The Coach's Playbook

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ABSTRACT

This paper presents an electronic playbook (COACH) for football. COACH combines gestural input, two-dimensional (2D) simulation, and three-dimensional (3D) animation to help coaches instruct players in an effective manner **before they take the field**. This part of the football coaching process is well-suited for non-traditional interface technology, because it requires coaches to discuss dynamic, 3D scenarios while within a classroom setting. We present a 2D gestural interface that allows coaches to use standard diagrams and gestures to set up a play, modify that play, and display a 2D animation. In addition, we demonstrate a virtual environment that allows coaches and players to view a play from any point of view, including the first-person perspective of one of the players. We present the results of a formative user evaluation given to the Brown University football team's coaching staff, and discuss what we have learned in developing an application to address this specific problem. Although the application focuses on football, we believe that the techniques described in this paper can be used to develop electronic playbooks for other team sports as well.

KEYWORDS: gestural interaction, 2D simulation, 3D animation, play design and simulation, sports technology

INTRODUCTION

One important part of a coach's job is teaching and reviewing plays with players in a classroom environment. This is a difficult task because a dynamic 3D environment is represented with static 2D images drawn on a whiteboard by the coaches. It can be difficult for players to make the leap from static whiteboard diagrams to a situation on the football field, especially given the variety of scenarios that may occur during the course of a game. This instruction is an essential part of a coaches' job, and because there is a limited amount of practice time on the field, both coaches and players must make the best possible use of the time available.

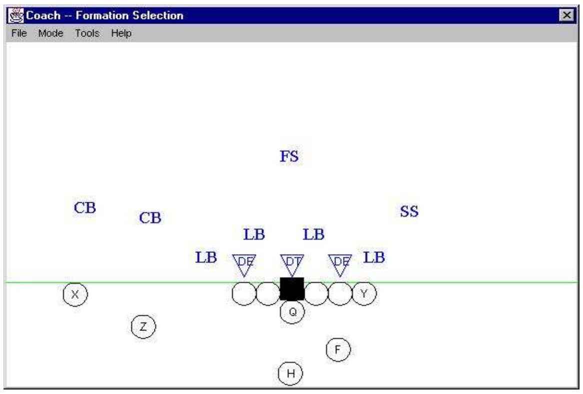

Figure 1: COACH mimics a traditional whiteboard teaching environment.

We have developed an electronic football playbook application (COACH) that helps coaches and players to understand, visualize, and discuss a play before they take the field (see Figure 1). COACH provides a gestural user interface that mimics a traditional whiteboard used for play design, analysis, and instruction. COACH provides a 2D simulation to allow coaches to illustrate and discuss dynamic aspects of a play, and it provides a 3D environment that allows players to view the play in a more realistic manner (e.g. from the first-person point of view of one of the players). Aside from being useful in a classroom environment, such a playbook could be provided to players to supplement the traditional paper playbooks that are provided for reference and review.

The contribution of this project is to demonstrate the integration and customization of gestural interface techniques and 2D and 3D simulation techniques for a specific problem area. At the end of this paper we discuss the results of an informal evaluation performed by the Brown University football coaching staff and discuss our learnings in applying non-standard interface technologies to this problem.

RELATED WORK

One of the coaching tools that has been developed in recent years is a simulation-based training system to improve quarterbacks' passing skills[12]. Walker and Fisk discovered that quarterbacks spend very little time in real game situations during practice each week. In addition, a quarterback's practice time is shared with other team members at his position. Consequently, this prevents them from receiving valuable repetitions during practice that are necessary to improve their skill and understanding of the plays. In their paper, Walker and Fisk identify four tasks that a quarterback must complete when passing the ball:

- Remember the pass patterns called
- Recognize the defensive set and coverage
- Remember the 'Read Sequence'[1]
- Execute the play.

Walker and Fisk's training system focuses on improving the user's ability to perform these tasks. In 1994, the Georgia Institute of Technology's football team used the system to teach four quarterbacks a new offense. Both the coaches and the players responded positively to the training system.

