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
- 1.6 GHz CPU, which runs a Linux 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 the NAO that can recognize objects and determine their coordinates
- Program the 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 nondeterministic polynomial time (NP hard) problem
- TSP is a combinatorial optimization problem, which is a type of discrete optimization problem
- Applications include planning, logistics, and microchip manufacturing

Method

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 was used
- The connected-component algorithm allowed for each object (red dot) to be labeled and recognized as separate
- Matlab functions for computing the centers of the dots were used to 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
  - 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" 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 solve and initialize sets of solutions