# Demulti Display: A Multiplayer Gaming Environment for Mitigating the Skills Gap

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## Abstract
Although doing sports and games together is effective to create good social connections, a large skill gap among players reduces the enjoyment in such activities. In this research, we technologically enhance sports and gaming activities in the real world. The gaming environment is aimed at mitigating the differences in ability without reducing the enjoyment. For the initial approach of the research, we implemented a setup for enhancing table games by using a liquid crystals display. The system shows different images to each player using a polarization-based technique. As the application, we implemented an augmented PONG game. The game has a function to support players depending on their scores in the match. This setup can apply to a projector for a wider gaming field for enhancing game activities requiring body movements such as Table Tennis and Air Hockey.

## Author Keywords
Augmented Sports; Skills Gap; Multiplex Imagery

## ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

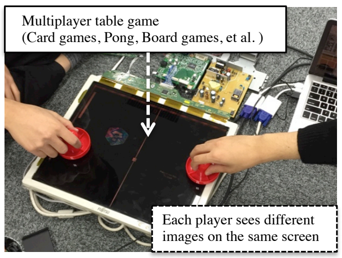



**Figure 1:** A multiplayer gaming environment configured by Demulti Display. The environment shows different images to each player looking at the same screen.

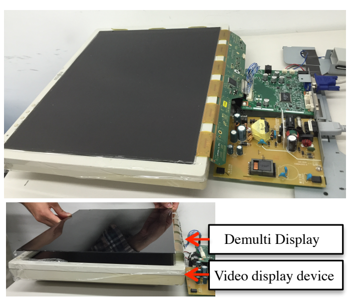



**Figure 2:** Demulti Display: A liquid crystal panel changing the polarization angles of lights from a video display device (Display, projector, et at.) on each pixel. Demulti Display is on a liquid crystal display in this picture.

## Introduction

Doing game activities together is good for creating social connections with others. However, significant differences in ability among players might reduce the enjoyment and create a sense of discomfort during the activity. In general, players with more experience make allowances for the opponents to avoid this situation. Nevertheless, this effort eventually reduces the total enjoyment of the event since other players sometimes feel the effort of the skill modification.

In the case of playing video games, players can fill the gap in ability among players without reducing the enjoyment. The reason is that players can use a stronger player character and/or useful items to modify their abilities. On the other hand, in the real world, acquiring abilities for a game consumes considerable amounts of time and efforts. Therefore, filling the gap during the activity is not feasible in most cases.

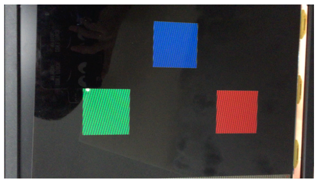
In this research, we technologically enhance games using tangibles in the real world to mitigate the skills gap among players. The installation improves their abilities in real-time depending on the scores in the game. For instance, in the case of an air-hockey game using paddles, the losing player can have skills of vanishing shots and/or curve shots. For the initial approach of the research, we implemented a setup for enhancing table-game experiences such as a board game and a card game (Figure 1). The system is a liquid crystal panel that can change polarization angles from a video display device such as a display and a projector. We named the panel Demulti Display. The gaming environment with Demulti Display can show different images to each player looking at the same environment, and change the difficulty of the game in accordance with their ability.

## Related Work

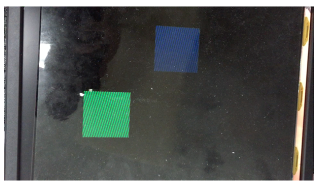
There are several types of research on technologically augmented sports and games. The Bouncing Star project [3], and HoverBall [7] aim to enhance sports using balls. The balls implemented by the projects fly and move in the gaming field by actuators such as a jet spraying device and propellers. The systems can moderate the skill difference among players in the activity. However, the applications are still limited due to the restriction of the machines such as battery life and robustness. Lumisight Table [4] and ExField [1] can provide different images to users surrounding a screen by using a parallax-barrier-based technology. The system shows some images simultaneously, but users can only see one of the images from the same direction. Therefore, the system cannot provide different images to users sitting or standing on the same side, which some board games require. ExPixel [8] can also provide different images to users by using a polarization-based technology. However, this setup requires two projectors with circular polarization filters, while our system can use an LCD or a projector for household use. In existing research on displays capable of presenting personalized information to different users, there are no investigations on skill-deference moderation in games [6, 5]. Augmented Reality glasses can provide the augmented gaming environment. However, the limited size of the field of view may reduce the experience.

