Screenless Interactive Tabletop Gaming with Capacitive Surface Sensing

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Figure 1: In this work, we introduce a capacitive-based system, extending traditional action point board games with automatic point-counting.

ABSTRACT

Many interactive systems that support tabletop games either augment the experience with additional elements or transform game components into digital counterparts, e.g., using mixed reality. However, as many users prefer tangible game elements, digital augmentations can disrupt the immersion they seek to enhance, often due to the complexity of the hardware used. Responding to this challenge, we designed a screenless interactive tabletop system with capacitive sensing. The system is suitable for novice players and provides automatic score-keeping. Our method eliminates the need for external sensors and retains all original game pieces intact. We evaluated our system in a study with a forest planting game ($n = 20$). Gameplay with our system exhibited shorter turn duration, and participants adopted more effective strategies than in traditional gameplay. These results underscore the potential of screenless interactive tabletops to amplify the gaming experience without causing distractions.

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CCS CONCEPTS

• **Human-centered computing** → **Interaction techniques**; **Interaction devices**.

KEYWORDS

Board Games, Capacitive Sensing, Tangibles, Touchscreen, Machine Learning, 3D Printing

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1 INTRODUCTION

Tabletop gaming is deeply rooted in human culture, providing players with immersive experiences that require strategic thinking, social interaction, and creativity [34]. However, traditional gaming is a manual activity, often burdened with laborious bookkeeping actions [1]. These can present challenges, which may reduce performance and lead to a less enjoyable gaming experience, particularly for players starting their adventure with a new game. Consequently, there is a strong strand of Human-Computer Interaction (HCI) research that aims to improve the user experience in tabletop gaming.

A considerable body of work on augmenting tabletop gaming largely stems from the tradition of studying interactive tabletops. Overhead projectors [6], electrochromic displays [13], and interactive tabletops [21] have been proposed to display essential game information or enrich the game experience. Some board games have been recreated in fully digital formats [9–11, 17, 37]. However, while offering additional visual feedback, such solutions may also distract the player from the core gameplay. This was apparent in a comprehensive study of content on tabletop gaming forums, which revealed that one of the most common reasons for resistance to the augmentation of tabletop games is the intrusiveness of electronics. Additionally, players complained that the lack of tactile and physical elements detracts from the overall enjoyment of the game [16]. Consequently, it is a challenge for HCI to develop interactive systems that can support players during tabletop games while minimizing user interactions with the system and preserving as many of the original game components as possible.

In this paper, we propose a screenless system designed to support tabletop gaming. For demonstration purposes, we developed the system to support the game *Photosyntesis*. Our solution uses a translucent capacitive sensing foil and removable conductive markers to detect player moves. This preserves the tangibility and original appearance of the game as much as possible. Point counting is entirely automatic, without requiring any data entry from the players during the game. To investigate the influence of our system on the game's progression and the player experience, we conducted a between-subject study with ten pairs of players who had no prior experience with the board game. We compared gameplay metrics and player experiences between original and augmented versions of the game. Our results show that gameplay with our system exhibits a shorter turn duration than in an unmodified game. Additionally, participants engaged in more efficient strategies when playing the augmented version of the game. Our results highlight the potential of similar solutions to enhance the overall gaming experience while preserving the essence of the original game.

The main contributions of this short paper are as follows: (1) a screenless tabletop game-piece tracking system for enhancing tabletop games; (2) an empirical user study to evaluate the system's influence on the gameplay; (3) practical insights to guide the future development of technologically augmented tabletop gaming systems. Additionally, we provide source code and design files for our prototype. [1]

2 RELATED WORK

In this section, we provide an overview of existing work related to augmented board games and tangible object tracking on tabletop surfaces.

2.1 Augmented board games

The integration of technology into board games represents a wide-ranging area of study, ranging from algorithmic support for finding better play strategies [5, 7, 14] to digital user experience enhancements [12, 15, 27]. Creating digital versions of tabletop games has been investigated in the development of interactive tabletops [21]. Another frequently discussed topic is the development of hybrid platforms, using projectors on traditional tables [6] or large tabletops [8, 20, 24]. Such platforms allow for easy adaptation to a given physical space. They facilitate the simple design, optimal presentation of boards, and fairness in role-playing games (RPGs) [8] and other strategy games with modular boards [28]. These systems also enable additional interactions, thanks to the detection and positioning of game elements with vision markers [8, 20] and vision systems [6].

