OuijaPlus: A Force Feedback Ouija Board

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ABSTRACT

In this paper, psychological, psychophysical, and physical models of Ouija phenomenon were explored. A haptic interface based on a position-controlled 3-DOF twin-pantograph robot was designed to simulate the second player in a two-people Ouija game. A user-study was conducted to examine the ability of this interface to provide Ouija-like experience. Preliminary results were analyzed and future improvements were suggested.

Keywords

Ouija board, haptic interface, robot control

1. INTRODUCTION

Ouija board(Fig. 1), as a special kind of talking board, has long drawn the attention from spiritualists, scientists, and psychologists. Its power to move "by itself" and give answers to questions seems all but magical.

Efforts to study phenomenon similar to Ouija spelling, such as table turning, can be traced back to as early as 1853[3]. Some studies in recent years, such as [1], provide further insight into the psychological mechanism of phenomenon involving involuntary movement.

Our aim is to build a haptic interface which simulates the movement of a player's hand in Ouija playing. For ease of test, the design is based on a simplified Ouija playing protocol: the answers to all questions should be either YES or NO. This is also the protocol we have adopted for user study.

The significance of this study is two-fold: if the interface is shown to resemble a human's hand playing Ouija, it could be used to record, analyze, and facilitate studies of Ouija phenomenon; secondly, the interface provides a constructive way of understanding physical side of Ouija phenomenon - we postulate model, implement the interface accordingly, and test its validity. If certain parameters of the system are found to be crucial to user's perception, we could pay more attention to related physical aspects, and vice versa.

In the following, we will first describe our understanding of Ouija phenomenon, postulate physical models, and formulate our design accordingly; we then discuss our user study and the results we have got; in the end, we propose improvements to the current system.

2. THE OUIJA PHENOMENON

The two "magical" things about Ouija board are:

1. Nearly everyone thinks it is the others moving the Planchette, but no one themselves will admit they have moved it.
2. Ouija board gives *meaningful* answers.

We tend to avoid the spiritual explanation, which is dominant in popular culture; this is because it says not too much more than that Ouija is mysterious and incomprehensible. Rather, we adopt a more psychological and psychophysical point of view.

2.1 Psychological and psychophysical explanation

We argue that phenomenon 1 occurs because of the unequal ability of human tactile and kinesthetic sensors. It is likely that the receptors mainly responsible for sensing the Planchette's movement are mechanoreceptors, specifically *Ruffini Endings* in charge of sensing skin stretch and static force on skin; on the other hand, it is the kinesthetic receptors being responsible for the perception of self-motion. We notice that there is a bandwidth gap between these two kinds of receptors: for mechano-receptive Ruffini Endings, the sensing bandwidth is $0.4 - 100$Hz, while for kinesthetic receptors, the bandwidth is only $20 - 30$Hz[4].

Moreover, relatively speaking, finger tips are the most sensible part of body in terms of sensing external forces, while in terms of sensing self-motion, they are worse than more proximal parts, say shoulders(just-noticeable difference(JND) for finger joint is 2.5 degrees while for shoulder is 0.8 degrees)[4].

In this sense, we are more capable in perceiving forces exerted on our body, than sensing the motion of our body(at least in regards of fingertips).

From a control point of view, this is analogous to the case that we have superior force sensors to position sensors. The control behavior generated may be interpreted as "incomprehensible" as in Ouija's case.

It is more subtle to explain phenomenon 2. If we were to believe it is the players responsible for the Planchette's motion, and they are not aware of it, how could they move it (jointly) toward meaningful answers? We believe this behavior is likely to lie in a broad category of *automatisms* – behaviors occurring without conscious will; other examples are hypnosis and sleepwalking. Theory such as ideomotor response has been developed to explain such phenomenon, for which please refer to comprehensive treatment such as [5] for details.

Indeed, part of our motivations for designing a haptic Ouija board is to gain more insight into this psychological phenomenon.

