“Fetch the ball, Oncilla!”

Semester Project in Micro-engineering

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Project description and motivation

- Goal: have the Oncilla robot follow a ball
  - Ball tracking (where is the ball?)
  - Locomotion toward the ball
- Part of the AMARSi project
- Nice behavior to make the robot look more like a real animal
Simplified world

- First draft on a simplified world:
  - No locomotion
  - Simple control

- Fixed robot with rotative camera which can also translate

- Goal: rotate the camera until the ball is centered and at a suitable distance
Simplified world

- For each control step:
  - Take a picture with camera
  - Threshold the image to keep only red (B)
  - Calculate ball area and center of mass:
    \[
    A = \sum_{i=1}^{N} \sum_{j=1}^{M} B[i,j]
    \]
    \[
    x_0 = \frac{\sum_{i=1}^{N} \sum_{j=1}^{M} j \cdot B[i,j]}{A}
    \]
    \[
    y_0 = \frac{\sum_{i=1}^{N} \sum_{j=1}^{M} i \cdot B[i,j]}{A}
    \]
  - Use PID-controllers on the rotation and translation to keep \( x_0 \) in the middle and \( A \) around a certain value
Ball detection

- Works fine when image completely inside
- Detection when ball is partially inside the image
- Find 3 suitable points to estimate radius and center of the ball
Implementation on Oncilla

Locomotion profiles

Yaw offset

Reference:

- Add vision and include it to the locomotion control
Implementation on Oncilla

• The robot should accelerate when the ball is far away and slow down when it comes closer
  – PID-controller on the speed depending on the ball size
• The robot should turn in order to keep the ball in front on it
  – PID-controller on the yaw_offset, which allows the robot to turn, to keep x0 in the middle of the image
Noise and Filter

- In order to reduce the noise, a weighted moving average filter is implemented on the ball area and center of mass. For each input data, the output is the weighted average of the N (50) previous data with decreasing weight.

Before

After
Implementation on the real robot

- Oncilla currently works on open loop
  - Enough for flat ground
- On open loop there is no posture control
  - Abduction / adduction movement not defined
  - No turning available

Reference:
Enable Turning

- Design a pattern for abduction/adduction
  - Draw foot trajectory and use inverse kinematics
  - Copy pattern from protraction/retraction joint
    - Poor overall results in simulation
- Altering the foot trajectory
  - Legs on one side will have shorter stride length than on the other side thus making the robot turn
Adding vision

- Simple webcam fixed in front of Oncilla
Image processing modification

- Goal: detect a ball of a given color in any environment

- Algorithm:
  - Conversion from RGB to HSV
  - Threshold on H and S to form binary image

Reference:
Image processing modification

• Algorithm:
  - Erosion filter to remove small blobs
  - Project the image onto x and y axis
  - Assuming the ball is the biggest blob, keep only the biggest 1D connected component on x and y
  - Limit additional image processing to the box defined previously
Results

- Red
Results

- Blue
Results

- Green
Results

- Yellow
Implementation on on-board computer

- Vision library used: Video4Linux (V4L)
- It takes around 35ms to grab a picture and save it for further processing
  - Too slow, cycle refresh time of Oncilla: 5ms!
  - Solution: take picture and find ball location continuously in a parallel thread
Control and Tuning

- Control analog to simulation but with P-controllers
- Less agility because of open loop
  - Maximum speed: 0.4m/s
  - Turning coefficient bounded between -0.3 and 0.3
- In place turning when no ball is seen
  - Speed = 0.3m/s, turning coef = ±1
- Moving average filter of length N=3
Noise reduction

- The ball detection algorithm will always detect the biggest object of the given color
  - Problem when the ball is not in the field view
Noise reduction

- **Solution:** Discard any input values when the difference between the current value of the area and the previous one is more than a certain amount.
Results
Conclusion

- Oncilla is following the ball if the ball is not moved too fast
- Possible improvements:
  - Improve dynamics by:
    - Faster computation time
    - Closed loop control