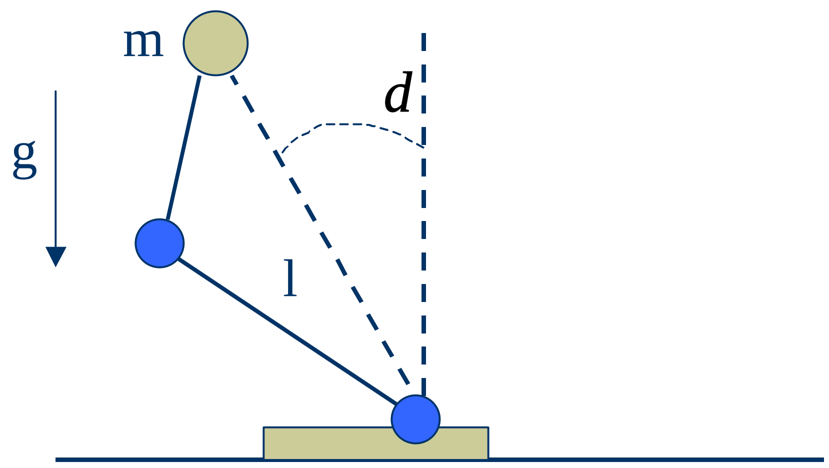
Multi Joint Pendulum Model

- The Force Gain from the Actuator



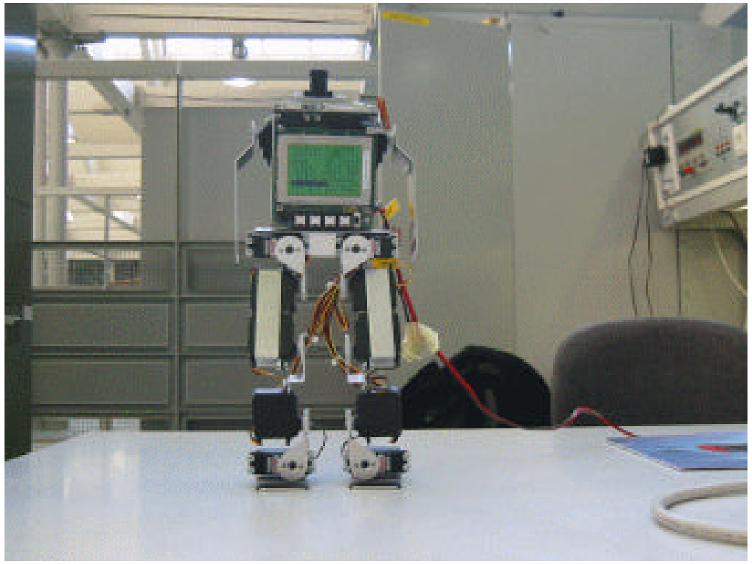
Ankle Pendulum Model

- Balancing the Mass to Shift it Left and Right from the Vertical Above the Pivot Point