However, such platforms can interfere with the original game board due to the need to replace original pieces with elements tailored to the detection (e.g., capacitive or vision) system [17, 24]. Furthermore, systems using projectors require mounting equipment above the table, making them difficult to move [6]. Tabletop-based setups significantly increase the cost of the system [8, 20].

Our proposed system does not necessitate intrusive changes to the game components. It preserves the game's original aesthetics, keeping costs low and eliminating the need for an overhead projector. At the same time, the system does not interfere with the decisions made by the player.

2.2 Tracking and identifying tangibles on tabletop surfaces

One of the most popular solutions for tracking tangibles on tabletops is an overhead camera paired with a computer vision system [33]. However, tracking with external cameras is often challenging due to occlusion and lighting conditions [26]. Vision systems based on in-cell light-sensing have also been used to detect touch on tabletops without external vision sensors [32]. A notable example is the Samsung SUR40, a commercial tabletop that has been employed in numerous tabletop research studies [2]. Radio Frequency Identification (RFID) has also been used to track tangibles on surfaces [18], in some cases supported by vision tracking [23] or capacitive sensing [29]. However, these approaches often require complex and expensive sensing hardware.

To address these constraints, previous research based on the early work of Rekimoto [25] explored the feasibility of employing standard capacitive touchscreens to detect tangible objects. Two main approaches are used for detecting tangibles on touch screens.

[1] https://github.com/Bill2462/automated-point-counting-photosynthesis

Figure 2: During the game, participants used original game pieces.

Conductive elements can be embedded within the object to passively emulate the effects of finger touches [30, 31]. Alternatively, capacitive measurements can be obtained from the touch controller and processed independently from the touch detection system. Most touchscreens use mutual capacitive sensing, which comprises spatially separated electrodes arranged as rows and columns [38]. More recent work has demonstrated the detection of everyday objects using custom capacitive sensing hardware [35]. However, this approach requires custom hardware that is not commercially available.

Our proposed solution differs from past efforts, offering a low-cost solution for tabletop sensing while preserving the original game format. We use an off-the-shelf, transparent, multitouch sensing foil, which can be placed on top of a regular table surface without modifications. We obtain raw capacitive images and use machine learning to recognize patterns produced by conductive markers attached to the game pieces. The markers can be produced cheaply using 3D printing and require no permanent modifications to the game elements.

3 DESIGN: PHOTOSYNTHESIS

In this paper, we demonstrate the capabilities of our sensing system in a practical scenario—augmenting gameplay in *Photosynthesis*, a board game by Hjalmar Hach [2]. We chose this game because it includes many game pieces, has non-trivial mechanics, and is not a highly popular game, which simplifies the recruitment of beginner players.

Photosynthesis is an action point-type strategic economic board game belonging to the area majority category. The game revolves around cultivating and growing trees in a competitive environment. The game's main goal is accumulating the most victory points by strategically growing, managing, and harvesting trees within the game's ecosystem. Victory points are acquired by harvesting trees. The number of obtained points depends on the location of the harvested tree and diminishes over time. The central region of the gameboard yields the most victory points, while the edges yield the least. Before a tree can be harvested, it has to go through a growth cycle involving four stages: seed, small tree, medium tree, and large tree. Each player action costs sun points, which are generated by player-owned trees when exposed to sunlight from the sunpiece. Sunlight can be blocked by trees that have the same or higher height. Trees under shadow produce no sun points. Tree placement and growth are, therefore, key strategic elements.

After each round, the sunpiece moves to the next location on the board, changing the shadow pattern produced by the trees. The number of sun points increases with tree height, with small trees producing a single sun point and large trees adding three sun points when illuminated. Seeds produce no sun points when they are illuminated. Thus, players must balance expansion and growth for optimal sun points. The optimal balance between growth and expansion changes as the game progresses. In short games, it is more optimal to focus initially on expansion and then shift focus to growth, as towards the end of the game, there will not be enough time to advance new trees through the growth cycle.

For the purposes of our study, we introduced modifications to expedite the gameplay. We reduced the number of rounds from 18 to 12. We also opted for a game played in pairs to address technical constraints related to point counting and mitigate potential group dynamics. The game setup used during the study is shown in Figure 2.

4 IMPLEMENTATION

In this section, we describe the implementation of our sensing system.

[2]https://boardgamegeek.com/boardgame/218603/photosynthesis. Manual available at https://ilo307.com/public/pdf/BO-PHOTO-002_RULES.PDF.

Figure 3: To enable recognition of game pieces, we outfitted the pieces with 3D-printed conductive markers that do not impede their original design.