Although, Walker and Fisk's system presents a good example of how technology may be used to improve a player's performance, their 3D animation was limited to the quarterback position only. Our application's 3D animation improves upon Walker and Fisk's presentation by providing a general environment that can be used by players of all positions. In addition, their system restricts the user to one camera angle. COACH allows users to adjust the animation's camera angle which provides players with a better understanding of each play.

Coach's Edge Football (CEF) is an example of a professional application for building a team's playbook[2] which allows coaches to create dynamic plays through an easy to use interface. Each play is then saved into an electronic playbook for future reference. Storing this information in an electronic form allows coaches to easily display and manipulate their playbook over time.

CEF's interface is awkward and cumbersome due to the vast number of modes and options that are available and the limitations in its usability. COACH eliminates cumbersome menus by allowing coaches to specify player assignments with free form gestures and adds to usability by providing pre-defined formations and assignments. In addition, CEF limits coaches to using basic 2D animations. These animations are created by supplying players with instructions at each time step. COACH provides both 2D and 3D animations that are created automatically from player assignments.

Inside The Playbook is a web site run by ESPN that analyzes the playbook of various NFL teams[4]. The site is updated weekly during the NFL regular season analyzing the strategies used by NFL teams in their upcoming game. Visitors may choose to view an animation of a team's play and read the accompanied expert analysis. This system offers a great 2D and 3D animation of a football play.

[1] This is the order in which a quarterback looks at his receivers to see if one of them has a chance to catch the ball.

Our application tries to reproduce the look and feel of ESPN's site while adding more realism to the animation. This is accomplished by allowing each player in the simulation to be customized with attributes. The current animation on ESPN's web site does not account for a player's individual skills such as speed and strength. COACH factors in players' skill sets through the use of player attributes.

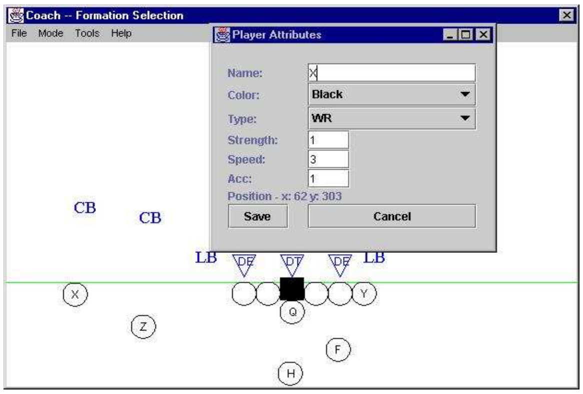

Figure 2: COACH allows users to customize the attributes, such as speed, strength, and acceleration, of each player.

2D PLAY DESIGN

COACH presents users with an electronic whiteboard used to design plays through a combination of gestural and traditional menu interaction. Coaches create plays by first selecting an offensive and defensive formation with a traditional menu system containing common formations used by coaches. Formations can then be customized by either adjusting a player's position through a drag and drop interface or adjusting individual player attributes (See Figure 2). Once a user has decided on an offensive and defensive formation, the next step is to create player assignments by assigning tasks to each player in the formations. Users assign tasks to players by creating free form gestures with the mouse. The user is finished designing a play when all players have received an assignment (See Figure 3) .

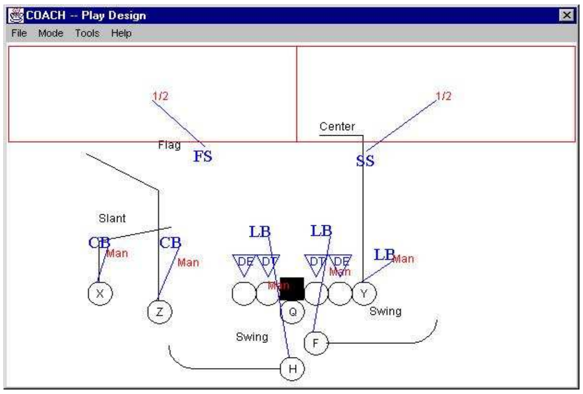

Figure 3: This figure depicts the finished design of a play.

