Time Warp Football

Stephen G. Lynn, Dan R. Olsen, Jr., Brett G. Partridge
Computer Science Department
Brigham Young University
Provo, UT 84602, USA
+1-801-422-7698

stephen.lynn@byu.net, olsen@cs.byu.edu, bgpartridge@gmail.com

ABSTRACT
We describe a system called Time Warp Football (TWF) which puts fans in control of the game watching experience. TWF uses annotated video streams to enable instantaneous forward and backward play-by-play navigation and on-demand switching between multiple camera angles. These features allow fans to easily watch and re-watch plays they are interested in from any camera angle. The annotations also allow for instantaneous game statistics whenever the fan desires. We took TWF into eleven different homes, connected it to the home TV, and provided a standard wireless video game controller to control the experience. Based on in-home user evaluations, we found that TWF provides an easy to learn interactive TV control system, effectively uses on screen prompts to enable groups to watch an interactive sporting event, and overall provides a successful interactive TV experience.

Categories and Subject Descriptors
H.5.1.Information interfaces and presentation (e.g., HCI): Multimedia Information Systems

General Terms
Design, Experimentation, Human Factors.

Keywords
Interactive, TV, television, sports, annotation, video navigation.

1. INTRODUCTION
There is growing interest in video based entertainment systems. Considering the success of sites like YouTube, Red Lasso, Hulu, and others, it is obvious that people value video entertainment. Most major broadcasting companies offer some type of high quality video streaming option and these offerings are constantly expanding. The success of these ventures makes it clear that people want access to the content they like, whenever they like. With increasing numbers of high quality video streams becoming available, the open question becomes: what more can be done with the viewing experience beyond the standard pause, play, rewind, and fast forward controls?

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Interactive television research aims at creating a TV viewing experience that puts more control in the hands of the viewer. Interactivity can take the form of content navigation and selection, social networking, shopping, or anything else people might want to do in the context of watching their TV. Current video streaming technology supports high resolution video, random access navigation with virtually no delay, and on demand access to content. These features facilitate a more interactive TV experience over the Internet.

Currently, when fans of American Football sit down to watch their favorite team, they have little control over their viewing experience. Broadcast TV puts fans at the mercy of the broadcast director for things like instant replay, viewing statistics, and camera angle selection. The current "state-of-the-art" football viewing experience available to home viewers is the Digital Video Recorder (DVR). DVRs allow fans to pause, fast forward, and rewind live or pre-recorded football games. This functionality allows fans to skip ads, watch plays over again, and skip dead time between plays. While these options provide greater control to the viewer, the experience using these controls is often frustrating [8] and is still limited to a single director's view.

Time Warp Football (TWF) is an Interactive TV system that puts control of the viewing experience into the hands of the fan. TWF uses annotated video streams to enable:

- Precision play-by-play navigation.
- On-demand switching between multiple camera angles.
- Real time statistics available at anytime.

These features provide fans with a truly interactive viewing experience. Unlike the typical rewind feature which requires fans to vigilantly monitor their rewinding video, hoping to resume play without going past the beginning of the play, TWF enables fans to review a play by pressing a single button and there is never a problem with overshooting. Trying to find specific points in a video using fast forward and rewind has been shown to be an extremely frustrating experience for TV viewers [8]. TWF eliminates this frustration by providing precision navigation controls that render the traditional fast forward and rewind options all but useless.

Because different plays are better seen from different angles, TWF allows fans to select the camera angle from which they want to watch the game. Fans wanting to re-watch a play from a different camera angle can switch between views at any point in the game with a single button press. We claim that TWF is a novel system that: provides an interactive TV control system that is easy to learn without any formal training, effectively uses on

screen prompts to enable groups to watch an interactive sporting event without getting lost, and overall provides a successful interactive TV experience.