## Demulti Display

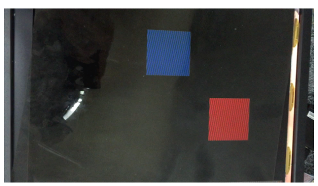
Demulti Display can be configured for a multiplayer gaming environment for table games. The environment can show different images to each player by a polarization-based technique. This technology enables the game to provide appropriate difficulty to each player looking at the same gaming field in accordance with the ability of the player. This should mitigate the skills gap among players without reducing the enjoyment.



(a) Three square-shaped graphics displayed on a liquid crystal display



(b) View from player 1 wearing glasses with polarizing sheets (polarizing angle 45°)



(c) View from player 2 wearing glasses with polarizing sheets (polarizing angle -45°)

**Figure 3:** A table gaming environment configured with Demulti Display. The environment can show different images to each player by a polarization-based technique. Two players wear glasses coated with polarizing sheets.

## Implementation

*System configuration*

Demulti Display is a liquid crystals panel, which can be mounted on a video display device such as a display and a projector. Figure 2 shows the configuration of a gaming environment using a display (LCD) with Demulti Display. Both of the panel and the display are connected to a computer. In the game, two players wear glasses made of polarizing sheets, and they can sit face-to-face or on the same side of the setup. The polarization angle of glasses for one of the players makes a right angle with the other glasses of players.

*Providing different images to each player*

The LCD under the Demulti Display emits polarized light from the screen. Each pixel on the panel has the ability to change the angle of polarized light. Therefore, the Demulti Display can create images, which have different polarization angles on a pixel-by-pixel basis. Figure 3 (a) shows the view of the display. (b) is the view of player 1 wearing glasses with polarizing sheets (polarizing angle $45°$), and (c) is the view of player 2 (polarizing angle $-45°$). As shown in Figure 3 (b), the red square on the right is invisible from player 1, and the green square on the left is hidden from player 2. The reason is that light shielding occurs when the polarization angles of light from the screen are at a right angle to the angle of polarizing sheets on the glasses.

*Liquid crystal panel*

We took the liquid crystal panel apart from a color TN-type LCD (VL-178SSL). We removed the liquid crystal layer coated with two polarizing sheets in the LCD. The number of pixels is $1280 \times 1080$. Each pixel consists of three sections to control the polarization angles for three colors (RGB). The rotation angles through each section are

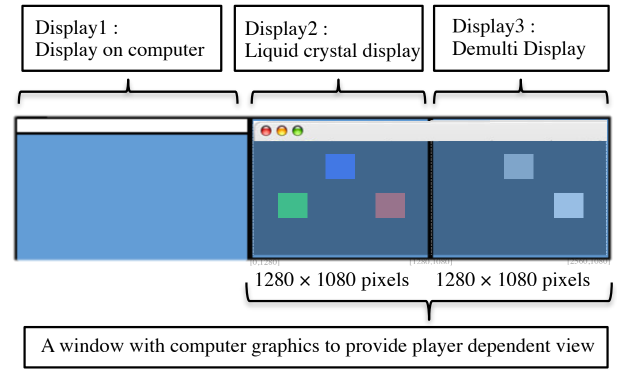



**Figure 4:** The multi-display configuration of the computer. A window with computer graphics to provide the player-dependent views is placed at the left edge of the display 2, and the right edge of the window matches with the right side of display 3.

changeable via a D-sub port in the same way as a sub-display connected to a computer. For instance, displaying whole white screen on the panel means rotating the polarizing angles by around $90°$ to $120°$ on all pixels. Displaying gray screen changes the polarizing angles by around $45°$ to $60°$. The rotation angle depends on the liquid crystal panel.

## Example Program

We shows a example for showing a blue square to each player, a green square to one of the players only and a red square to the other player as shown in Figure 3 in this section.

*Display setting*

The multi-display configuration of the computer is shown in Figure 4. Figure 5 shows the window to change the polarization angles for providing different images to players. The display on the computer, LCD, and Demulti Display are

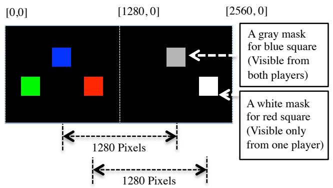



**Figure 5:** A window to show the red square only to one of the players, and green to the other player, and blue square to both of the players.

recognized as display 1, display 2, and display 3 respectively. Display 2 is placed at the right side of the display 1, and display 3 is set just right side of the display 2 in the multi-display setting. In Figure 4, we generate a window of $2560 \times 1080$, and place the left edge of the window to the left edge of display 2. The right side of the window matches with the right edge of display 3.