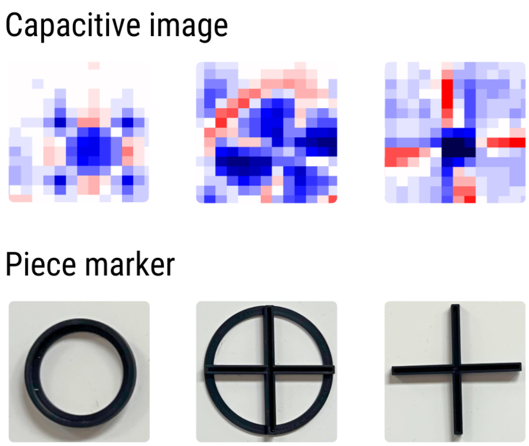

Figure 4: Each conductive marker shape produces a unique pattern of coupling changes, which can be recognized using a machine learning classifier.

4.1 Capacitive sensing

Our sensing system uses a commercially available capacitive multitouch foil and controller manufactured by Green Touch (GT-TF-XTC43.0L-1 [3]). Raw measurements are extracted from the debug interface at a rate of 1 Hz. During system startup, we measure the baseline coupling inherent to the sensing foil and subtract it from the following measurements to obtain a capacitive image that shows coupling changes due to the presence of the objects. When the object is placed on a surface covered by the foil, it generates a distinctive pattern of coupling changes. This pattern is specific to the object's properties and is usually localized to footprint contact areas.

[3]https://www.greentouch.com.cn/?list_21/308.html

4.2 Game piece markers

The original game pieces have minimal contact with the sensing surface, resulting in undetectable coupling changes. Therefore, we equipped each piece with a 3D-printed conductive marker. The markers were 3D-printed from Proto-Pasta Conductive PLA [4] and attached to the base of each piece without the need for glue, as shown in Figure 3.

Photosynthesis requires eight different markers for trees and one for the sunpiece. Figure 4 shows example markers and their capacitive images. The original cardboard sunpiece was too large for a 3D-printed marker. It was, therefore, replaced with a laser-cut equivalent made from an acrylic sheet and equipped with a copper foil marker.

4.3 Footprint classifier

We chose not to implement board tracking in our system. Instead, we positioned the sensing surface directly on top of the printed game board. We extracted capacitive images corresponding to game-board field locations and used a Support Vector Classifier to recognize the piece marker footprints. We trained two SVCs: one for tree pieces and one for the sun piece. The tree SVC uses nine labels: eight tree-piece markers and one label for an empty field. The sun SVC is a binary classifier. We gathered datasets by placing each game piece in random orientations on selected areas of the gameboard and capturing field images. Samples labeled "No piece" were chosen randomly from unoccupied fields. The tree piece SVC was trained on 4375 samples evenly distributed between classes. The sun classifier was trained on 704 samples. The tree and sun models were tested on test sets containing 704 and 340 samples, respectively. The tree SVC achieved 94.2% accuracy. The sun SVC achieved 99.6% accuracy.

4.4 Move detection

We compared the classifier output to the previous game state to detect moves. To reduce oscillations between different labels caused by measurement noise, we implemented a triggering system based on the differences between consecutive measurements. To further reduce the error rate, we implemented three additional error correction mechanisms: hand rejection, partial footprint rejection, and prediction voting ($n = 3$).

4.5 Automatic bookkeeping

As emphasized in previous works, digital tools should not diminish tangibility [15, 16, 27]. Instead, augmentation can be used to lessen the burdensome parts of the game, e.g., "doing math" [27]. Therefore, we chose automatic point counting as the main feature of our system. Detected moves are used to update the current sun point stock, player scores, and the next expected reward from harvest. All scores can be viewed in real-time by accessing a website on a mobile device, as shown in Figure 6. Since each mistake in move detection would propagate into the future and result in incorrect data being displayed until the end of the game, we included provisions for the manual review and correction of detected moves (Figure 7).

[4]https://proto-pasta.com/pages/conductive-pla

Figure 5: During MANUAL gameplay, participants used a cardboard point counting board, where the point count is set by placing a coin on the correct number.