2.2 Physical Model of Ouija Playing

In order to design a control mechanism that could mimic the behavior of a player's hand, we need to analyze the process of Ouija playing in more detail physically. In the following we discuss the model we adopt.

2.2.1 Start-up

What makes Planchette start moving? We propose that it is because of the break of balance between joint-force of players and static friction: when the joint-force from the players is greater than the static friction between board and Planchette, Planchette will start moving in the joint-force direction. This will be more likely to happen when players get tired suspending their arms in the air while keeping slight contact with the Planchette - this explains why the Planchette does not start moving instantly.

2.2.2 Intermediate

What keeps the Planchette moving? We propose that it is because of the players' false estimation of motion of Planchette. The players subconciously follow the motion of Planchette rather than trying to move it; but since the players are in contact with the Planchette, the only condition that the players are actually following the Planchette (or when static friction between their fingers and Planchette is zero) will be when *all* players are *accurately* estimating the Planchette's future motion. This condition is extremely hard to fulfill according to our psychophysical analysis above, thus is highly unlikely to occur. What is more likely to happen is that when players follow the Planchette, they are constantly over/under-estimating the true trajectory of the Planchette and thus their fingers will temporarily apply positive/negative forces. This over/under-estimation of trajectory and force resulted could be well modeled by a spring-damper system(as in Fig. 4). One end of the system will model the estimated (desired) position and the other end the current position. It can be further shown that this system is equivalent to a PD position controlled robotic end-effector, which is exactly what we have implemented.

2.2.3 Stop

We propose that when the Planchette approaches "Yes" or "No", the players will tend to decelerate the Planchette by applying negative forces.

3. DESIGN AND IMPLEMENTATION

3.1 Mechanical Design

The force-feedback Ouija system is developed on top of Quanser 3-DOF Pantograph robot (see Fig. 2).

Mechanical linkages are designed to hold the Planchette under pantograph gripper so that Planchette has tight contact with the mounted Ouija board while still has some rotational freedom around gripper axis.

Figure 1: Two people playing Ouija

3.2 Controller Design

3.2.1 PD controller

As rationalized above, the controller we adopt is a PD position controller, specifically, a joint-space PD controller.

The basic idea of position control is to express the desired robot behavior in commands that control desired position, and to execute such commands through controller. The top level control loop is as shown in Fig. 3. In each loop, we first define our desired Planchette position in *Task Space* - the Cartesian space user interacts with - using a certain set of trajectory planning strategy; then we apply inverse kinematics to obtain the desired position in *Joint Space* - expressed through angles of each of the motor arm; next we command the robot to approach the desired position through Joint Space position controller, and sense the position in Joint Space; in the end, we pass the sensed position back to trajectory planner through forward kinematics, in order to compute the desired position in Task Space for next time-step.

The equation of PD controller is:

$$F = K_T(K_P(p_{desired} - p_{current}) + K_D(p_{current} - p_{prev})) \quad (1)$$

Where K_T is the motor torque constant. We could adjust the response of the controller by adjusting K_P and K_D, which affects the dynamic characteristics such as percent overshoot and time to first peak.

More intuitively, we think of the PD controller in Eq(1) as equivalent to a mechanical spring damper system, as in Fig. 4. When we change K_P and K_D, we are changing the damping and stiffness of the equivalent mechanical system. It is exactly this spring-damper system we are using to model the effect of another player's hand.

3.2.2 Trajectory Planner

To drive the above PD controller, we have devised a set of *ad hoc* trajectory planning strategies, which we have nicknamed "Random Walker", "Follower", and "Safekeeper". These strategies reflect respectively the start-up, intermediate, and stop state of the physical model introduced above.

