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TicTacSpot

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Abstract

Through this research, we explore SPOT's advanced mobility, and manipulation abilities to facilitate interaction with humans in the context of playing a simplistic game, Tic-Tac-Toe.

To achieve this, we have integrated object detection to identify personalized X-pieces, tailored specifically for SPOT for easy pickup. In addition, SPOT's arm is deployed to manipulate those pieces, ensuring seamless gameplay. Lastly, we use fiducial detection to not only locate the game board but also to comprehend the current state of the game.

Building on these accomplishments, we are striving to enhance user accessibility and enjoyment by improving gameplay mechanics. Overall, the act of playing Tic-Tac-Toe with SPOT serves as a way to investigate the potential of robotics in everyday life.

Project Goal

Purpose:
Out goal is to enhance user accessibility and enjoyment by improving gameplay mechanics and enabling SPOT to play Tic-Tac-Toe with a human operator.

Objectives:

- Design and Develop an algorithm that is capable of enabling SPOT to identify the game board and pieces accurately
- Develop a custom model to SPOT's specific custom pieces
- Implement a Tic-Tac-Toe playing algorithm to leverage SPOT's capabilities of making strategic moves
- Develop an identification system for the game pieces and board for SPOT to identify
- Integrate fiducials into the game board to find orientation, open spots, and game states

Concepts of Operation

Sample Images

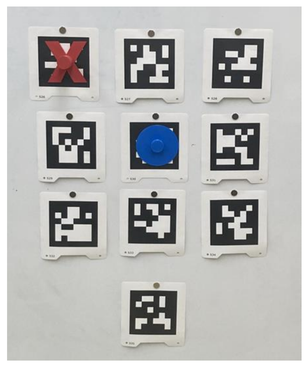


Figure 1: Board Layout

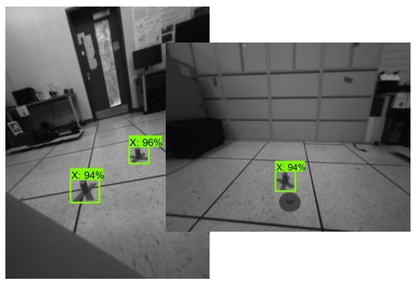
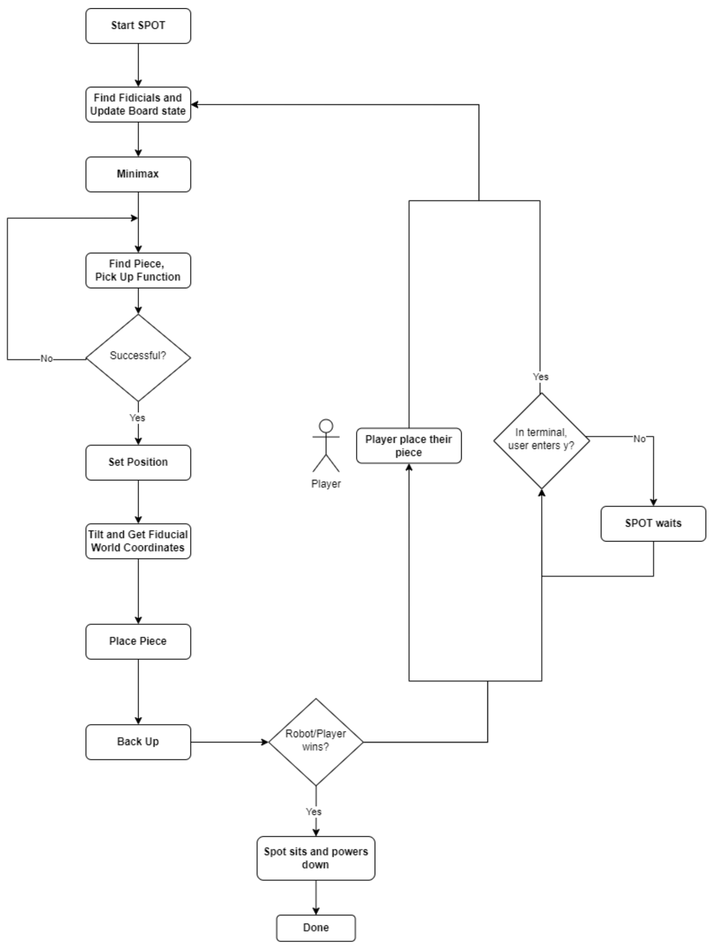