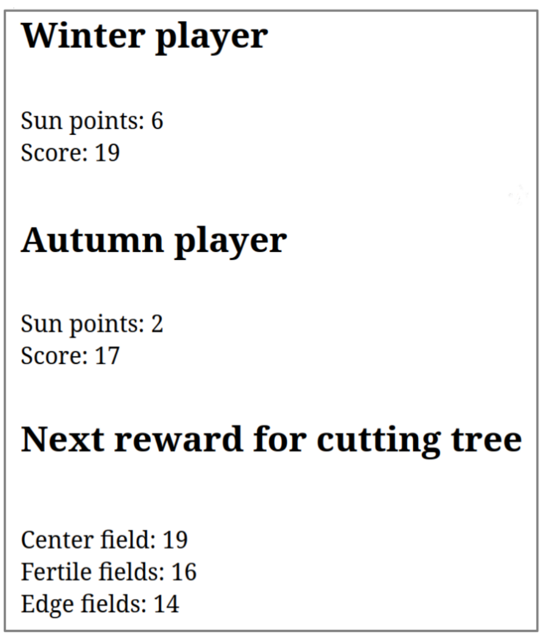

Figure 6: During gameplay with the AUTOMATIC system, the point dashboard visible in this screenshot was shown to the participants.

5 EVALUATION

We conducted a user study to investigate how our system affects gameplay in *Photosynthesis*.

5.1 Conditions and Measures

The experiment was designed as a between-subject study. Participant pairs were randomly divided into two groups, five pairs in each.

Automatic Scoring System (AUTOMATIC): In the AUTOMATIC condition, the victory and sun point counts were displayed on a tablet placed on the table and updated automatically throughout the game, as presented in Figure 6.

Manual Scoring System (MANUAL): Participants assigned to this group had to count sun points manually using the board shown in Figure 5.

We kept count of each purchase of seeds, small, medium, and large trees. We also tracked each player's management actions (seed planting, growth from small to medium and large trees, and harvesting). These data were used to analyze each player's strategy. Additionally, we recorded round duration to quantify the pace of the game. The Game Experience Questionnaire (GEQ) was completed by participants after the game. The GEQ results are available in the supplementary material but are not presented here due to the scale's unknown psychometric properties [19]. Errors made by participants were recorded during the MANUAL condition. Detected moves were also captured during the AUTOMATIC condition and used to record system errors.

5.2 Participants

We recruited participants using university mailing lists, social media, and snowball sampling. In total, 20 participants (10 female, 10 male) aged between 18 and 56 years old ($M = 24.63, SD = 8.45$) were selected. The participants had no previous experience with the tested game. Recruiting novice participants ensured that there would be no bias if proficiency levels differed across conditions. Most participants ($n = 13$) reported playing board games at least once a month. The most frequent game partners were friends ($n = 17$) and family ($n = 9$). The most frequently played types of games were economic/strategic games ($n = 14$), party games ($n = 14$), and action point games ($n = 15$). No remuneration was provided for participation in the study.

5.3 Apparatus

The game was set up on a standard wooden table. A capacitive sensing foil was attached to the tabletop using masking tape. A PC was used to run the automatic point-counting system and supervisor control panel. We recorded audio and video during the game. In the AUTOMATIC condition, a tablet was placed on the table, serving as a scoring pad.

5.4 Procedure

After welcoming the participants, we obtained informed consent and conducted a demographic survey. One experimenter provided a comprehensive explanation of the rules of the game. In the AUTOMATIC condition, participants were familiarized with the layout of the digital scoring pad. The original analog counting board was