Simply put, we use "random walker" to model the start-up process and to detect user micro-movement; we use "follower" to keep the Planchette in motion and to amplify user's

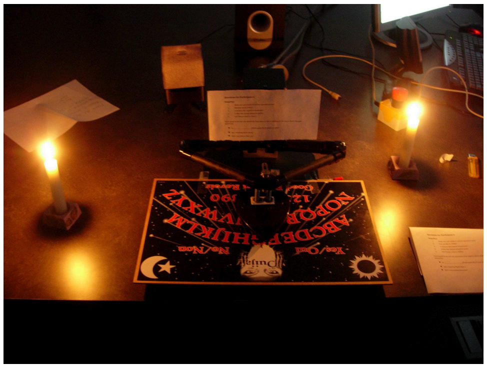

Figure 2: Planchette and board mounted on pantograph robot.

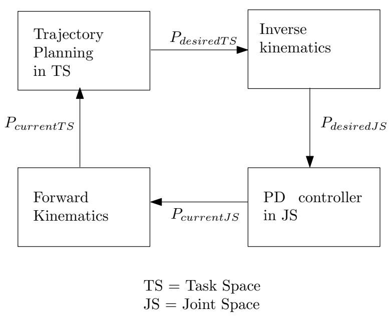

Figure 3: Controller top-level block diagram

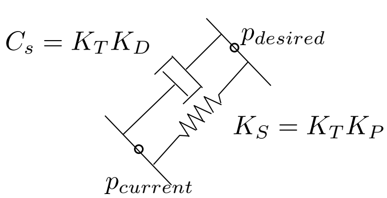

Figure 4: Spring-damper model

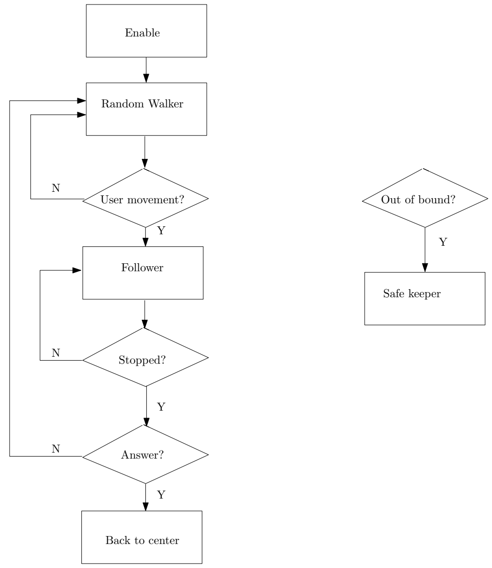

Figure 5: Flow chart of trajectory planner

input; and we use "Safekeeper" to confine Planchette's motion inside the boundary of board. A flow chart of deployment of each function is as shown in Fig. 5.

After enabling, the trajectory planner will generate the desired position according to current state of system: If Planchette is not in motion (velocity lower than a threshold v_{thrd}), "random walker" is brought on-line; if Planchette is in motion, "follower" will be functioning; if Planchette is out of bound, "safekeeper" will constrain the motion.

A diagram showing how the three modules generate next-step desired position is as shown in Fig. 6.

"Random walker" sets desired position as follows:

$$p_{desired} = p_{current} + p_{random} \tag{2}$$

where p_{random} is a uniform random vector with mean 0. The maximum norm of p_{random} is chosen such that the resulting force generated by PD controller barely moves the Planchette under "random walker" mode. In this way, Planchette moves most easily in the direction of $p_{desired} - p_{current}$ under user's touch. If user happens to move in this direction, Planchette will possibly move beyond v_{thrd}, and trajectory planner will enter "follower" mode.

The desired position update equation of "follower" is:

$$p_{desired} = k(p_{current} - p_{prev}) + p_{current} \tag{3}$$

where k is chosen such that the force generated by PD controller will gently pull the Planchette in the user's moving direction. In this way, follower "amplifies" user's motion.

Because the behavior of "follower" is inherently unstable – it will keep accelerating if user lets go, we need to employ safety conditions. This is especially crucial when pantograph is near singular positions, that is, when robot arms fully extend out. In singular positions, control command will fail to execute and the robot will become unstable and dangerous.