Combining Gestural and Menu-based Interaction

COACH uses a combination of gestural and menu-based interaction which takes advantage of familiar skills known to its user base. Traditionally, coaches use a shorthand notation to describe each player's assignment during a play. COACH uses a similar notation that allows coaches to express player assignments without searching through menus. This is accomplished by a gesture-based interface aimed at accelerating the player assignment process.

Although gestures present a powerful method of interaction and constitute a large portion of our interface, we recognize that traditional menus are better suited for some tasks. Simple operations, such as formation selection, are difficult to express with gestures, but are easily created with menu-based interaction. As a result, by providing both interaction styles, our application gives coaches a familiar and easy to learn interface.

Gesture Recognition and Feature Extraction

COACH's gesture recognition system is based on Rubine's algorithm [11] which extracts various gesture features that are used to help classify the input gesture. Rubine's algorithm works well when the gestures in the gesture set are relatively distinct. For instance, two of the features that Rubine uses are the sine and cosine of the initial angle of the gesture. These features provide useful information when recognizing gestures for numbers and letters, but perform poorly for our gesture sets (see Figures 4). Our gestures all contain similar initial angles and, as a result, the sine and cosine provide the recognition algorithm with no useful information. Many of Rubine's features do not provide us with enough information to accurately recognize COACH's gestures. To solve this problem, COACH uses a generalized feature set (see Table 1) that stresses underlying principles of pass patterns[7].

Gesture Feature	Description
Gesture Length	The length of the input gesture is computed by summing the length of each sample point
Height	The change in the y component between the first and last points in the input gesture
Width	The change in the x component between the first and last points in the input gesture
Gesture Direction	This attribute determines if the gesture is in the out direction, moving away from the football, or in direction, moving toward the football

Table 1: The feature set used by COACH's gesture recognition algorithm.

For example, coaches and players differentiate a slant route and a post route by the length and height at which the routes are run. Therefore, our gesture recognition algorithm extracts height and length features from a gesture.

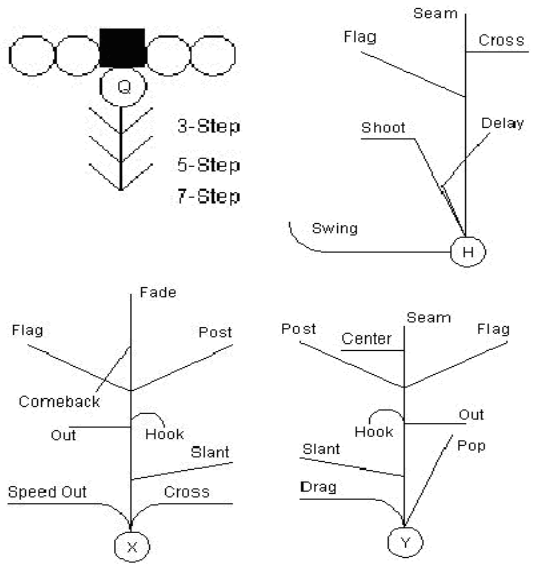

Figure 4: This figure depicts the gesture sets used by offensive players.

Input gestures are created from a list of points along the path generated by the user's mouse. These gestures are associated with an individual player when the starting point of the input gesture intersects that player's bounding box. As the user continues the input gesture, new points are added and the input gesture re-computes its feature set (See Figure 5).

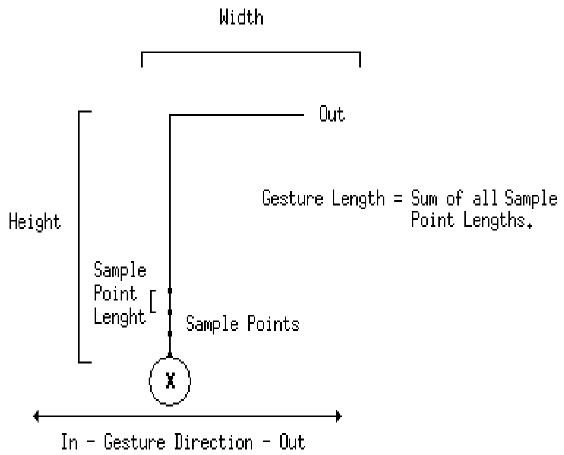

Figure 5: Graphical representation of the feature set for an Out assignment.