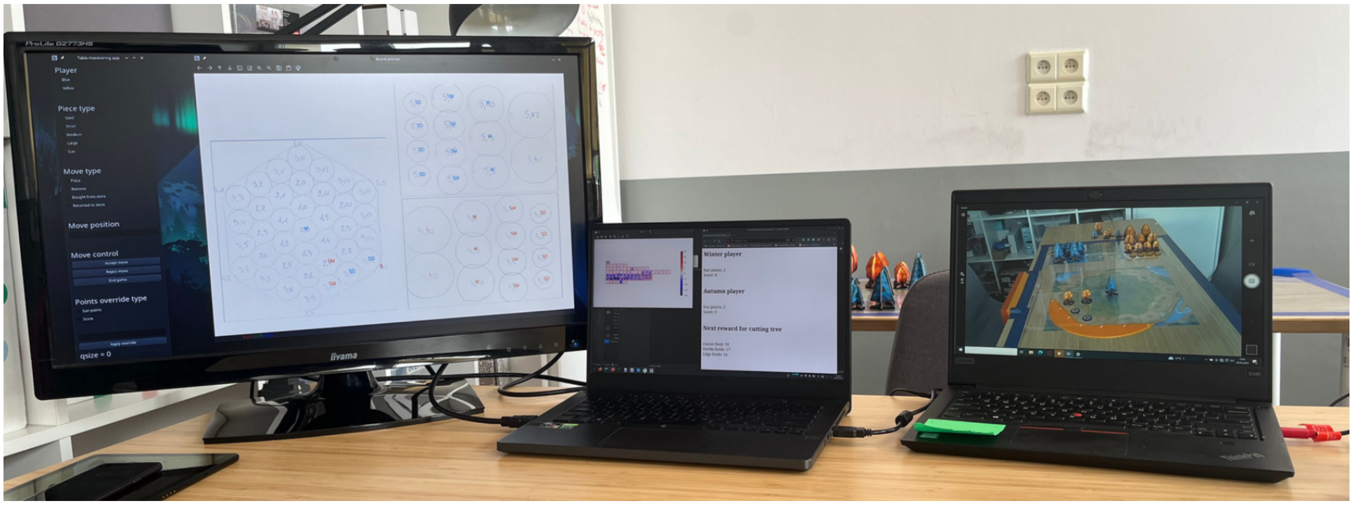

Figure 7: During the study, the researcher managing the system had real-time access to the game state and could correct errors before they affected the values visible to the participants.

used in the Manual condition. Subsequently, participants engaged in twelve game rounds (two sunpiece revolutions around the board).

At least two researchers were present during each experiment. During the game, the participants could seek clarification about any uncertainties regarding the rules. At the game's midpoint, the participants were reminded that their final scores depended heavily on the number of harvested trees and that this action had to be completed before the game's conclusion. In Manual condition, participant errors were recorded by the researchers in a prepared table.

After the game, participants were directed to separate rooms for individual debriefing interviews. Participants from both groups were asked about their thoughts regarding the game and about problems they often experience with board games. Then, participants from the Manual condition were prompted to think of boardgame automation ideas and possible consequences of automation in boardgames. Participants from the Automatic condition were asked about their experience with the system and any desired improvements.

6 RESULTS

In this section, we report and analyze the quantitative and qualitative results from the study.

6.1 Game metrics

For each participant, we counted the total number of actions by type. Figure 8 shows the standard mode boxplot for action counts. A t-test was used to identify significant differences between conditions. We found a statistically significant difference ($t(18) = -2.223$, $p = .039$) between the numbers of small trees purchased by players playing with automation ($M = 1.90$, $SD = 0.88$) compared to the condition without automation ($M = 3.70, SD = 2.41$). We also found that players playing with automation ($M = 4.10$, $SD = 1.29$) planted significantly fewer seeds ($t(18) = -2.803$, $p = .012$) than players playing without automation ($M = 8.20$, $SD = 4.44$).

Moreover, rounds played with the automation system ($M = 152.0s$, $SD = 82.06$) were on average shorter ($t(117) = -2.225$, $p = .028$) than rounds played without automation ($M = 182.0s$, $SD = 64.1$), see Figure 9.

6.2 Errors in the automatic scoring system

In the Automatic condition, we compared the output from the move detection system with the manually sanitized moves used to compute game scores during the game. Differences were treated as errors.

During five experiments, the system correctly recognized 85% of the player's moves. We split the discovered discrepancies into four categories. Almost half of the errors (42%) resulted from activities not being detected. Moves recorded when no move had been made accounted for 35% of errors. Classifier errors accounted for 17% of mistakes. The final 6% of discrepancies were caused by a software error in the board state estimation algorithm, which was not discovered during testing.

6.3 Errors in manual scoring

All ten players committed at least one error related to point bookkeeping or shadow mechanics. The most frequent error, committed by six players, was forgetting to add sun points generated by a tree to their score. The second most frequent error, committed by half the participants, was subtracting too few sun points during purchases from the store. Additionally, six participants committed some type of error related to applying tree shadowing mechanics, with 65% of errors relating to incorrect shadow length. The high number of errors shows that novice players would benefit from an error detection and correction system. On average, the players' error rate was ($M = 0.180, SD = 0.128$).

