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# DESK GAMES DIGITALIZATION USING RADON TRANSFORMATION AND COLOR SEGMENTATION

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**ABSTRACT**

The research is focused on real-time digitalization of board games. The information about the game progress in real time is frequently demanded by media in broadcasted tournaments. Recent solutions usually consist of an electronically modified playing board and modified playing objects. This system tends to be expensive and fits to top level tournaments more than casual regional tournaments with limited resources.

The goal was to create a system, which is easy to assemble and use while keeping the transmission and processing in real-time. The chosen solution utilizes a digital camera to obtain input data as a video stream. The data are then processed by Image processing methods. The proposed algorithm includes Radon transformation for board and playing field localization, then methods of Color segmentation for detecting the objects on the playing board. The system was modified and tested in a Chess game.

**Keywords:** Image processing, Radon transformation, Color segmentation

## 1. INTRODUCTION

Recently, streaming of board games in real-time on the internet is in demand, for example, during the chess world championships. One possibility would be simple streaming of a view on the playing board without any modification. This variant is usual in the case of sport games, but not quite useful in case of board games. Necessary information about move history and game progress in real time is missing.

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Furthermore, the objects in board games aren't always clearly recognizable. Due to these facts, there is a need to transform video data to a more simple variant – separate moves. Concretely in card games, a raw video stream is not usable for game analysis, since data contains redundant information. More usable would be data in the form of the clear position of cards on the playing surface, or alternatively in the form of position changes during the game. This information would be graphically presented by various choices. Saving clear data is also favorable for data disk space. Another type of game is classical board games. Similarly, to cards games, optimal data obtained from a video stream would be just the position of game pieces on the board, which is usually formed by a grid, e.g. a chessboard. The research in this paper is primarily focused on the Chess game, where all the thoughts were realized.

Chess is a game for two players, one player plays with white pieces, and the second one with black pieces. Both players take turns to move. Pieces move on the chessboard from one square to another. These squares are algebraically described by numbers from 1 to 8 and letters from ´a´ to ´h´. Progress of a whole game can be written by a notation containing symbolic codes representing the exact movement of a piece. Thanks to the notation, the whole game can be replayed in the future. Complete rules are published on the web of the international chess organization FIDE (Fide web, 2017). Today the most used system for streaming the chess game is the electronic chessboard made by the company DGT - Digital Game Technology (DGT web, 2017). The principle of the system is scanning a signal transmitted by special chess pieces containing an electronic chip. The signal is read by the electronic chessboard, which is able to recognize the location and the type of piece. Data is collected and transmitted by a serial link from the chessboard to a computer. Additionally, a chess clock is part of the chess set. It´s task is to record time to think about the game of both players. Newly, a system using Bluetooth technology can be bought.

In practice, approximately 10 serially connected digital chessboards are used in a tournament. This solution is greatly favored by players, because the chess set is almost identical to a classic chess set and doesn´t in any way disturb the players during the game.

In tournament practice, approximately 10 electronic chess sets are connected in a series. From a player's point of view, this solution is very favorable, because the board and pieces don´t differ from a classical set. Furthermore, signal transmission is very reliable with minimal technical failures. In contrast, there are also some cons. One of them is a single-purpose device. An electronic chessboard can´t be used for any other games, just because of a different number of playing squares. Another disadvantage is the high acquisition price.

There´s no other producer on the market and the device is not mass-produced. Finally, the weight is quite high.

A prototype of the electronic chessboard is described in the paper: "Low Cost Electronic Chess Set" (Nasrul et al., 2017). Under each playing square the Reed switch is installed, which works on magnetism. In default state, the switch is disconnected. When enclosed with a magnet, the switch is connected. The magnet is hidden in a chess piece, and when moved, the correct square is influenced. The piece is then localized, but color and type aren´t recognized. This uncertainty can be minimalized by playing from a known starting position.

In the paper: "Work Chess Playing Robotic Arm" (Musa et al., 2014), a digital camera is already used to scan the playing board. Testing pieces are specially modified such that each type of piece can be recognized. In the top view, there is a circle ornament painted on the top of the piece. The circle image transformation is used to locate the circles. On the other hand, the color of the piece is not recognized.

The next method of image processing is Edge detection. If the color of a piece is different from the color of the square under it, the silhouette of the piece appears, after applying the edge detection. So, empty and occupied squares can be differentiated (Sokic and Ahic-Djokic 2008)

Alternative research about camera image methods focused on object detection in games like chess or checkers is described in (Beran et al, 2016).