2. RELATED WORK

2.1 Move Networks

TWF works on top of video streaming technology developed by Move Networks [2]. This technology supports high-definition video streams over standard home broadband connections with virtually no buffering delays. The Move video format is actually an aggregate of small streamlets (sections) of the video. A client-side Move video player only needs the next streamlet in order to continue play back and therefore does not have to buffer or download large chunks of data while the viewer waits for the video to play. This allows the viewer to skip around within a video clip with virtually no lag time. A great interactive experience hinges on the ability to instantaneously move from one part of the video to another. Building on top of the Move player, we can deliver high-definition interactive video to viewers in their own homes, over their home broadband connections.

While the Move player provides an excellent foundation for building interactive TV experiences, it is worth noting that none of our techniques are directly bound to the Move player. TWF could be built on top of any streaming service that provides high quality video, random access streams without buffering delays, and easily switches between video streams.

2.2 Annotating Video

Video annotations are metadata which describe video content. Annotations for a football game might contain things such as the start and stop times of individual plays, penalties on a specific play, or points scored during a play. These annotations are useful for providing meaningful navigation control as well as extra information about different parts of the video such as game statistics.

There are two main ways to annotate video: automatically and manually. Automated annotation involves pre-processing the frames of a video for scene detection [4, 6, 10, 11, 15]. Scene detection in a football game would translate to finding the start and stop of each play automatically. The problem with annotating football video using automated scene detection is that football video often has statistic pop-ups, instant replays, and camera angle changes. These dramatic changes, which will typically be detected by an automated system as a new scene, do not necessarily coincide with the natural breakdown of a football "scene". For example, changing from the end-zone camera to an aerial camera in the middle of a football play would result in a new scene annotation which is incorrect in the context of the football game. Basing an interactive football experience on such annotations could be disastrous as viewers wanting to skip to the start of the next play may end up in the middle of the next play because of a misclassified play boundary.

Because sports are unpredictable and there is a low tolerance among fans for getting play boundaries wrong, we use a manual annotation system. There are many different ways to approach manual annotation [9, 10, 12]. One approach called Media Streams [9] uses an iconic language to describe actions, events, and relationships within the video sequence. While a powerful annotation system, Media Streams captures more complex relationship information than our interactive controls require. Other manual annotation approaches focus on identifying relationships between events and scenes within the video in a post production manner. We need to be able to quickly (in real time) annotate event boundaries which are meaningful to the fan to support a live viewing experience. These real time requirements render post-production approaches unusable for a system supporting live sporting events.

2.3 DVD Navigation

Existing DVD systems support many of the same interactive opportunities that TWF provides. All DVDs support skipping around scene-by-scene, and could easily be programmed to support jumping between alternate camera angles. The main limiting factor of a DVD system is the storage limit of a DVD. Providing multiple camera angles for an entire sporting event would likely take up more space than a typical DVD could hold. The other downside to DVD systems is that they only provide access to pre-recorded content. Watching a live sporting event is impossible using a DVD delivery mechanism. TWF provides the same interactive options as a DVD system but without the space or time constraints.

2.4 Interactive Video Navigation

The ability to interactively navigate video is at the heart of creating interactive experiences for digital video. A very similar interactive television experiment was presented by Li et al. [14]. They experimented with a number of genres including sports and news using a tasked-based user study in a lab environment. Their results showed that most people wanted to skip through the video content watching only the parts that interested them. Thus the most commonly used navigation tool was skipping around based on shot boundaries. While these findings are encouraging they are based on a task-based evaluation that does not closely reflect a true viewing experience where entertainment is the only goal. It is difficult to say how these results translate into a home viewing environment where entertainment is the only goal. As Chorianopoulos and Spinellis point out, traditional human-computer interaction (HCI) evaluations typically involve some task-based method where participants are asked to achieve some goal. Task-based user studies do not account for the entertainment value of an interactive system [6]. TWF builds upon the findings of Li et al. by providing additional interactive navigation controls. We then take their work one step further by evaluating the use of the interactive controls in the natural home viewing environment of football fans with entertainment as the only goal.