6.4 Delay introduced by the system

The system's reaction was caused by two factors. Firstly, the sampling frequency of the capacitive sensing foil was 1Hz. Secondly,

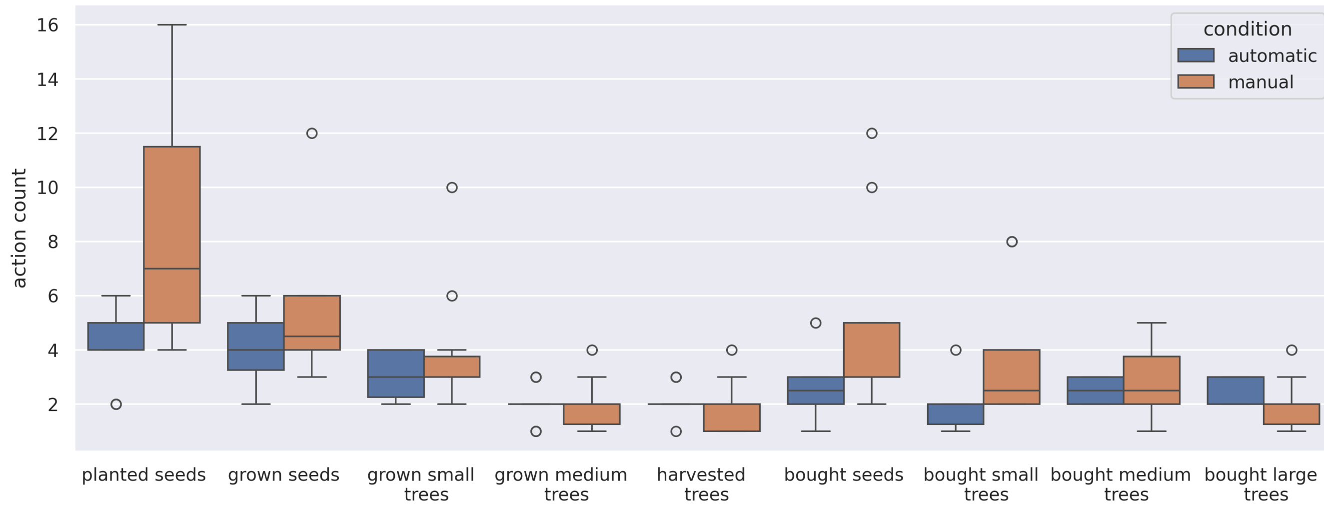

Figure 8: Cumulative counts for each action in the game *Photosynthesis* in each experimental condition. All actions made by the players were recorded.

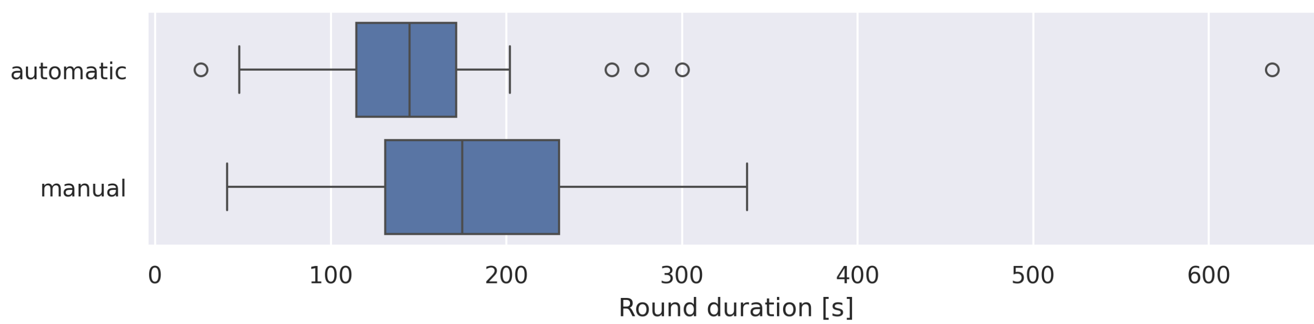

Figure 9: Round durations were determined from the video recording. The round durations were significantly shorter with the automation system, $t(117) = -2.225$, $p = .028$.

to avoid errors, each action detected by the system had to be accepted manually by one of the experimenters. It took between 2 and 3 seconds for the system to detect the placed piece. We compared timestamps in the move detector and game logs to determine the delay caused by the manual move review. On average, each game consisted of 114 moves. The average delay for correctly detected moves was ($M = 5.7s, SD = 3.14$). For incorrectly detected actions ($M = 4.2, SD = 4.02$), the average delay increased to ($M = 10.2s, SD = 5.24$) due to the need for manual correction. Additional data on delays are available in the supplementary material.

