Computer Vision and Route Planning for Humanoid Robots

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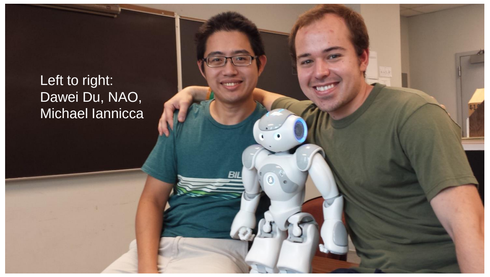
Background and Objectives



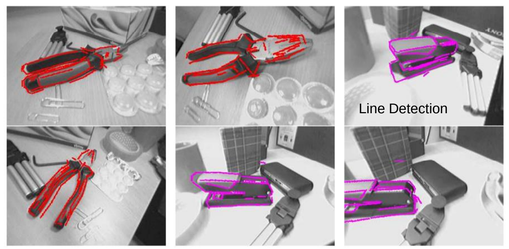
- NAO is a humanoid robot developed by Aldebaran Robotics
- NAO has 25 degrees of freedom
- NAO is fully programmable in various environments, including Python, C++, .Net, Java, and Matlab
- Sensor network includes two high-definition (HD) cameras, four directional microphones, sonar rangefinder, two infrared emitters and receivers, inertial board, nine tactile sensors, eight pressure sensors
- NAO includes a 1.6 GHz CPU which runs a Lunix kernel

Research Objectives

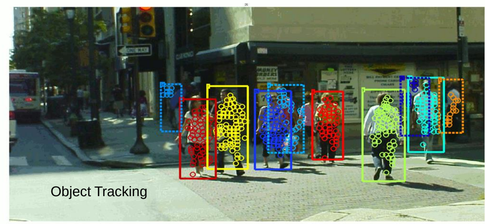
- Test NAO's functionality and test Matlab application programming interface (API)
- Write Matlab code for open-loop controlled walking
- Implement a vision system for NAO that can recognize objects and determine their coordinates
- Program NAO to solve the traveling salesman problem (TSP), allowing NAO to traverse the shortest path

Computer Vision

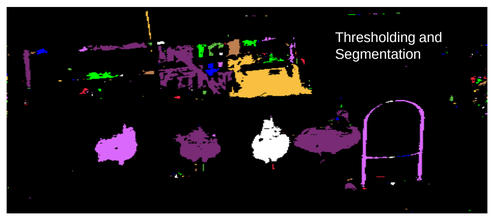
- Computer vision is essential to the field of robotics
- Computer vision is needed for path planning and obstacle avoidance: moving a robot from point A to point B
- Applications include video tracking, motion detection, object recognition, and learning



Taken from http://www.cs.bris.ac.uk/~damen/MultiObjDetector.htm



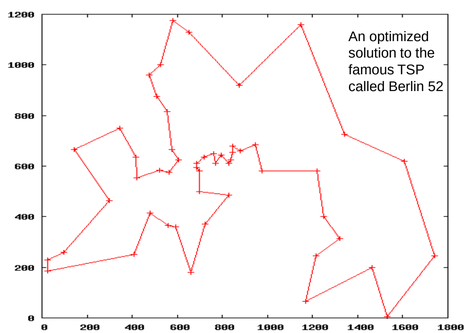
http://www.seas.upenn.edu/~katef/papers/ECCV2012_TwoGranularity.pdf



Taken from http://homepages.inf.ed.ac.uk/rbf/HIPR2/label.htm

Traveling Salesman Problem

- Given a list of cities and their locations, what is the shortest possible route that will visit each city once and return to the city of origin?
- Given more than a few cities, this problem becomes a nondeterministic polynomial time (NP hard) problem
- TSP is a combinatorial optimization problem, which is a type of discrete optimization problem
- Applications include planning, logistics, microchip manufacturing, and many others