Another application of video navigation is hypermedia [5, 13]. This is the idea that videos can be linked together providing more in-depth coverage of a particular piece of content similar to hyperlinks on the Internet. In Girgensohn et al [13] a "how to" video was presented with hypervideo functionality. The user could navigate from the top level "how to" content to more details about a particular instruction or technique and also return back to the original content. This same idea was used for news video navigation in Li et al. [14]. These approaches switch between separate video streams to provide supplementary video content. In the same way that hypervideo applications allow viewers to switch between different video streams to access new information, TWF supports multiple video streams for the same game. The difference with TWF is that the alternate video

streams all cover the exact same event from different camera angles rather than each video stream covering separate topics. This simplifies the annotation and control of the video experience.

Chorianopoulos and Spinellis [6, 7] present a unique interactive experience for watching music videos. They demonstrated a system which allowed viewers to skip between music videos. Their system also displayed additional information about the music video similar to VH1's popular Pop Up Video. They also had an advertisement insertion scheme. The results from their user tests indicated that viewers were willing to accept inserted advertisements in exchange for the new navigational and informational features. Viewer's willingness to endure ads in exchange for increased interactive features shows that people have more than a passive desire for increased control over their viewing experience. TWF aims to provide a compelling interactive experience that satisfies people's desire for more control.

"Sky Sports Active" [3] and "Hockey Night in Canada" [1] are commercial implementations of interactive TV systems similar to TWF. These systems provide interactive features such as on-demand replay and multiple camera angles. However, the interactivity of these systems is severely limited by their broadcast technology base. Each camera angle is broadcast on a different cable channel. These systems rely on the viewer's DVR to allow them to fast forward/rewind through content. Since modern DVRs cannot record each of the different camera feeds broadcast on multiple channels simultaneously, full interactivity is not possible. In contrast, because TWF is built on video streams accessed over the Internet, our system allows viewers to move forward and backward on any camera angle at any point in time regardless of what they have previously viewed.

3. INTERACTIVE EXPERIENCE

Time Warp Football (TWF) uses multiple high-definition video feeds, streamed over the Internet, to provide unprecedented control of the viewing experience to American football fans. A game annotation file provides all the information needed to enable precision play-by-play navigation, intelligent camera angle switching, and real-time game statistics. TWF supports a live game viewing experience using a standard TV, a wireless video game controller to control the experience, and a home broadband connection.

3.1 TWF Architecture

The high level architecture of the TWF system is relatively simple. Figure 1 shows how each component of the system interacts with the other components. The *Annotator Program* takes as input a single video stream from the *Streaming Service* and stores the generated annotations in the *Annotation Repository*. The *TWF Client* accesses the *Annotation Repository* to get the annotations associated with the desired game and, using the information found in the annotation file, loads the appropriate streams from the *Streaming Service*.

3.2 Generating Annotations

TWF needs to know several pieces of information about each play to provide interactive controls. Metadata such as the time offsets of the beginning and end of each play, the position of the ball on the field, and the current down, provide TWF the information it needs to support interactive navigation. We created a simple game *Annotator Program* that allows a single person to capture all of the required metadata in real-time as the game is being played. The annotations used in the evaluation of TWF were captured using our *Annotator Program* by a single person, watching the game in real time, with no option to pause.

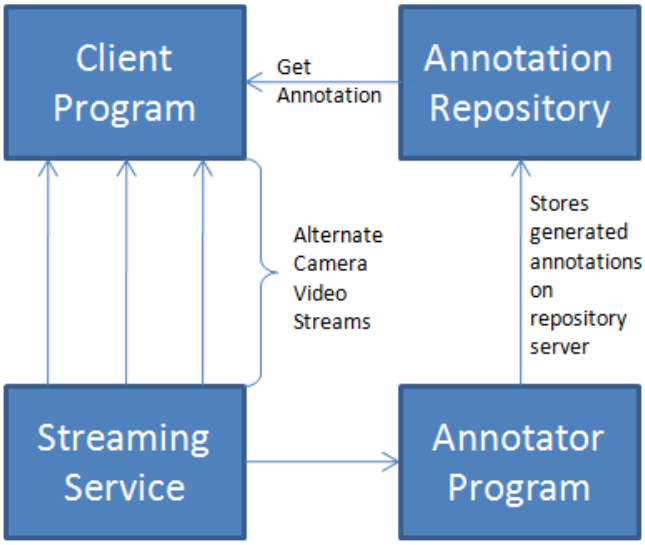

Figure 1. TWF Architecture.