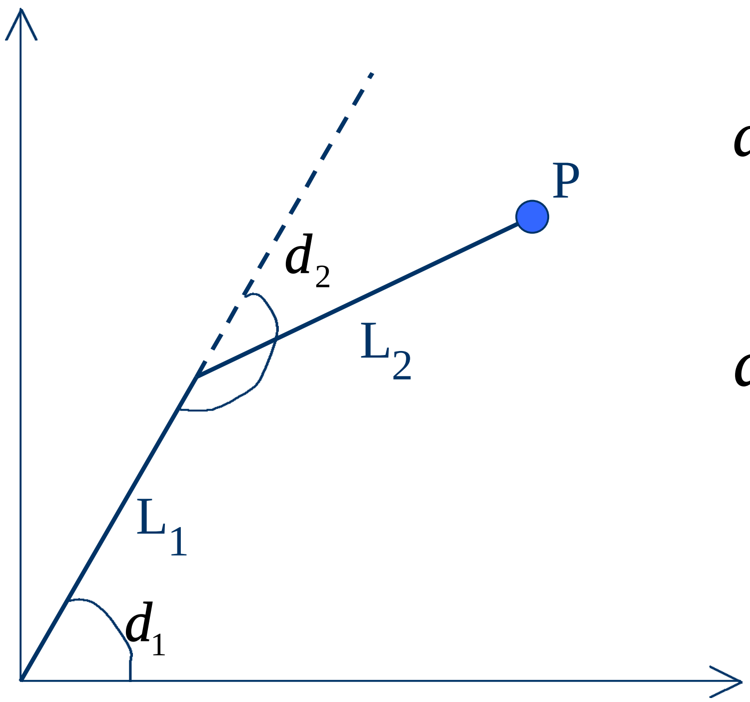
Walking Algorithm

- Inverse Kinematics
- Bezier Curve
- Software Design Scheme
- Implementation



Inverse Kinematics

- The Center of Mass within the Supporting Area

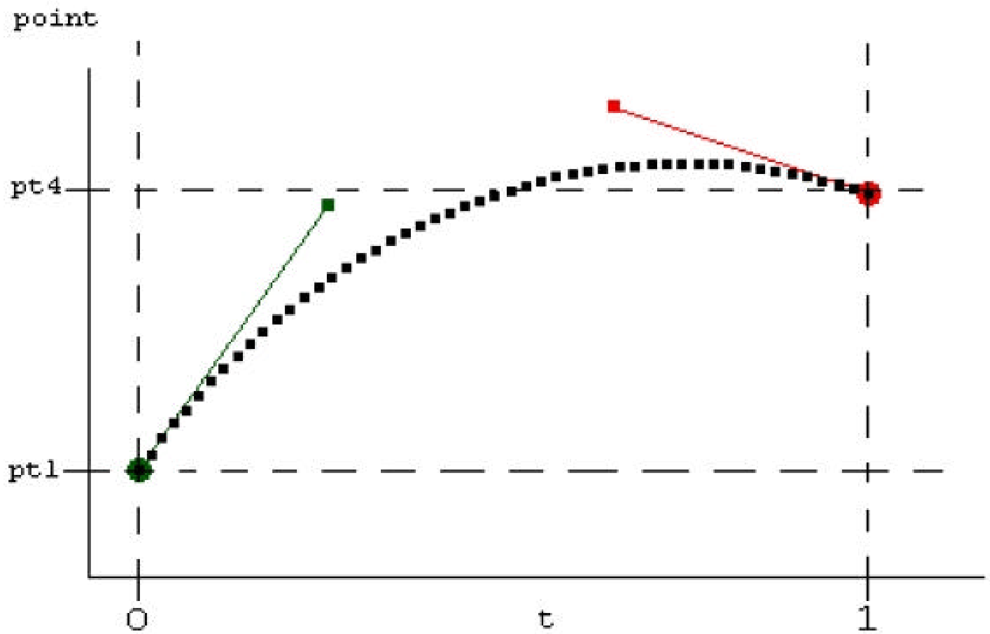


$$d_1 = \frac{-(L_2 \cdot \sin(d_2)x) + (L_1 + L_2 \cdot \cos(d_2)y)}{(L_2 \cdot \sin(d_2)y) + (L_1 + L_2 \cdot \cos(d_2)x)}$$