A proposed solution, which reduces the disadvantages mentioned above, is to get a position of figures on the chessboard using a digital camera and methods of image processing. This solution is universal and can be applied to other similar games like Checkers or Go. The only difference is just in dimensions of the playing board. Additionally, an algorithm can differ according to the concrete appearance of playing set.

The first part of the paperwork describes a new method of searching for a chessboard in an input image, using Radon transformation. Borders of the chessboard can be determined by dominant points in a Radon accumulator.

The second part analyses space of individual board squares using Colour segmentation and Edge detection. The position and colour of each piece can be determined by an adaptable color filter.

## 2. DESCRIPTION OF ALGORITHM

The algorithm is primarily designed for scanning the chessboard from an upper view. It provides the best conditions for searching borders of the chessboard; image distortion caused by perspective is decreased to minimum. Furthermore, individual pieces visually should not overlap, when considering the adequate height of the camera above board.

In the first step, the algorithm searches for borders of the chessboard using Edge detection and Radon transformation. This method also finds borders of each square. The second step is focused on detection of pieces by processing the image after the Edge detection. Then, the Color detection is applied. A specific color filter is chosen for light and dark pieces. As result, we collect enough information to digitalize the whole position.

**Fig.1.** Input image captured by camera

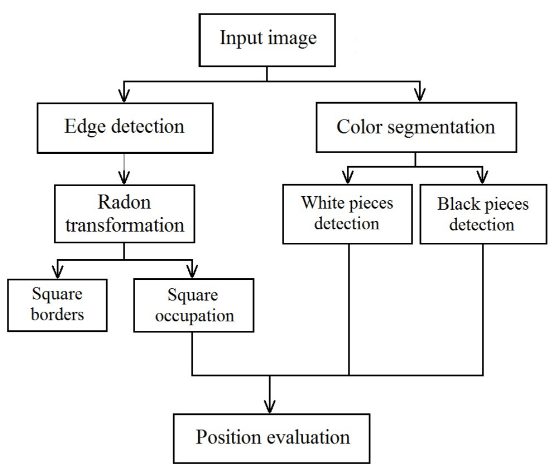


**Fig.2.** Scheme of algorithm

**Localization of chessboard**

The Edge detection is the first method applied on an input image. The output image consists of white spots indicating a sharp change of brightness on the same place in the original image.

Regarding the picture below, the chessboard is clearly visible. Furthermore, the borders of each piece helps us to decide, whether a square is occupied or not.

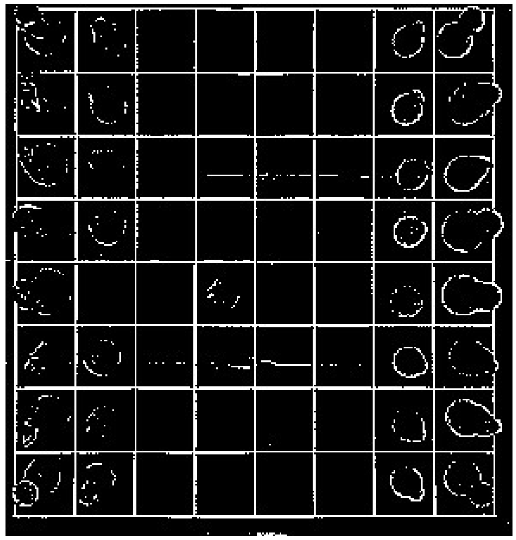

**Fig.3.** Edge detection

In the next step, the Radon transformation is applied directly after the Edge detection. This method was chosen because of its ability to localize straight lines in the image.

Radon transformation is defined by formula:

$$r(\theta,l)=\iint f(x,y)\delta(x\cdot\sin\theta-y\cdot\cos\theta-l)\,dxdy \quad (1)$$

where $\theta$ is the angle and $l$ is the length of normal vector of line, along which we integrate.

The output image, called Radon accumulator, contains a queue of peak values representing horizontal and vertical lines on the chessboard. If a perspective distortion is not considered, the second queue of peak values is shifted 90 degrees.