Figure 2 shows the football *Annotator Program*. The program has the following components:

- A three state button for capturing the beginning and end offsets of each play and for finalizing a single annotation.
- Quarter and down selectors.
- A double slider that tracks the current ball position and the first down marker.
- A series of check boxes used to track relevant statistics such as scoring, penalties, fumbles, and interceptions.

The person annotating a game, the annotator, starts by pressing the green three-state button labeled "Start Play" to mark the beginning of the play. The program changes the label of the button to read "End Play" and changes the color to red allowing the same button to be used to mark the end of the play. When the play is over the annotator presses the button again to mark the end of the play. The program switches the button label to "Log Play" and changes the button color to blue. The annotator uses the down time between each play to update the ball position and first down sliders. This down time is also used to mark things such as points made, whether it was a passing or running play, and which, if any, turnovers or penalties occurred. Finally, the annotator presses the "Log Play" button to finalize the play annotation and the program resets the controls, ready to log the next play. Annotations are stored in the *Annotation Repository* as they are generated.

In reality, broadcasters already have methods for capturing most of this information. A production implementation of TWF might pull this annotation information from existing systems making a manual annotation program unnecessary. We created the *Annotator Program* to facilitate the generation of the game annotations and as a proof-of-concept that a single person could indeed annotate a game in real-time and capture all of the

metadata TWF needs. The annotations generated by the *Annotator Program* are available real time via a web service.

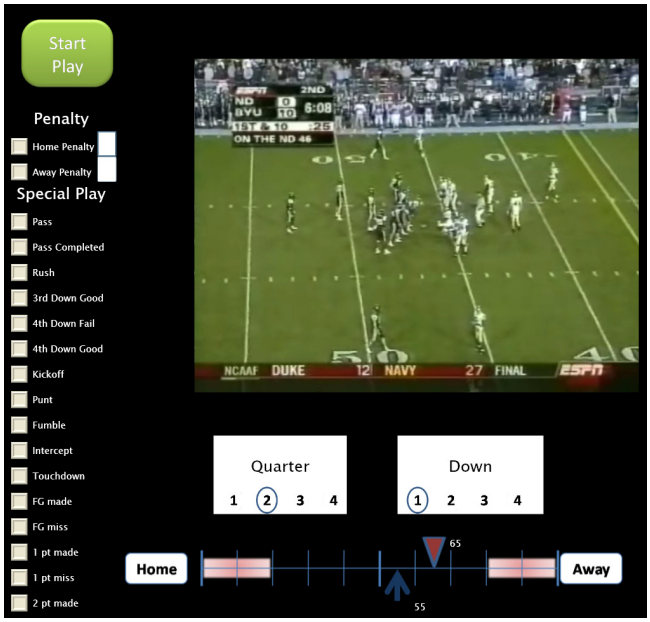

Figure 2. American football Annotator Program.

3.3 Annotation Format

Football games, and many other sports, can be modeled using a tree structure where tree nodes represent different segment types: the game, quarters, series, and plays. These segment types create a hierarchy in which the game is made up of quarters, quarters are made up of series, and series are made up of plays. Each node of the tree constitutes a clip in the annotation file. Every clip contains a segment type, a start time offset, an end offset, a unique id, and any other relevant metadata for that segment type. For example, clips representing plays contain the start position of the ball, what the current down is, and the current game statistics up to that point in the game.

Our *Annotator Program* captures the game annotations in this tree form. Figure 3 shows a simplified excerpt of an annotation file generated by our *Annotator Program*[1]. The first clip is of type quarter and contains two child clips of type series. Each series clip in turn contains a single play clip. An annotation file contains a simple hierarchy representing an entire football game.