*Software setting*

The computer graphics to provide the player-dependent views is as follows. The setup shows the red square only to one of the players, and green to the other player. Both of the players can see the blue square.

We create three 200 pixels squares on display 2 for the LCD in the window between [0,0] and [1280,0] as shown in Figure 5. In addition, we create two 200 pixels squares on display 3 in the windows between [1280,0] and [2560,0]. The X value of the gray square is 1280 pixels right of the blue square, and the X value of the white square is 1280 pixels right of the red square. Both squares' Y values are the same as them. This setting matches the physical size and position of the white and gray square with the red square and blue square respectively as shown in Figure 6.

The mechanism to provide different images to players is shown in Figure 7. The pixels on the red square rotate the polarization angle by around $90°$ counterclockwise from the original angle. The pixels on the blue square rotate the polarization angle by around $45°$. By the rotation, the polarization angles on the red square become $-45°$, and those on the blue square become $0°$. For this reason, player 1 (polarizing angle $45°$) cannot see the red square, and player 2 (polarizing angle $-45°$) cannot see the green square.

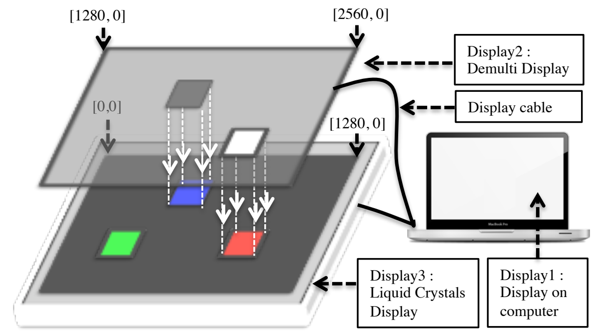



**Figure 6:** The resolution and size of the LCD are the same as the Demulti Display. The size and position of the white and gray squares physically match with the red square and blue square respectively.

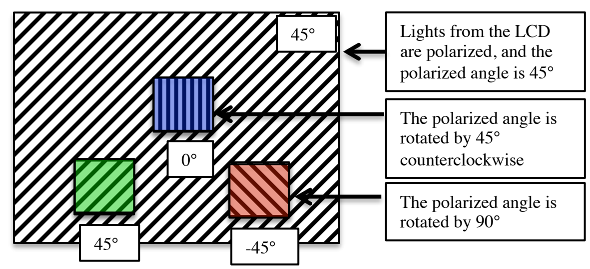



**Figure 7:** Polarization angles on the environment. The masks on Demulti Display rotate polarization angles. By the rotation, the polarization angles on the red square become $-45°$, and those on the blue square become $0°$.

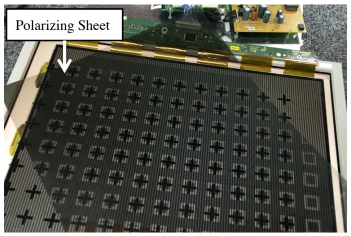



**Figure 8:** A calibration method for physically matching the sizes and intervals of masks on Demulti Display with the graphics on the LCD.

## Calibration

The size of the computer graphics on the LCD must physically match with the masks on the Demulti Display. For calibration, the LCD displays fixed size crosses on the screen in the same intervals, and Demulti Display shows squares on the screen in the same way. By mounting a polarizing sheet, we can see both of the graphics on the LCD and the panel as shown in Figure 8. For matching the physical sizes of the graphics on the display and Demulti Display, users can expand and/or scale down the graphics by a simple GUI.

## Application: Augmented Pong Game

We implemented an augmented pong game using the function to provide different images to each player. In the game, players control bars to bounce a ball to other side using paddles in the real world. A USB camera takes images of the fields around each paddle, and the system tracks the paddles using an image processing technology known as optical flow. In the gaming area, a box titled "Item" appears at a random place at random intervals. If the ball hits the box, the player gets one supporting item giving them an advantage in the game. We implemented two items from the "item" box as follows.

**Small ghosts bouncing the ball:** A number of ghosts appear in the gaming field. They are invisible for one of the players. They bounce the ball to the other direction when they hit the ball.

**Big ghosts hiding the ball:** A few ghosts appear in the filed. One of the players cannot see the ball while it is under one of the ghosts.

Since one of the players cannot see the ghost, he/she cannot predict the direction change of the ball in the game. This function enhances the difficulty in the pong game only for one player. Moreover, the losing player gets stronger support than the winning player, such as bigger and more ghosts. Therefore, players would be able to enjoy the game independent of their skill even if there is a large skill gap between players. For a pilot study to validate the function, two players played the game. During the game, one of the players commented, "The bounce of the ball by a hidden goat is unexpected and difficult to receive." However, the other player mentioned, "I can slightly see the ghost, and can predict the bounce indeed." This contradiction is caused because the system still has a limitation that it can not completely hide the image for one of the players. We found the system can increase the difficulty only for a player, but more quantitative analyses are required to validate the concept [9, 2].