6.5 Interview results

All debriefing interviews were recorded (total duration 2 h 26 m) and transcribed verbatim. We used the pragmatic approach to the thematic analysis described by Blandford et al. [3]. We used an inductive coding strategy to obtain the initial set of codes. Three researchers independently coded a representative 20% of the material to develop an initial coding tree. We then organized a collaborative session where we derived a coding tree based on the open-coded dataset. The entire data corpus was assigned to two researchers, who re-coded the set with the codebook. Analysis was concluded in a collaborative session, where two researchers iteratively grouped and generated initial themes until they were agreed upon. The analyzed dataset resulted in three themes: *level of interference*, *struggles during gameplay*, and *technical considerations*. We illustrate our results with quotes highlighted in italics and identified with the participants' IDs.

6.5.1 Level of interference. The participants presented contrasting opinions about the desired level of board game augmentation. A few participants stated that board games are inherently analog and that any technological intervention would disturb the gameplay. Some participants were eager for smart features but raised concerns that excessive automation might make the game too easy, impeding engagement. Interestingly, the critical factor encouraging the players to use augmentation was the need to play by the rules. Since all participants were playing the *Photosynthesis* game for the first time, many felt overwhelmed by the amount of information about the gameplay and the new rules. Employing intelligent features to facilitate the learning process was deemed especially beneficial. However, the desired levels of interference varied between participants. Some participants advocated for displaying information about the game's state (current round, active player, time, etc.), often suggesting the display of additional information about important values (e.g., prices of planting/buying). Alternative ideas were also proposed, such as tracking and flagging player errors and missteps. One participant argued that smart board games should indicate player errors but not enforce sticking to the rules. Moreover, they highlighted that some mistakes are a crucial part of the player experience.

> *(P5_2) The system doesn't have to enforce playing by the rules, but it would be great if it flagged the errors so that we are aware of them. But, I would say that some arguments about the rules during the game are part of the fun.*

One person noted that an advantage of automating rule-keeping is that often, no player wants to take the role of an adjudicator. Transferring this burden onto the computer could, therefore, contribute to fewer conflicts during the game.

Regarding automatic point counting, almost all participants who used the system explicitly stated that this feature helped them to focus more on the strategy instead of tedious bookkeeping actions.

> *(P1_2) I really liked that I didn't have to think about counting points.*

To overcome the problem of differing levels of desired system interference, some participants advocated for an option to turn off all or selected features. Many people stated that they would use smart features only while learning the game and that they would no longer be needed as soon as they were proficient.

Our study shows that the desired level of automation within the board game context varies among players. Participants were especially enthusiastic about using smart features to learn new rules and perform calculations. Moreover, while automatic rule-keeping was considered interesting, it was suggested that it should play an informative, passive role.

6.5.2 Struggles during gameplay. Our participants shared several struggles that they faced while playing board games. These struggles could be resolved by augmenting board games with interactive systems. One of the most frequently mentioned problems was learning and understanding the rules of new games. Many participants found reading instructions a barrier to playing a new game.

> *(P6_1) Sometimes, when you play a game for the first time, not everyone understands it right away. Some people just need more time to grasp the rules and develop the tactics.*

Some participants complained about players who cheat and admitted that they often feel embarrassed and naive when it turns out that some of the players were cheating.

Other problems included losing focus on the game. Participants shared how they often struggle to keep track of rounds, turns, points, and other numerical values throughout the game. The high mental demand made it difficult to relax during the game.

Our results highlight that people face a variety of problems during board games. The most frequently mentioned struggles relate to complex instructions and disagreements over the rules. Future systems augmenting board games should consider these issues to make board games more accessible to different users.

6.5.3 Technical considerations. The participants elaborated on several possible design, implementation, and technical issues with board game automation systems. Some participants stated that they were concerned about the complexity of the setup and possible technical issues impeding gameplay. Two participants were concerned about the potentially higher price of the game. One participant also remarked that using an external device is a source of possible technical problems.

Participants also shared feedback specifically related to our system. While most participants trusted the automatic calculations, the key issue they raised was the high reaction time, which they found annoying. Moreover, the participants suggested that the point dashboard should be based on graphical representations rather than text-based. One participant pointed out that while the game's aesthetics were appealing, the display was somewhat unattractive, spoiling the immersion. They suggested matching the display style to the game's aesthetics.

Regarding the system's effects on the gameplay, some participants noted that automatic point counting helped them focus on the strategic aspect of the game. Furthermore, some players commented that automatic point-counting reduced their mental workload, contributing to less tense gameplay and richer social interactions.

One participant remarked that the foil did not seem to require a lot of preparation before the game and could be stored easily.