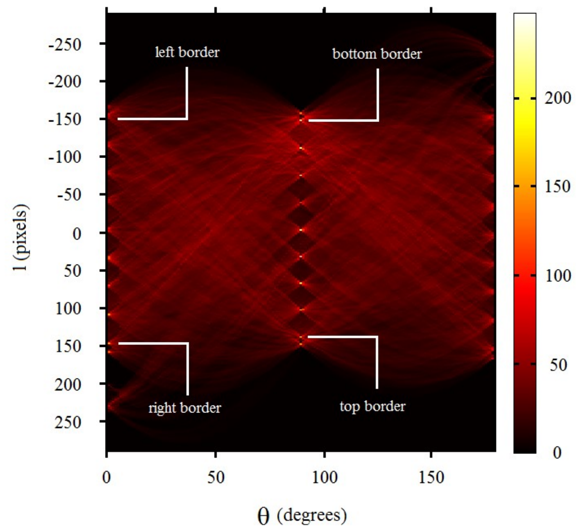


**Fig.4.** Radon accumulator

In total, there are 9 vertical and 9 horizontal lines bordering the chessboard. The normal vector of each line is determined by local peak values in Radon space.

While searching for the peaks, these steps are followed:

Find 20 – 25 local peaks in Radon accumulator,

resolve two angles present the most times - $\theta_1$ and $\theta_2$, (difference between them is 90 degrees),

resolve average distance among the peaks,

scan areas of $\theta_1$ and $\theta_2$, and localize exact position of each peak.

In case of successful localization of the peaks, two matrices containing $\theta$ as angle and $l$ as length of normal vectors will be received:

for horizontal lines

$$M1 = \begin{pmatrix} \theta_{1i} \\ l_{1i} \end{pmatrix} \qquad (2)$$

where $i = 1 \ldots 9$ ,

for vertical lines

$$M2 = \begin{pmatrix} \theta_{2j} \\ l_{2j} \end{pmatrix} \quad (3)$$

where $j = 1 \ldots 9$.

The last step is to find the intersections for each pair of lines. For any two vectors:

$$\vec{u_i}(\theta_i, l_i) \equiv (x_i, y_i) = (l_i \cdot \cos(\theta_i), -l_i \cdot \sin(\theta_i)) \quad (4)$$

a

$$\vec{v_j}(\theta_j, l_j) \equiv (x_j, y_j) = (l_j \cdot \cos(\theta_j), -l_j \cdot \sin(\theta_j)$$

The intersection is gained by:

$$[x, y] = [x_i + x_j, y_i + y_j] \quad (5)$$

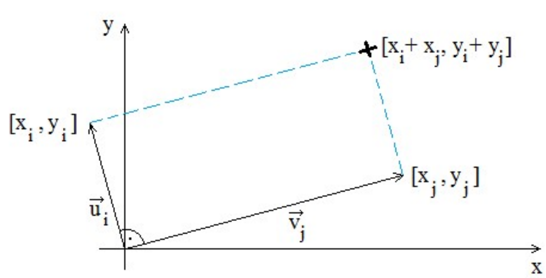


**Fig.2.** Finding the intersections

By consequential determining of all possible interactions, we reach all net depicting borders of the chessboard and all the squares:

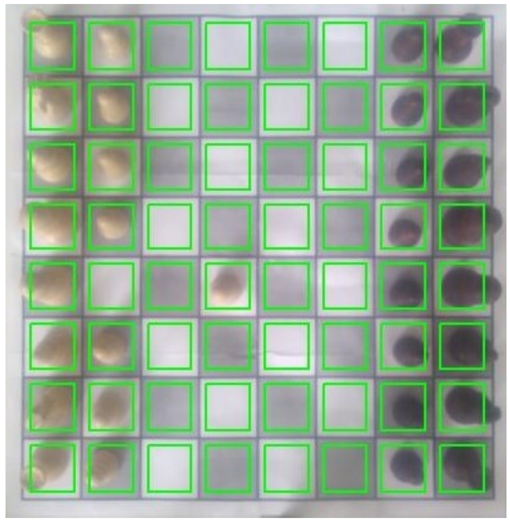

**Fig.3.** Localization of the squares

**Detection of pieces**

There are two ways to determine occupancy of a square. The first one is to go through an area of the square and measure the amount of edges, using an input image after Edge detection. For successful recognition, colours of a piece and a square under must be different enough. If so, the results are truthful.

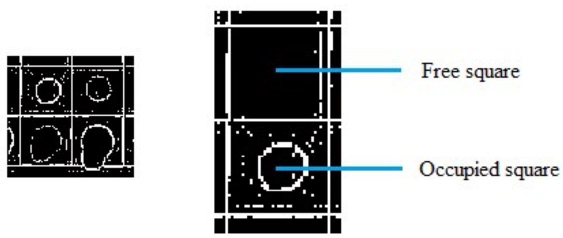


**Fig.7.** Square occupancy by Edge detection

The second method for separation of pieces and squares uses the Colour segmentation. It is necessary to choose a suitable color model.