## Limitations and Solution

The system uses linear polarization to separate images to each player. Because of this, the function is only available when players view the gaming field from fixed angles. For example, if player1 moves the head position or orientation, he/she can somewhat see the graphics for player 2 in the gaming field. Therefore, players cannot change their head positions. Another issue is that players can slightly see the graphics hidden even if the panel rotates the polarized angles by $90°$ counterclockwise from the original angle from a player.

Circular polarization instead of the linear polarization solves the first issue as follows: If we put a quarter-wave plate on the Demulti Display, the panel emits circular polarization. In this case, the players can wear 3D glasses using circular polarization, which are widely used for 3D movies. To let player 1 only see right or left handed circularly polarized lights, we can put a half-wave plate on one side of the

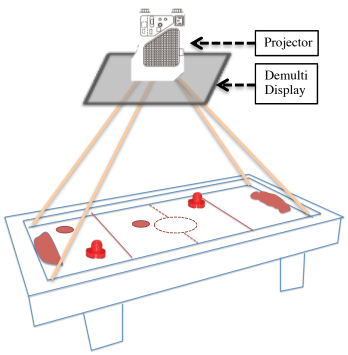



**Figure 9:** Augmented Air hockey using a projector with Demulti Display. The setup can hide the puck from one of the players by projecting exactly same color as the puck or by showing fake pucks in the field.

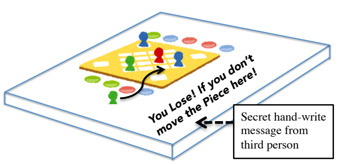



**Figure 10:** Board games enhancement. In the game, an experienced third person can help the less experienced player by showing secret messages or diagrams only visible from him/her in the gaming field.

glasses. To let player 2 only see the opposite rotation direction of circularly polarized lights, we can put a half-wave plate on the other side of the glasses. This plate reverses the rotation direction of the circular polarization. Therefore, the 3D glasses with a half-wave plate carry only left or right circularly polarized lights to player 1 or player 2 respectively. A characteristic of TN-type LCD causes the second issue. Using an IPS-type LCD as Demulti Display can solve the problem. Using a DLP-Link type of 3D projector is also an alternative; however, this requires customized active shutter glasses where each side can down the shutters at the same time. We can also use the projector for providing the augmented games for more than 2 players by combining it with our polarization-based technology.

## Future Work

As the initial phase of the research, we used an LCD under the panel. Thus, the gaming field is quite small. However, the setup can use a projector for a larger gaming field. In this case, we can use the function works with tangibles such as Air Hockey and Table tennis. To make the setup general, we can make gaming API that directly controls the two monitors for game developers.

### *Air hockey*

Figure 9 shows a future application on Air hockey using a projector with Demulti Display. For skill-gap mitigation, the environment can hide the puck from one of the players by projecting exactly same color as the puck to the gaming field, or projecting fake pucks which have the same color and the size randomly in the field. The system uses polarization. Since polarized lights become natural lights when reflected, we have to put a silver screen on the gaming field which can sustain the polarization property even after the reflection. We can also paint the gaming filed by a silver spray instead of having the screen.

### *Board games*

The system can apply to board games. Figure 10 shows an example of a board game with Demulti Display. In the game, an experienced third person can help less experienced player in the game by writing a secret message only visible for him/her in the field. This function is useful when one of the players is new to the game, and he/she needs an experienced supporter. Previously, in this situation, the assistant needs to tell the advice aloud, but sometimes the other player can hear the message. This reduces the enjoyment in the game. However, Dumlti Display can avoid the situation since the adviser can just write messages and/or diagrams in the environment.

## Conclusion

We have introduced the Demulti Display, a panel to configure a multiplayer table gaming environment. The game can provide appropriate difficulty to each player following the ability and/or the score of the player. Therefore, the environment would make games enjoyable even if there is a significant skill gap. We took a polarization-based approach to providing different images to each player. For the first trial of the research, we used a liquid crystal display to configure a table gaming field with the Demulti Display. We also implemented an augmented pong game to adjust the gaming difficulty for each player depending on the score. The setup can use a projector to provide a larger gaming space. Therefore, the system can be applied to sports and games using a 3D space such as Air Hockey and Table Tennis.

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