The "safekeeper" is the first level of safety – it automatically decelerates Planchette if Planchette is far from origin. The further away, the larger deceleration. The deceleration is only functional in the direction away from center; when user tries to move the Planchette back to center from bound-

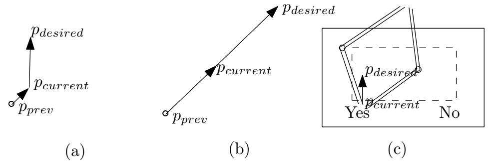

Figure 6: Trajectory planning for (a)Random Walker, (b)Follower, and (c)Safekeeper. For (c), the safety boundary is shown as dashline.

ary, "safekeeper" will not prevent this, and "follower" will be functioning. In this sense, "safekeeper" complies with the physical model of stopping described previously.

The second safeguard is that the motor current will automatically cut off in regions around singularity. The third level of safety is a keyboard-controlled enable/disable – the system is only actuated when an enable key is pressed. With these safeguards, the robot has stayed safe and stable all through our user study period.

An additional function is *back-to-center*; when deployed, it generates a trajectory that automatically moves the Planchette back to starting position. This was developed during the later part of user-study to enhance the illusion of tele-Ouija. The detailed reason will be explained in user study part.

3.3 Controller Implementation

The controller is mainly implemented in Simulink. The model is compiled using Realtime Workshop and downloaded to WinCon Server on the same machine. WinCon server in turn facilitates real-time data acquisition and control of the robot.

4. USER STUDY

4.1 Aim

The primary objective of user study is to evaluate OuijaPlus. This evaluation is done based on user's feelings after having two Ouija sessions, one with traditional Ouija and one with OuijaPlus. The users compare the two "versions" of Ouija using a questionnaire. We have also tried to pin-point factors that might affect user's responses in doing this comparison.

4.2 Users

Our users include people who believe in Ouija as well as those who do not. Through this mix of people we have tried to get an unbiased response for both the versions of Ouija. We had eight users in total. Most of our users were students between the ages of 20-29. There were two female users.

4.3 Experiment Design

The users had both a traditional Ouija session and a OuijaPlus session during our experiment. We had two participants and one coordinator for each session. One of the partipants were the primary participant, called participant A. The other participant was the fixed player in all the studies, called participant B. Participant B was one of the student investigators. We gave two sets of questions to both participants: One for Traditional Ouija and one for OuijaPlus. There were some fixed questions in the question sets which included general Ouija questions and some factual questions. Users were encouraged to ask any questions they wanted to ask in addition to the fixed questions. The purpose of having fixed questions is to help user get comfortable with the game and to make sure the questions that will help us with the analysis are answered. Factual questions are included so that they can be used to test if players' subconscious mind is functioning. All the factual questions included are either based on recent events or material that were likely to have been covered by students in their earlier years of education.

During the experiment, participant A will play traditional Ouija with participant B. They will take turn in asking questions; coordinator will record answers to the factual questions. After all the questions are asked and participant A feels comfortable enough to do the comparison, s/he will be asked to play using OuijaPlus.

We used deception to convince participant A that playing OuijaPlus is similar enough with playing with another person. We told the user, before starting the OuijaPlus session, that they would be playing over the Internet with the participant they played traditional Ouija with. They were told that the other person had a similar setup in another room and they would be able to communicate with them as well as to see the board. After the OuijaPlus session, when users had finished the questionnaire, they would be informed of deception and apologized to.

4.4 Set-up

The experiment set-up involves three computers: one for controlling robot, two for communication; one set of traditional Ouija; OuijaPlus; candles; and speakers for communication and music playing. During the session, coordinator was in charge of logging answers, taking video, and enabling robot; participant B was responsible for interacting with subject(Participant A), and pretending playing through teleoperation.