Our gesture recognition algorithm compares the feature set of the input gesture with the feature set of each gesture in a player's gesture set. Each gesture in a player's gesture set contains an ideal feature set for that gesture. The difference in feature sets is computed using the following equation.

$$E_g = \sum_{f \in Feature} \left(\frac{|(F_{input,f} - F_{g,f})|}{F_{g,f}} \right) \qquad (1)$$

where E_g equals the error value of gesture G, $F_{input,f}$ equals the value of the input gesture's feature, and $F_{g,f}$ is the value of gesture $G's$ feature. The smallest value computed identifies the gesture, G_s, with the minimum error value E_{Gs}.

$$E_{Gs} = \min_{g \in Gesture} [E_g] \qquad (2)$$

These equations work for the general case but are improved upon by adding some additional requirements. Before E_g is computed, gestures are eliminated from candidacy by examining a gesture's direction. The direction of the gesture is defined to be the direction in which a player is moving at the end of the input gesture. If the direction of the input gesture does not match the direction of a gesture in the player's gesture set that gesture is removed from candidacy.

Some players use a simplified version of this algorithm. For example, the QB Player has a limited set of gestures that can be differentiated from each other by height. When a QB Player receives an input gesture, only the height feature is extracted. The gesture whose height is closest to the input gesture is selected as the QB Player's assignment.

Additionally, all defensive players use a different gesture recognition algorithm. First, the algorithm determines if the defender is in man or zone coverage. This is determined by the end point of the input gesture. The D Player is assigned man coverage if the gesture's end point intersects the bounding box of an offensive player. If there is no intersection detected the D player is assigned a zone coverage. Finally, if the player is assigned zone coverage, the algorithm determines the correct zone for the player by checking the zone in which the gesture's endpoint lies.

2D Play Simulation

In addition to play design, COACH allows users to simulate plays in a 2D environment with VCR-like controls (See Figure 6). Users can start and stop the simulation with the left mouse button while the right mouse button resets the position of all players.

The simulation model used by COACH is a simplified version of the techniques used by Reynolds[10]. Reynolds claims that the behavior of a flock of birds is a result of the interactions between individual birds. These interactions can be simulated using a particle system where particles exhibit the specific bird behaviors that lead to flocking. COACH takes a similar approach to simulating a football play. A particle system is created in which each particle exhibits the behaviors of an individual football player. The behaviors include following an assigned task, colliding with other players, and reacting to specific circumstances such as defensive players reacting to offensive players while in zone coverage.

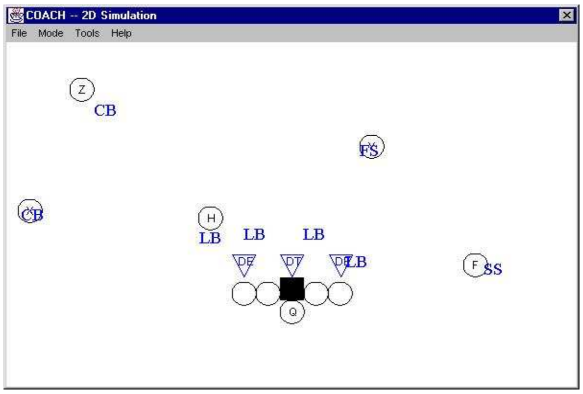

Figure 6: This figure depicts a single frame in a running simulation.