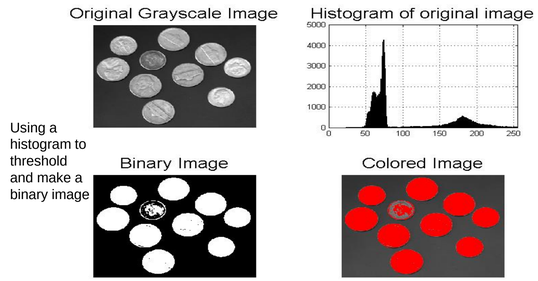


Thursday, September 4, 2014

Methods

Thresholding and Segmentation

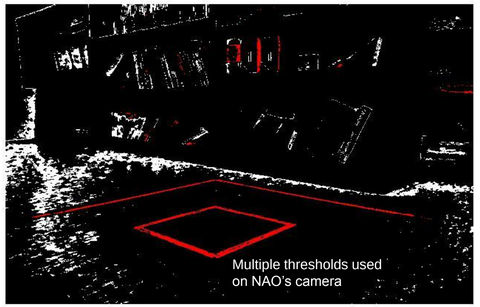
- Thresholding and segmentation algorithms are used to locate objects or extract various features from an image
- Histograms are used to find the best threshold values
- Using threshold values, binary masks are used to perform various calculations
- For segmenting, a connected-components algorithm is used
- The connected-component algorithm allows each object (red dot) to be labeled and distinguished
- Matlab functions for computing the centers of the dots determine the most likely pixel coordinates

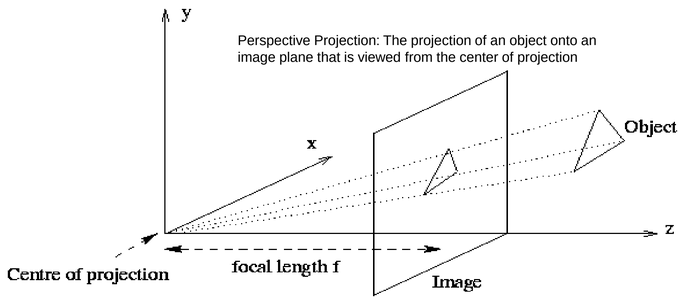


Taken from http://www.mathworks.com/matlabcentral/answers/uploaded_files/4938/red.png

Perspective Projection

- Using perspective projection principles, the size or position of an object can be determined, but camera calibration is required
- Camera calibration finds the position of the camera relative to a given object
- Intrinsic camera parameters:
  - Focal length of the camera
  - Pixel scaling factors
  - Lens distortion coefficients
  - Optical center (located via vanishing points)
- Vanishing points are determined using linear regression





Taken from http://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES/OWENS/LECT1/node2.html

Brute Force Optimization

- An open n-city TSP has $(n-1)!$ possible solutions
- This number of possible solutions becomes impossibly large for even moderate values of n
- Our traveling salesman problem is solvable because only a few "cities" (red dots) are used
- A brute force method, also called exhaustive search, is used to find a solution to small TSPs
- The brute force method calculates each possible solution and selects the best solution
- A symmetric distance matrix is calculated that includes all of the inter-city distances
- The minimum distance gives the optimal route

Heuristic Optimization

- For any TSP containing more than about 10 cities, a heuristic (non-brute-force) method must be used to find a reasonable solution in a reasonable amount of time
- A heuristic algorithm involves finding a near-optimal solution from a subset of all possible solutions
- Cleverly developed heuristic algorithms are used to initialize sets of solutions and create better candidate solutions

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Electronic Control Optimization of a Regenerative Leg Prosthesis

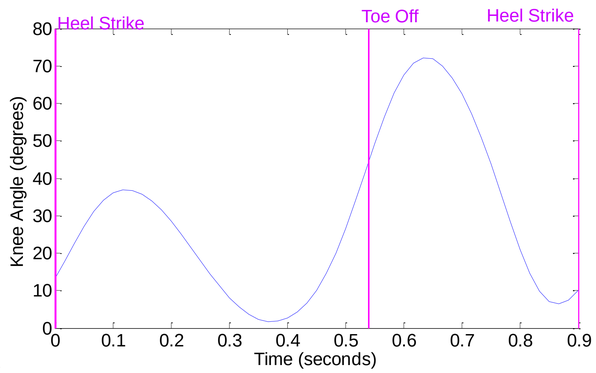
Taylor Barto and Dan Simon

Background and Design Requirements

- Proper prosthetic knee-angle tracking reduces health complications in amputees
- A motorized prosthesis improves knee-angle tracking
- Energy storage in supercapacitors enables longer prosthesis life than batteries can provide