3.4 Navigation Devices

One key component of any interactive TV system targeted for home use is that it must be easy to learn. Any home entertainment system that requires people to be trained before they can successfully use the system will have a very difficult time succeeding. TWF is designed to enable viewers of all ages to quickly and easily learn how to control the system without any training.

[1] We simplified the annotation file for this paper by removing most of the game statistic attributes to better illustrate the structure of the annotation file without getting lost in all of the statistics.

TWF is configured to display correctly on a standard home TV and is connected to an off-the-shelf wireless video game controller that is used as the remote control for the experience. Figure 4 shows a picture of the actual wireless video game controller TWF uses.

```
Clip {
        StartOffset : 100
        EndOffset : 323
        ClipType : “Quarter”

        Clip {
                StartOffset : 100
                EndOffset : 120
                ClipType : "Series"

                Clip {
                        StartOffset : 100
                        EndOffset :120
                        ClipType : "Play"
                        Home_Touchdown : "0"
                        Away_Touchdown : "0"
                }
        }
        Clip {
                StartOffset : 134
                EndOffset : 323
                ClipType : "Series"

                Clip {
                        StartOffset : 104
                        EndOffset : 114
                        ClipType : "Play"
                        Home_Touchdown : "0"
                        Away_Touchdown : "1"
                }
        }
}
```

Figure 3. Simplified excerpt of an annotation file.

Because video game controllers provide a simple set of generic buttons that inherently have no meaning, TWF uses on-screen semi-transparent overlays (Figure 5) to assist the viewer in learning the controller functions. Video overlays are brought up by pressing and holding one of the four menu buttons found on the front of the game controller. These overlays enable the viewer to learn the system quickly, with almost no training.

The number of navigation options TWF offers exceeds the number of buttons on the game controller. TWF makes use of the menu buttons appearing on the front of the controller so that, when pressed, they change the function of the remaining buttons. Holding a menu button down displays the control overlay corresponding to that menu. Figure 5 shows the default control's video overlay. The layout of the overlay matches the layout of the buttons on the game controller making it easy for viewers to match buttons on the screen with buttons on the controller. Pressing another button on the controller will activate the command associated with the currently active menu. The commands we felt would be most commonly used are available on the default menu. The default menu commands can be

activated with or without the corresponding menu button held down. Multiple menu options provide a large range of easily learned control functions and a self teaching mechanism for using the common functions without visual distraction.

Figure 4. Video game controller used by TWF.

Figure 5. Default navigation control overlay.

TWF's control overlays enable viewers to quickly learn the navigation controls as they watch the game without any formal training. The only thing viewers need to know is that pressing the front menu buttons will display all of their navigation options. Since the overlays are available at any point in the game, viewers can feel confident that they are in control of the system and can easily find options with which they may not be completely familiar.

3.5 Precision Navigation

One key feature of TWF is the ability to navigate the game both forward and backward based on clip boundaries. With a single button press, viewers can skip forward to the start of the next play, backward to replay the current play, forward to the start of the next series, or replay the current series. Jumping directly to the start of the desired play removes the need to fast forward or rewind to find specific points in the game. Though we provided fast forward and rewind, they were rarely used once subjects understood the play-oriented controls.

The annotation file described previously makes precision navigation possible. While the tree structure of the annotation file shown in Figure 3 nicely captures the structure of the game, it is not easy to work with in practice. We found it much easier to flatten the tree into separate ordered lists corresponding to each segment type. Flat lists make forward and backward navigation by segment type a simple matter of finding the clip that corresponds to the current offset and moving to either the next or previous clip in the list. Accomplishing the same thing when the annotations are stored in tree form is much more complicated.

TWF provides the following navigation commands:

- Next Play / Next Series – Uses the current video offset to find the current play or series clip, advances to the next clip in the corresponding list of clips, and repositions the play head to the start offset of that clip.
- Back Play / Back Series – Uses the current video offset to find the current play or series clip. If the current offset is within the first three seconds of the clip, TWF goes back one in the list of corresponding list of clips and repositions the play head to the start of that clip. If the current offset is beyond the first three seconds of the clip, TWF repositions the play head to the start offset of the current clip to replay the clip.