The simulation attributes of a player class are updated using simple dynamics. First, the new acceleration is computed using the information obtained from the player's assignment

$$\bar{A} = A_{sign} \cdot |A| \qquad (3)$$

where $\bar{A}$ is the new acceleration, A is the old acceleration, and A_{sign} is the sign of the acceleration. Next, $\bar{A}$ is added to the current velocity, $\bar{V}$, to calculate a new speed.

$$\bar{V} = (V + \bar{A}) \times \frac{\min(\| V + \bar{A}\|, V_{max})}{\| V + \bar{A}\|} \qquad (4)$$

The right hand term of equation 4 ensures that the velocity is not greater than the maximum speed of the player. Next, the assignment direction, D_{assign}, is applied to $\bar{V}$.

$$\Delta P = D_{assign} \cdot \bar{V} \qquad (5)$$

Finally, the player's position, $\bar{P}_1$, is updated by adding the old position, P, to ΔP.

$$\bar{P}_1 = P + \Delta P \qquad (6)$$

After a player has calculated its new position, collision detection must be performed with all the other players in the other formation. Each player checks its bounding box for an intersection with the bounding box of another player. If the player detects an intersection, a collision is assumed. A collision results in a player adding a collision component to its new position.

Collision components are calculated in a four step process. First, players calculate their force component, F_p, applied to the collision. This force is computed using the player's speed V, and strength S.

$$F_p = V \cdot S \tag{7}$$

Second, the direction of this force D_{push} is calculated using the direction of the player's push, D_{assign}.

$$D_{push} = -D_{assign} \tag{8}$$

Next, the difference is computed between the two player's force vectors,

$$F_{Diff} = |(F_{p,o} - F_{p,d})| \tag{9}$$

where F_{Diff} is the computed difference, $F_{p,o}$ is the force applied by the offensive player, and $F_{p,d}$ is the force applied by the defensive player. Finally, the player with the weaker force updates its position by applying the force difference in the opponent player's push direction.

$$\bar{P}_2 = \bar{P}_1 + (D_{push} \cdot F_{Diff}) \tag{10}$$

It should be noted that a player's push direction is the direction opposite its gesture direction. This is because players are taught to push opponents away in the opposite direction.

3D PLAY ANIMATION

Animation mode allows players to visualize assignments in a 3-dimensional environment (See Figure 7). A play may be viewed from a first person perspective in addition to an arbitrary camera location. One of the goals in spending time on the practice field is to get players to associate visual information to an opponent's specific strategy. This visual information often includes peripheral vision. By allowing players to repeatedly view an opponent's play from his predicted perspective in 3D, players can fully comprehend their role in the play. This mode is aimed at improving players' understanding of the play and to better utilize off-the-field training time.

Our 3D engine is a modified version of the Waltz Animation System [1]. The Waltz Animation System is a behavioral based animation system which supports autonomous agents. This system is very similar to Perlin's Improv system [8] and Bloomberg's system [9] used for multi-level direction of autonomous creatures. The Waltz Animation System allows different behaviors to be assigned to different players. For example, one team may have an aggressive linebacker, who is more likely to blitz, while another team may have a conservative linebacker, who thinks more about defending a pass.

Figure 7: Coach's 3D simulation.

USER EVALUATION

The Coach's Playbook was presented to coaches from the Brown University Football team. The coaches were given a demo of the program and a short narrative on the goals of the application. After the demo was completed, the coaches gave some feedback as to how effective The Coach's Playbook would be for their purposes.

The demo consisted of going through each mode of COACH and explaining its functionality. The coaches were then shown how to create a play from beginning to end. The coaches were then asked to create some simple plays and use the 2D simulation and 3D animation. The coaches commented on each of the application's modes as they used the system and answered a short questionaire when they finished (See Appendix A).

The coaches were able to quickly create plays after a few minutes of practice. They felt comfortable using the gestural interface and thought it an improvement over classic menu interfaces. The fact that the application's gestures resemble the shorthand gestures they currently use to describe player assignments helped them to learn the system quickly. They were disappointed that The Coach's Playbook did not contain more gestures. Tasks such as motion and blocking assignments cannot be assigned in the current implementation. These tasks are very important for a coach and these gestures need to be added before a coaching staff can use The Coach's Playbook.