> *(P3_1) I like that it's rather easy to store in the house. (...) If the system communicates via Wi-Fi, I always have it at home, so I consider this system could be a "plug and play" solution.*

Interestingly, a few participants did not realize that the capacitive foil was part of the system. Instead, they thought the move detection was based on image analysis from the overhead camera (which was used to record the gameplay for later analysis).

While the unobtrusive form of the foil was usually treated as an advantage, one participant expressed concern about whether the surface could be used like a typical table. For example, they suggested that food and beverages are often consumed during board games, and they would like to put dishes and other items on the foil while playing.

The participants generally trusted the system and liked the idea of an intelligent smart surface. However, the key issues for them were the system's high reaction time, which impeded the game's dynamism, and the unattractive design of the display.

7 DISCUSSION

In this section, we discuss our key findings and compare them with past literature.

We used automatic bookkeeping in our system. Automatic bookkeeping has been suggested as a desirable augmentation of board–games [27]. Our analysis shows that the automatic counting system positively impacted the players' performance. Game statistics indicate that participants purchased fewer small trees and planted fewer seeds. Because the game mechanics penalize planting numerous small trees and seeds in the final rounds, especially during short gameplay sessions (due to their lack of influence on the final score), we conclude that the participants playing with the system adopted a more effective strategy. Furthermore, the automatic system significantly reduced the duration of individual rounds, making the gameplay more dynamic. Yet, we are aware that whether such augmentation limits engagement should be further investigated. As Xu et al. [36] note, 'chores' (defined as functional actions within the board game) can support social interactions, facilitating engagement.

A large proportion of the move detection errors made by the automatic system can be attributed to issues such as glitches in the manufacturer's implementation of the debug port, conservative triggering thresholds, overly simple markers, and lack of a classifier feature extraction stage. These issues can be fixed in further iterations, significantly improving performance and allowing for unsupervised deployment. Furthermore, all errors were made during the growth phase. During the photosynthesis phase, the system achieved 100% accuracy. Capacitive sensing, therefore, presents itself as a feasible way to detect board game pieces on tabletops. 3D printing also proved capable of producing compact, easy-to-install, inexpensive conductive markers for the game pieces. Several participants reported that they thought that moves were detected by overhead cameras, highlighting the unobtrusiveness of our solution over systems based on external vision sensors.

7.1 Towards screenless tabletop sensing in games

Our study suggests that screenless tabletop sensing could subtly alter how players interact with and perceive tabletop games, especially when they are still learning the game. By reducing reliance on screens, there seems to be a subtle shift towards a more tangible game experience. Preserving tangibility in hybrid board games is considered an important design goal [15, 16, 27]. Our findings suggest that when the tangible elements of a game are more pronounced, players gravitate towards more strategic gameplay behaviors. Moreover, the nature of screenless sensing may allow for more direct interaction with game components, possibly enabling a smoother game experience. Interestingly, a few participants speculated that the overhead cameras were used for move detection, indicating that screenless approaches might be less obtrusive than traditional methods such as external vision-based systems, which are widely used in hybrid boardgames [6, 22]. This raises an intriguing question regarding the potential for screenless sensing to offer a more integrated game experience, with technology subtly supporting gameplay. Screenless sensing could allow the user to capitalize on the enhancements provided by tabletops [4] without the distraction of a screen.

7.2 Limitations

Several current limitations of the system should be the subject of future work. Our system exhibited a detection accuracy of 85%, rendering unsupervised real-world deployment unfeasible. To enhance detection precision, more careful design of markers and optimization of the triggering mechanism is advised. Furthermore, while our system can be easily integrated with many common board games, titles with more complex mechanics, such as piece stacking, are not currently supported. Our study spanned only 12 rounds. During extended game sessions or after long-term use, players might foster interactions with the system that are different from those observed in our study. Moreover, our participant pool was composed solely of novice players. Automation might also impact experienced players differently, necessitating further research.

8 CONCLUSION

In this paper, we have reported on the implementation and evaluation of a tabletop automatic point-counting system for enhancing board games. The system was tested in an action point game, *Photosynthesis*. According to the participants, our research prototype did not impede the gameplay but facilitated focus on the game mechanics. This allowed the participants to develop more effective strategies by shifting focus to key aspects of the game during the very first playthrough. The participants also reported their struggles with board games more generally and offered ideas for future player support systems. Our study shows that capacitive sensing is a promising avenue for augmenting tabletop board games. We hope this work will contribute to understanding how augmentation can enhance board games without impeding the player experience.

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