# Demo: ROX Player - A Xiangqi Playing Robotic System


Kaifeng Zhao
Beihang University
Beijing, P.R. China

Liqiang Bao
University of Chinese
Academy of Sciences
Beijing, P.R. China

Qing Li
Beijing University of
Posts and
Telecommunications
Beijing, P.R. China

Mengxin Cao
Beijing University of
Posts and
Telecommunications
Beijing, P.R. China

Zhiyuan Liu
Beijing University of
Posts and
Telecommunications
Beijing, P.R. China

Guang Li
Megvii Inc. (Face++)
Beijing, P.R. China
liguang@megvii.com



## Abstract

This demonstration presents a Xiangqi (Chinese chess) playing robotic system which can play against human players on physical chess board. With RGBD camera and deep learning algorithms for detection and recognition, our system tracks chess board, pieces and human actions to manipulate the pieces with a robotic arm implementing the move strategy from AI Xiangqi engine. We conducted experiments to verify the usability of our system and the user feedback demonstrates that our system provides a better game experience than traditional GUI interaction.


## 1 Introduction

With the fast development of computer chess and AI, playing chess with a virtual AI opponent has become a common form of chess playing. However, traditional game interaction of GUI can hardly keep human enjoying the game. Research [3, 4] reveals that the embodiment of AI affects human response towards it and playing against a tangible opponent on physical chess board leads to more enjoyment than playing against a virtual opponent with GUI. Therefore, a robotic system playing with human on physical chess board provides better interaction experience for human players. To provide Xiangqi fans with a game manner of more joviality, we developed the Xiangqi playing robotic system which can play with humans naturally on physical chess board. The main tasks of robotic Xiangqi playing system are piece perception and precise manipulation. Instrumented boards and pieces with RFID or magnetic components [5, 6] is a robust solution for real-time piece localization and recognition yet not applicable to normal pieces. A more general method for arbitrary setting of board is using computer vision algorithms for detection and recognition [2, 7]. Piece manipulation is a tabletop object manipulation problem. We use a robotic arm as manipulator with a Kinect camera as environment sensor. In addition, appropriate coordination with human player is required to guarantee a natural game experience.

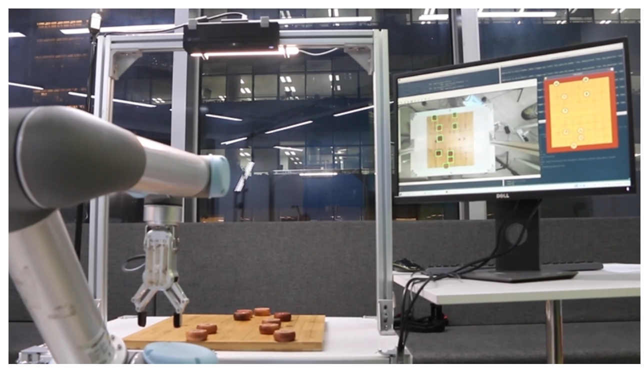

**Figure 1. Overview of ROX Player.**

## 2 System Overview

For the poor user experience induced by the intangibility of AI opponent in traditional GUI interaction, we propose a Xiangqi playing robotic system, ROX Player, to provide a natural game experience on physical board for Xiangqi fans. ROX Player uses computer vision algorithms for perception of chess board, pieces and human player and robotic arm for manipulation.

ROX Player contains the following components and the system overview is demonstrated in Figure 1:

(a) UR5 robotic arm as the manipulator for piece movement.
(b) Kinect v2 camera as environment sensor.
(c) Vision Component for perception of chess board, pieces and human hand.
(d) Xiangqi engine proposing move strategy for AI, modified from an open-source engine ElphantEye[1] of equivalent strength to human champions


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(e) External loudspeaker for voice interaction
(f) Computing platform with GTX 1070 and i7-7700K

## 3 Perception

The perception of ROX Player includes board localization, piece detection and recognition and hand detection.

### 3.1 Board Localization

We derive the four corners of board through edge detection on RGB images of board and determinate the grids through perspective interpolation. With the depth information of points from Kinect camera, we can calculate the space where the board is on.

### 3.2 Piece Detection and Recognition

To ensure the robustness of ROX Player, we have strict performance requirements for piece detection and recognition. We collected a piece detection dataset of 10K+ samples and a piece classification dataset of 20K+ samples. The pipeline conforms to a classification-after-detection pattern, using YOLO for detection and MobileNet for classification on cropped images, which proved to perform better than conducting detection and classification together in experiments. In practice, the average test time of detection and classification of all the pieces on board is 0.7s, mAP at IOU=0.5 is 99.3% and the accuracy of classification is 99.93%, which can ensure high reliability of recognition of piece perception and high efficiency for real-time interaction.

### 3.3 Hand Detection

We acquire the signal of the human player completing a move by hand detection, based on which we ensure a natural and implicit turn taking coordination with human. Combining the RGB image and depth map from Kinect camera, we assume a hand is detected when we recognize a hand in RGB image and the depth of corresponding area is over a threshold. The disappearance of detected hand leads to the signal of completing human player move and instructs ROX Player to react.

## 4 Manipulation

We employed a robotic arm as the manipulator. In addition to general motion planning, we customized the obstacle avoidance logic for piece manipulation.

### 4.1 Motion Planning

Piece manipulation is a problem of motion planning. We use easy-handeye library for calibration of robotic arm and map the board plane to a rectangular coordinate system to calculate the world coordinate for points on the board, then we can use python-urx library to control the arm to manipulate any pieces.

### 4.2 Obstacle Avoidance

Adjacent pieces can be obstacles when we trying to grab an encircled piece. For obstacle avoidance, we determine a suitable angle of the gripper each time according to the pattern of surrounding pieces. There are three candidate gripper angles of horizontal, vertical, and 45 degree angle, respectively for pieces without left or right neighbor, pieces without upper or lower neighbor, or otherwise.

## 5 Pilot Study

We conducted experiments involving 20 participants playing against ROX Player on physical board. The initial position is set before experiments and no human intervention is made during the game. The usability of ROX Player is verified by finishing all 20 games against human players and all the participants consider ROX Player more enjoyable than playing with traditional virtual opponent. The negative feedbacks about ROX Player include slow manipulation, huge size and occasional imprecise gripping. For safety consideration, we limit the movement speed of arm and this is a trade-off between safety and efficiency. The robotic arm we use now is industrial model which can be replaced by some customized smaller arms. For the slight offset of gripper, it occurs when the lighting is unstable and more train data with various lighting will contribute to the robustness of detection.

## 6 Future Work

The usability of our system still needs to be improved. A customized robotic arm with smaller size suitable for playing chess game is necessary. The robustness of visual perception in noisy environments like outdoor scenes can be improved by more various training data. Another direction is to improve the embodiment of AI, like grippers more similar to human hands or a humanoid visualization of AI which can respond to and react with humans for realistic game experience.

## 7 Conclusion

We present ROX Player, a Xiangqi playing robotic system with the capabilities to play on physical boards with humans. ROX Player perceives board, pieces and human action with RGBD sensors and ensures a natural piece manipulation,which proves to provide a better game experience for Xiangqi fans in experiments.

## 8 References


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## Demo Setup

### Hardware Used

UR5 Robotic arm
Kinect v2 camera
PC with GTX 1070 and i7-7700K
Dell P2318H monitor

### Space Needed

1m * 1m for robotic arm
60cm * 80cm for chess board
70cm * 70cm for PC and monitor

### Special Equipment

Xiangqi board and pieces