The standard model RGB, represents a colour by brightness of red, green and blue components. Other colors are made of these basic colours and they are not separated in this model.

An alternative color model is HSV. It defines a colour by these components – Hue, Saturation and Value. This layout is more suitable for colour segmentation and thus easier to filter concrete sections of color hue.

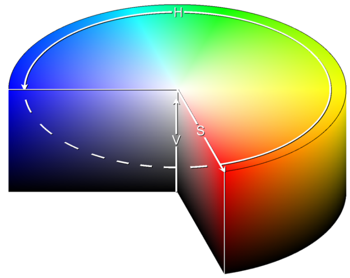


**Fig.4.** HSV Model (Colour HSV model, Online)

The next picture shows the input image after transformation from RGB to HSV color model. As a benefit, the difference between chessboard and pieces is higher than in the input image:

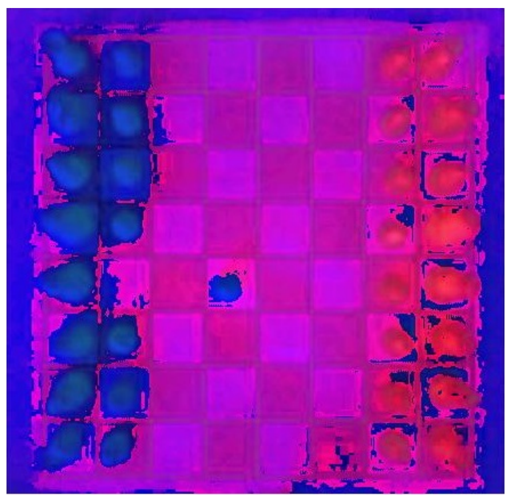

**Fig.9.** Output image in HSV model

Finally, each piece is considered to be white or black by threshold - how much of concrete colour is present in square area. In Fig. 9, white pieces are coloured red, black pieces coloured blue:

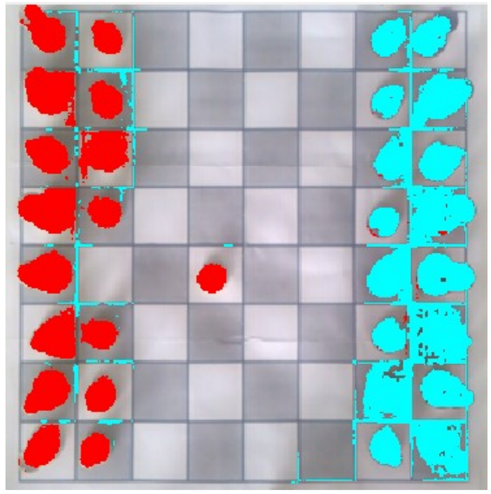

**Fig.10.** Colour filtration in HSV model

## 3. MEASURED RESULTS

The algorithm was tested on 10 games with an average number of 40 moves. The first measured parameter was probability of localizing the chessboard to the number of image frames. Finding 9 horizontal and 9 vertical lines, bordering all squares, was considered as a successful localization.

Success rate was approximately 95%. Mostly, problems occurred when a player was moving a hand above the chessboard and covered the view of the camera. This method, using the Radon transformation, tends to be effective for many board games, because a playing board is mostly determined by sharp edges, lines, and square motives.

The second measured parameter was success rate of piece detection and recognition of proper color. Tests showed that methods of Edge detection and Color segmentation could provide almost flawless results. A very important parameter was intensity of illumination. If the intensity of light impacting on chessboard is too low, the methods usually end in failure. It was necessary to prolong a time of exposition. Eventually, an external source of light was added. Then, borders of pieces after Edge detection were much stronger and quality of colours was improved. During the tests, 9 to 10 games were played having satisfying light conditions.

## 4. CONCLUSION

The proposed algorithm fulfilled predefined requirements, and pieces were correctly detected and recognized by colour. In future development, the algorithm will be focused on recognition of the exact type of piece, e.g. queen or king. To accomplish this requirement, a new system will need a digital camera with higher resolution and methods of image processing for recognition of objects and their shapes in comparison to predefined patterns. This will concretely be in terms of Pattern recognition and Template matching. By applying small modifications, the algorithm can be used for other desk games like Checkers or Go, where only the dimensions of the playing board are different. Our own research pointed out the importance of sufficient illumination of playing board, which can change during the game. Further work will be focused on determining minimal illumination necessary for successful application of Radon transformation and Color segmentation.

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