4.5 Problems and Solutions

We discovered after two user trials that they both felt the Planchette was moving too fast and there was vibration in the beginning (This can be reflected by the first two subjects' response to the question "which aspects of OuijaPlus make you think it is not giving you the real Ouija feeling": Planchette's motion is strange). We tried to improve on this by lowering the Planchette to increase friction with the board and by decreasing Random Walker update rates. After this improvement, only one out of six later subjects chose this option.

Through questionnaire and interview, we found out another factor users did not like about our system was that it did not feel like playing with another player. We tried to enhance the illusion of playing with another player by doing the following:

1. Use remote desktop to control the robot using one of the communication computers; in this way we created the illusion the robot is not controlled by the computer connected to it (and could actually enable tele-control from another room, but we did not try).

2. Implement a "back-to-center" function which brings the Planchette back to the starting position when a keyboard command is invoked. This illusion is quite effective: when one of our later subject asked the "teleop-

erating" opponent to move the Planchette so he could see the opponent was in fact controlling it, we invoked this function to convince him. He was genuinely deceived. (We told him the truth afterwards for sure.)

4.6 Results

Results are calculated on basis of responses of users to the questionnaire.

4.6.1 Comparison between Traditional Ouija & OuijaPlus

OuijaPlus was compared with Traditional Ouija on various factors which, in our opinion, contribute to overall feeling of Ouija session. The results are:

- 50% of the users found connection with other player better in Traditional Ouija, while 37.5% of users found OuijaPlus better.
- 87.5% of users found Traditional Ouija and OuijaPlus equal in their ability to give answers; 12.5% users found OuijaPlus better.
- 50% of users found that the amount of concentration was the same in both versions. Equal percentage of people believed that they were able to concentrate more on one of the two versions (25% for each version).
- 75% of user found OuijaPlus was at least as quick in giving answers as Traditional Ouija. Half of these users believed that OuijaPlus was quicker.
- 100% of users found ability to give answers to questions previously unknown to user same in both versions.
- 62.5% of users found interaction with other player better in Tradional Ouija. 12.5% users found OuijaPlus better with interaction and 25% found them equal.
- 87.5% of users found OuijaPlus at least as easy to use as Traditional Ouija. 37.5% users found OuijaPlus easier and 12.5% found Traditional Ouija better.
- 100% of users found that OuijaPlus gives at least as much satisfaction of use as Traditional Ouija. 37.5% users found OuijaPlus better.
- 87.5% of users found that OuijaPlus has at least as much ability to engage player as Traditional Ouija. 25% found OuijaPlus better at this and 12.5% found Traditional Ouija better.

4.7 Success of OuijaPlus session

To determine overall ability of OuijaPlus in providing successful Ouija sessions, we test the following hypothesis:

Null Hypothesis: $H0 : \mu 0 = \mu 0+$: OuijaPlus is as successful at having Ouija Session as Traditional Ouija.

Alternative Hypothesis $H1 : \mu 0 < \mu 0+$: OuijaPlus is more successful at having Ouija Sessions than Traditional Ouija.

Here $\mu 0$ is the mean of responses regarding success of Ouija Session and $\mu 0+$ is the mean of responses regarding success of OuijaPlus session. Using t-Test of two samples with unequal variances, with 95% confidence level, we rejected null hypothesis in favor of alternative hypothesis that OuijaPlus is more successful at having Ouija Sessions.

4.8 Factors affecting playing experience

Correlation between following factors and "similarity of experience between Ouija & OuijaPlus" was evaluated:

- Ability to start giving answers early
- Frequency of giving answers
- Naturalness of the movement of Planchette
- Lightness and ease of use of Planchette
- Giving feeling like playing face to face with other player

In the user group we studied, strongest correlation occur between the similarity factor and the factor "the game is like playing face to face". The correlation coefficient for this factor is: 0.64.

This means not being able to play face to face might contribute to user's experience of not having an as authentic Ouija experience. This is confirmed from our interview with user.