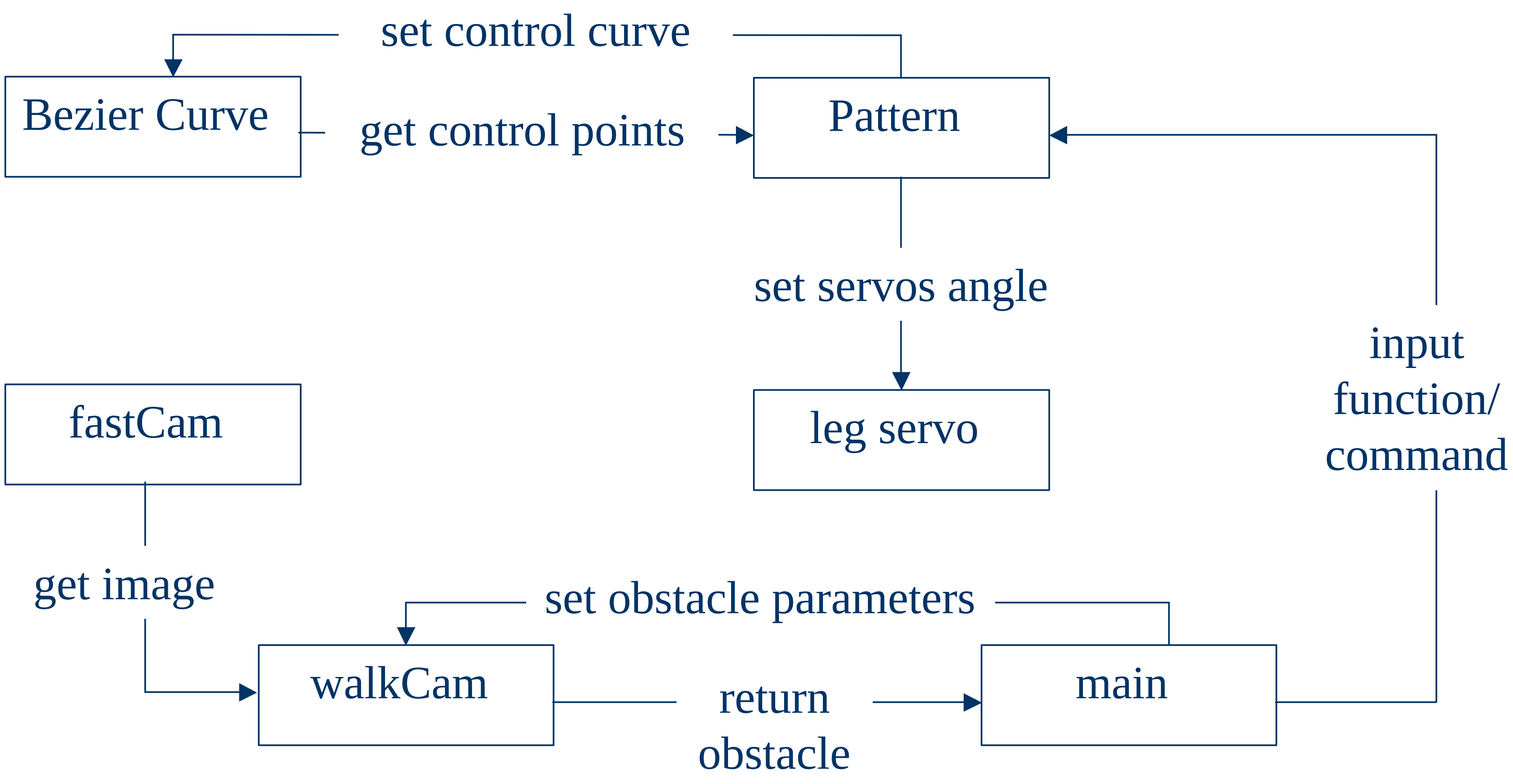
$$d_2 = \frac{\cos(x^2 + y^2 - L_1^{\ 2} - L_2^{\ 2})}{2 \cdot L_1 L_2}$$