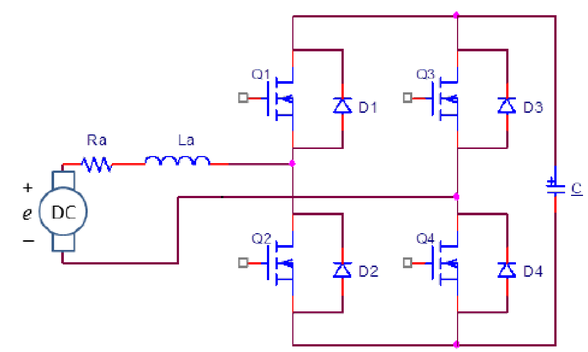
Design Requirements:

- Control system output matches desired knee-angle data
- Store maximum energy during gait cycle



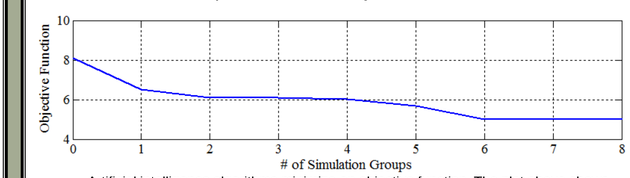
Voltage Source Converter

- Operation is similar to a standard motor controller circuit
- Four modes of operation
- Modes are selected by signals sent to transistors (Q1 – Q4)



Optimization

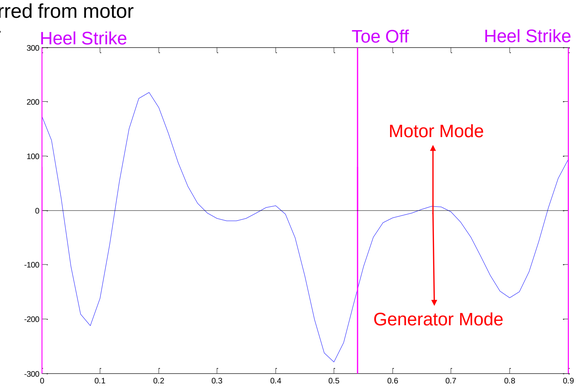
- Artificial intelligence algorithms optimize physical parameters and control parameters to achieve desirable outcomes
- Desirable outcomes:
  - Accurate knee angle tracking
  - Efficient energy storage
- Some sample parameters that can be optimized:
  - Capacitor specifications
  - Transistor specifications
  - Error multipliers in control system



Artificial intelligence algorithms minimize an objective function. The plot above shows the algorithm gradually learning to achieve desirable outcomes by minimizing the inverse (undesirable outcomes).

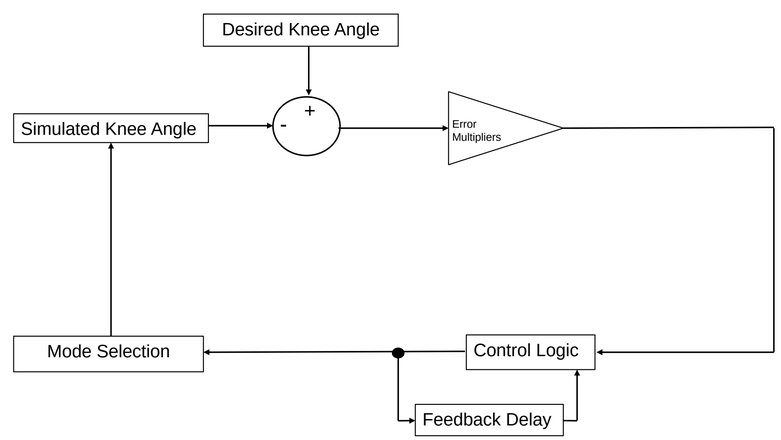
Dynamic Mode Switching

- Four operational modes
  - Motoring
    - Power at knee is positive
    - Energy is transferred from supercapacitor to motor
  - Generator
    - Power at knee is negative
    - Energy is transferred from motor to supercapacitor
- Dynamic switching between modes provides better energy storage
- Dynamic switching occurs in real time



Control System

- Feedback controls mode switching
- Control logic allows prosthetic knee angle to track desired knee angle



Parallel Optimization

- Many simulations are required for artificial intelligence algorithms to optimize variables
- Parallel code uses multiple computer processors to run many simulations at the same time
- Parallel optimization greatly reduces the amount of time required to optimize independent variables

Future Work

- Apply circuit to enhanced prosthesis simulation
- Control ankle motor in addition to knee motor
- Build circuit for prototype prosthesis

Acknowledgments

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Supercapacitor image from Digikey