The coaches enjoyed the 2D simulation the most. They could not stress enough the value of a tool that allows them to explain player's assignments in a dynamic simulation they could control. It is difficult for coaches to explain assignments on a static white board. Assignments are not static and cannot be fully explained using a static medium. This mode will help players understand the concepts behind each play better than the methods used currently. Both coaches did feel that the simulation could be improved by allowing users to adjust player assignments during the simulation. This would allow coaches to display the mistakes a player is making when performing an assignment. The coaches could then adjust the player's path to show the proper way to execute the task. An example of this would be the path a linebacker takes when dropping into his zone in pass coverage. Coaches would like to show the player how that path is vulnerable to the offense play. Then the coaches could show the proper path to take to the zone.

The Coach's Playbook's 2D simulation was originally intended to be used as a strategy tool not a learning tool. Coaches would customize each player to have the same attributes as the real player who would run the pay. The simulation could then give an estimate of how successful the play will be. The coaches thought that such a tool would be useful, but very hard to develop. They did not think a computer could accurately predict the outcome of a play with enough accuracy to be useful.

The coaches were not able to get a full demonstration of the 3D animation when the demo was given. This mode was only 80% complete, but the coaches liked what they saw. They stressed the importance of players visualizing their tasks before a game. This mode would enable players to take home animations and view them when they had the time. For players in school with varying schedules this would be very beneficial. The coaches thought it would be great if this mode allowed coaches to save an animation in a portable format for the players to bring home and view.

They also commented on The Coach's Playbook as a complete tool. They thought it would be a great tool to be used as an electronic playbook and teaching tool. They also thought it was not flexible enough in general. They could not add new gestures and formations as they wanted. The addition of this functionality would greatly benefit the program. Overall their impression was that The Coach's Playbook was a useful but incomplete tool. They thought it had great potential and expressed interest in following the development of the system.

FUTURE WORK

COACH is still in an early stage of development, and as such, there are a number of areas for future work. First, COACH does not present the user with a full set of player assignments. Users cannot specify some basic tasks such as blocking assignment, defensive blitzes, and pre-snap motion. These additional features are essential to the usability and completeness of our application. Second, COACH's gesture recognition engine is heavily dependent on gesture attributes rather than gesture shape. If a user draws a short Post gesture, it is recognized as a slant due to its height. The recognition algorithm can be improved by additional gesture features such as the gesture's breaking angle. This is the angle the player first breaks when executing the gesture. This feature would allow the system to identify the shape of the gesture rather than the relying on the gesture's height and width. In addition, COACH should incorporate a training system that allows a user to alter a gesture's feature set to more comfortable values. Lastly, COACH needs to improve on its 3D engine. Currently, COACH does not present the user with realistic player running motion which is important for creating an accurate training and visualization environment.

CONCLUSIONS

In this paper, we have presented, The Coach's Playbook (COACH), a tool which assists coaches and players to understand, visualize, discuss football plays before they take the field. COACH is a valuable application since it blends different research fields to address real life problems. By using a gestural input, coaches can rapidly create player assignments while avoiding the pitfalls of traditional menus. Both real-time 2D and 3D simulation of football plays allows coaches to present a detailed description of a play aimed at improving the player learning environment. Based our formative user evaluation, COACH shows promise as a useful tool. With the incorporation of future work, COACH will present an interesting example of a cross discipline solution to a real world problem.

Acknowledgments

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APPENDIX A

This appendix shows the questionnaire that was given to the the Brown University football coaching staff as the primary method for qualitative evaluation.

Questionnaire

1. Does your weekly preparation mimic The Coach's Playbook process? What changes need to be made?

2. What is your opinion of the gestural interface? How could this be improved?

3. Do you think the 2D simulation is useful? How could this be improved?

4. Do you think that the 3D animation is useful? Would the players use it?

5. Would The Coach's Playbook improve your productivity during the week? Do you think you would use it?

6. Do you think The Coach's Playbook would help the player preparation?

7. Do you think it would take you a long time to learn to use The Coach's Playbook?

8. How does this program compare to other programs you've used?

9. What is the most limiting aspect of this program?

10. If you could add any feature to the program what would it be?