Bezier Curve

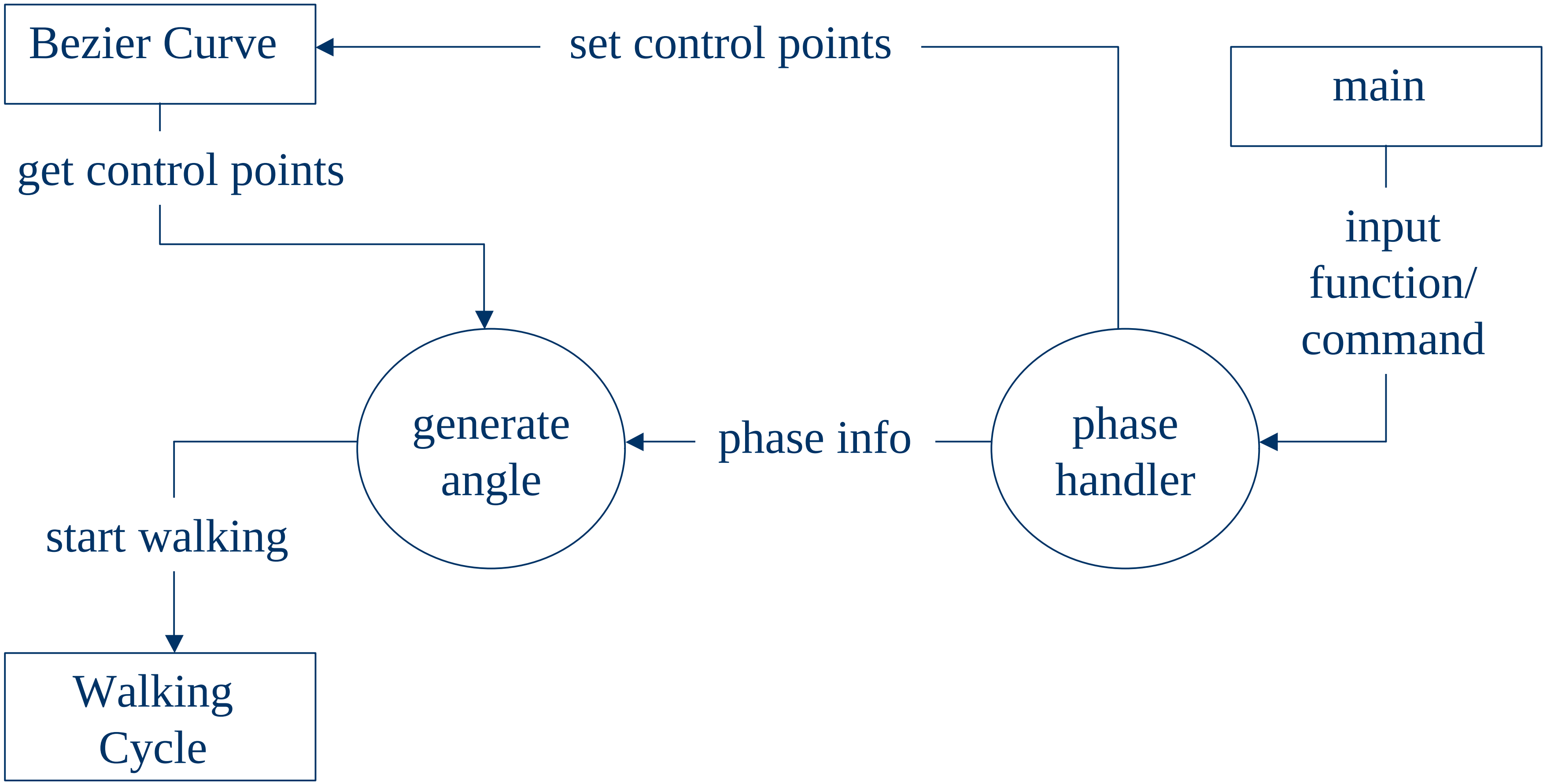
- Pierre Bezier, 1970's CAD/CAM
- Cupid Equation: 4 Parameter Points