Figure 2: Object Detection Sample Images captured from SPOT's Front Right Camera and Back Camera



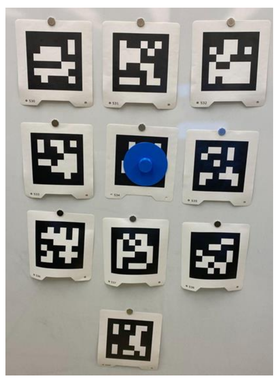
Implementation Details

This project was developed using Boston Dynamics's robot, SPOT, in its virtual environment and Python Programming Language.

- ***Object Detection***:
  - Utilizing object detection by using TensorFlow to enable SPOT to recognize custom made X-piece.
- ***Minimax (Alpha and Beta Pruning)***:
  - Minimax is a decision making algorithm. Alpha and Beta Pruning is an additional optimization to the Minimax algorithm to decrease the number of nodes evaluated.
  - Utilized this algorithm for SPOT to decide on the following moves of the Tic-Tac-Toe game.
- ***Robot Arm Manipulation***:
  - Develop Python Scripts that use SPOT's SDK which allows SPOT to pick up and place game pieces with accuracy.
- ***Board Design:***
  - The design and implementation of the game board for SPOT is achieved by incorporating nine fiducials for identification (a 3 by 3 group). Refer to Figure 1
- ***Pieces Design:***
  - X Pieces were personalized and made specifically for SPOT for easy pickup.
  - Each piece, including the players pieces (O-piece), was all 3D printed with the material Polylactic Acid (PLA) Filament
- ***Fiducial Recognition:***
  - A fiducial is a visual marker that SPOT is able to easily identify. Uses cameras to look in all direction.
  - Using the position of the fiducials, SPOT is able to detect which fiducial space is taken by a piece and which are left for SPOT to place an X-piece.

Experiments

Figure 3: A picture of SPOT picking up a X-Piece successfully



```
530 531 532
533 534 535
536 537 538
[530, 531, 532, 533, 535, 536, 537, 538] 8 30
Detection done, found players move....
-----------------Board State:-------------
530 531 532
533 O 535
536 537 538
Player pieces: 1
SPOT's Pieces:  0
Total Pieces on board:  1
----------------------------------------
```

Figure 4: SPOT discerns the state of the board through detection of a list of fiducials. In the Find Fiducial state, if one fiducial ID is absent, SPOT infers that the player placed their piece in that particular location.

```
Found X...
Sending grasp request...
0.3332674503326416 sec): MANIP_STATE_GRASP_SUCCEEDED
Gripper Degree Percentage: 0.3332674503326416
Failed to grab
Found X...
Sending grasp request...
20.943849563598633 sec): MANIP_STATE_GRASP_SUCCEEDED
Gripper Degree Percentage: 20.94155502319336

Grasp finished, Carrying...
Carrying Finished, Stowing...
Placing Piece....
(0, 0) 530
SPOT Walking to Board
```

Figure 5: Minimax Decision. The move SPOT chooses is based on a coordinate system. In this example, (0,0) represents the top left fiducial of the board

Optional Features To Be Added

- **Human Detection**: The absence of a human in the front cameras would signify it will be SPOT's turn. This proposed advancement would allow SPOT to autonomously know when it's its own turn.
- **Dance:** Have SPOT dance when SPOT wins the Tic-Tac-Toe game
- **Dynamic Board Detection:** Have SPOT detect where the board is without an extra Fiducial at the bottom
- **Auto Set-up**: Have SPOT set up the game board and prep before the game
- **Levels of Difficulty**: Have SPOT play with different levels of difficulty of the Tic-Tac-Toe game.

References

"About Spot." About Spot - Spot 3.2.3 Documentation, https://support.bostondynamics.com/s/article/Robot-specifications

"Spot Arm - Mobile Manipulation." Boston Dynamics, https://support.bostondynamics.com/s/article/Spot-Arm-specifications-and-concepts

"Tutorial: Playing Fetch with Spot." *Tutorial: Playing Fetch with Spot - Spot 4.0.0 Documentation*, dev.bostondynamics.com/docs/python/fetch_tutorial/fetch1#.

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