**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

**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 non-deterministic 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

**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

**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

**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
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 prosthetic use than batteries can provide

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

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

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

Control System

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

Future Work

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

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Supercapacitor image from Digikey

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