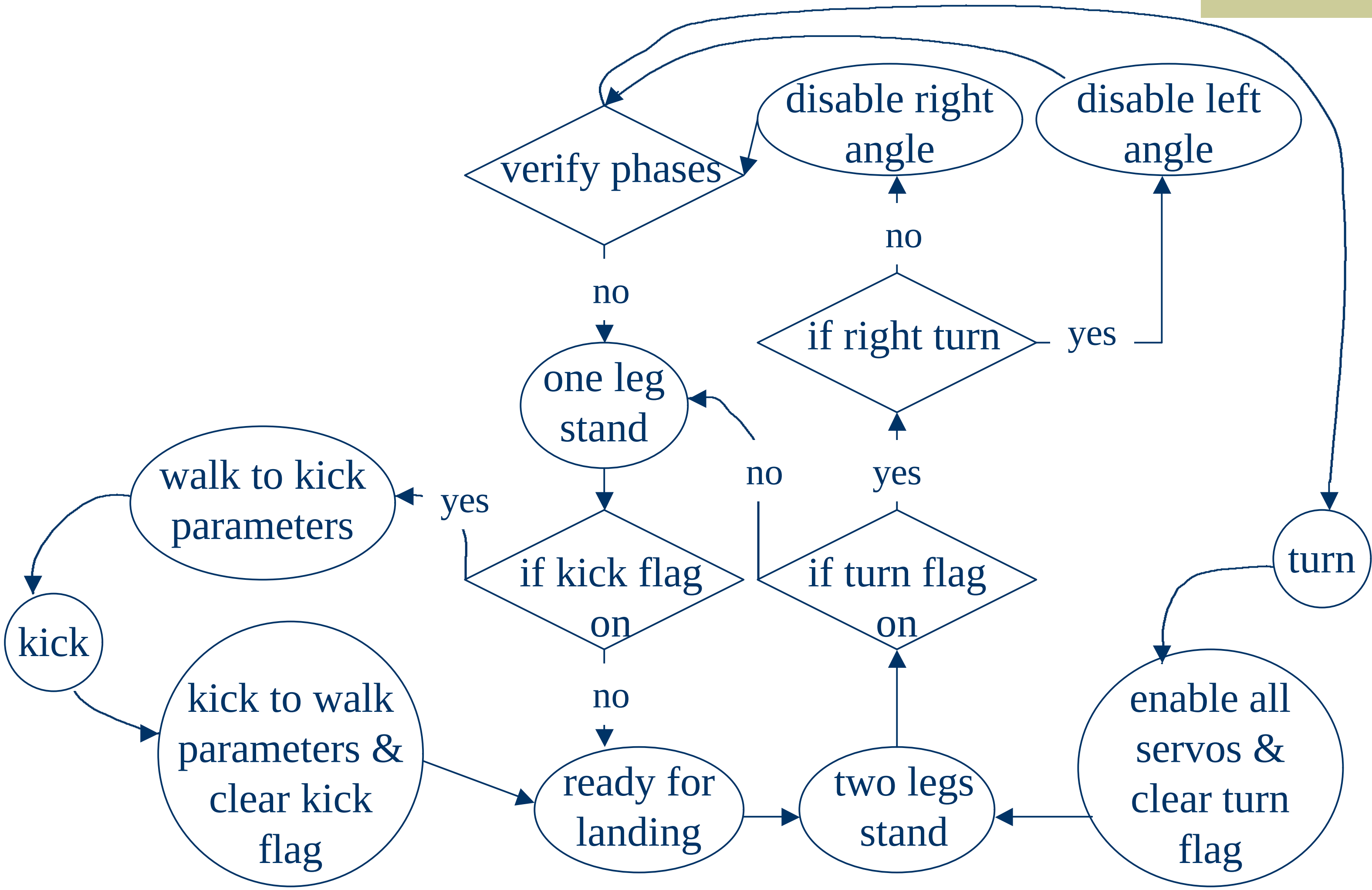
Software Design Scheme



Pattern Generalization System



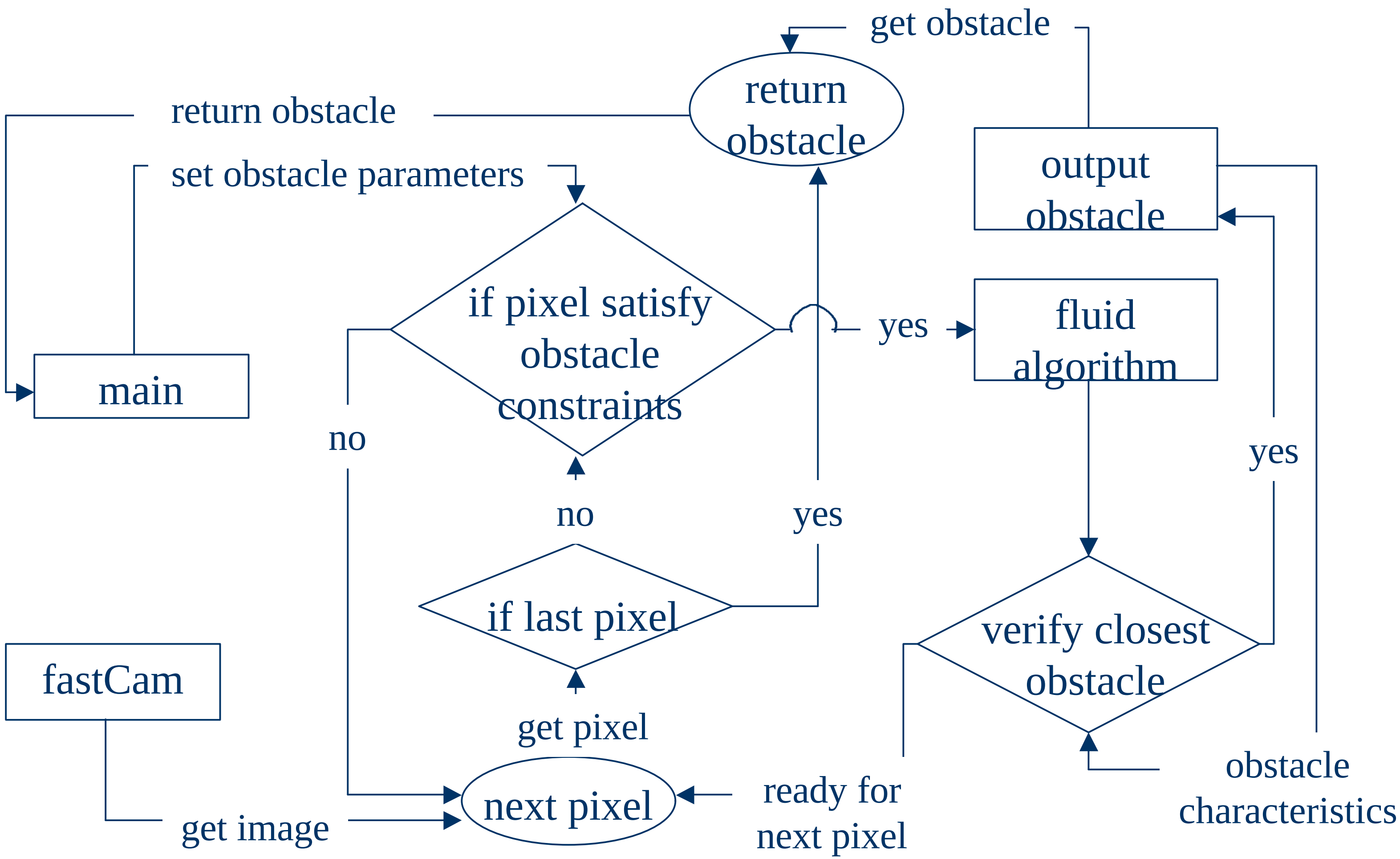
Walking Pattern



Vision Algorithms

- Information from Environment
- Obstacle Avoidance

Fluid Algorithm



System Evaluation

- Bezier Curve for Pattern Generation System
- Phases for Pattern Generation System
- Obstacle Detection

Conclusions

- Modeling
- Walking Algorithm
- Future Work
  - Orientation Measurement
  - Intelligent Control
  - Path Planning
  - Reinforcement Learning
- Final Impression