The interesting thing is, one of the experienced players actually preferred the non-face-to-face aspect of OuijaPlus, since in this way he could not feel directly another player's influence, and thus attributed the motion more to mystical origin, which surely enhanced the aura of Ouija phenomenon.

4.9 Success of the Session

There is a strong correlation between the user's feeling of the success of Traditional Ouija session and success of OuijaPlus session (Correlation Coeff: 0.65). Surprisingly, there was not a very strong correlation between similar playing experience (Correlation Coeff: -0.4). This suggests that success of Ouija session in playing OuijaPlus does not depend on similarity of playing experience between Traditional Ouija and OuijaPlus. There is also evidence that lightness of planchette and ease of playing OuijaPlus is related to success of OuijaPlus session (Correlation Coeff: -0.81).

4.10 Connection with Ouija

There is a strong correlation between feeling connection with Ouija during Traditional Ouija session and feeling it during OuijaPlus session (Correlation Ceoff: 0.78). This means, users who feel connection with Ouija during traditional Ouija session are more likely to feel the connection with Ouija during OuijaPlus session.

4.11 Relationship between User's Answer and Ouija's answer

We hypothesize that when plachette moves in response to a question, it would move towards the answer in user's mind, i.e., the answer user knows or guesses. There can be two cases:

- Ouija gives the same answer as what user knows.
- Ouija gives answer different than what user knows.

Sometimes, user doesn't know the answer consiously but knows the answer in their subconcious mind or is inclined towards an answer. This corresponds to the following two cases:

- Ouija gives the same answer as what user guesses.

- Ouija gives answer different than what user guesses.

We first need to establish that there is a relationship between what user knows or guesses and what response Ouija gives. In our study, we can imply this by calculating percentage of responses for the above four cases for both traditional Ouija and OuijaPlus. User's answer were obtained through questionnaire, while Ouija's answers were logged by coordinator. Notice here we do not consider the influence of participant B, since her influence averages out across the study.

These are the average percentage of responses found in our study:

- Ouija gives the same answer as what user knows: 57.14%
- Ouija gives answer different than what user knows: 42.86%
- Ouija gives same answer as what user guesses: 40.48%
- Ouija gives answer different than what user guesses: 59.52%

For OuijaPlus:

- OuijaPlus gives the same answer as what user knows: 41.67%
- OuijaPlus gives answer different than what user knows 58.33%
- OuijaPlus gives same answer as what user guesses 70.48%
- OuijaPlus gives answer different than what user guesses 29.52%

It is of interest to note OuijaPlus agreed with user's guess much more often than Ouija (70% vs. 40%), which may indicate the answers OuijaPlus gives do reflect part of user's intension. The validity of this result needs to be verified through more extended user study.

5. DISCUSSION

5.1 Trick of deception

The use of deception is quite crucial in the user study of our system. We have noticed that engineering students, especially those with robotic knowledge are hard to deceive (Sadly these students are also our major source of subjects).

The use of deception is very similar to the tricks used by magician. In technology context, Arthur C. Clarke once cleverly noted: "Any sufficiently advanced technology is indistinguishable from magic."[2] For people who understand related technology, the magic is no longer magical. Therefore, it would have been much better to have people from outside engineering curriculum to test our system.

5.2 Limitations and Future Work

One key problem still existing in the current system is: the robot tends to oscillate when switching back and forth between "random walker" and "follower". Unfortunately, fast switching is very likely to happen because we are only using the velocity threshold v_{thrd} as switch condition, and velocity can cross this threshold up and down several times in short interval during start-up.

The tentative solution we have tried out is to employ a timer mechanism that inhibits switching back to "random walker"for a period of time when "follower" is on-line . This solves the oscillation problem but makes the system not so responsive. We did not adopted this solution in the end.

The stability of switched-control is in fact a very deep topic. It will be helpful to investigate some of the solutions in literature and look for an appropriate answer to our problem.

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