Figure 6. Navigation action overlay.

When jumping to the next or previous play, TWF finds the start offset of the play and subtracts two seconds from that time, effectively starting playback two seconds before the actual start offset of the play. The reason for this buffer is to give the viewer time to orient themselves to what is showing in the video before the play actually begins. Jumping directly to the start offset of the play is often frustrating because the play is underway before the viewer recognizes the transition occurred and is able to get reoriented to the currently playing video.

3.6 Visual Prompts

Jumping around in a video stream can be a disorienting experience for viewers, especially for those not holding the controls. Our initial implementation of TWF did not have any transition indications when people would navigate forward or backward through the game. This navigation would happen so fast that even the person holding the controls would often get lost and not be able to follow what's going on in the game. For viewers without the controls it was even worse. Not being the

one controlling the experience, they had no possible way of knowing if they were jumping forward or backward through the game and sometimes would not even realize they had jumped at all. TWF mitigates this issue by providing an on-screen overlay indicating the last action taken, with a subsequent overlay (Figure 6) giving the down and yards-to-go information for the newly selected play. This overlay information gives feedback to the person controlling the game that the requested action was performed and also helps the rest of the viewers know where they are in the game.

3.7 Alternate Camera Angles

Current broadcast TV programs are limited to a single stream requiring show directors to piece together a broadcast that will appeal to as broad an audience as possible. One advantage of using Internet-based video is that multiple streams can be made available for a single broadcast with little effort and nearly no additional expense to the broadcaster. For any given football broadcast there are a variety of cameras filming the game from a number of different angles. Cameras showing views from the sideline, end zones, line-of-scrimmage, and even above the field are all available for any given play. Unfortunately, most of this video footage is wasted since the only thing made available to the viewer is whatever the broadcast director pieces together to go out for the standard broadcast. TWF provides a way for the video from every camera on the field to be made available to the home viewer.

For our prototype, TWF uses three separate camera angles covering the same game. The viewer can choose to watch the game from the normal TV broadcast view, a wide angle sideline view, or a wide angle end zone view. The two additional views came from video recorded for the coaching staff. The availability of the coaching cameras gave us the video we needed without interfering with standard broadcast television practice. Ideally there would be more camera angles to choose from but these three camera angles were the only ones available to us. Because each of the video streams is synchronized, a single annotation file is used for all three streams. The TV broadcast view is important because it provides a more dynamic view of the game that is appealing to viewers who prefer to relax and "just watch the game." For viewers wishing to take a more active role in their viewing experience, TWF enables viewers to switch between any of the cameras on the field based on individual user preferences.

Because viewers switching camera angles often want to re-watch an interesting play from a better angle, TWF facilitates this desire by automatically replaying the current play anytime an alternate camera angle is selected. Switching between camera angles is implemented by changing the video feed the player is streaming. When a viewer selects an alternate video stream, TWF saves the current video offset, switches the video stream to the stream containing the new angle, looks up the last play clip with a start offset less than the current offset, and sets the play head to the start offset of that clip. All camera angle switches are accompanied by an on-screen overlay indicating what camera angle is now being viewed. All of this adds up to a viewer initiated instant replay, from whatever angle the viewer wants, with the press of a single button. The switching between streams generally takes less than two seconds even though the video is served from hundreds of miles away.

3.8 Statistics

The final interactive feature that TWF provides is real time game statistics available at any point in the game. Pressing one button on the controller brings up game summary statistics as seen in Figure 7. Similarly, a separate button will bring up statistics summarizing the current drive. Fans no longer have to wait for the broadcaster to show game statistics or check the Internet for the current statistics. TWF provides up-to-the-play statistics for every play in the game.

Game statistics are embedded in the annotation file that supports TWF. When a viewer brings up a set of statistics, TWF gets the current video offset, scans the list of play clips to find the last clip with a start offset less than the current offset, and loads the statistics associated with that clip into the on-screen overlay.

Figure 7. Game summary statistics.

Providing statistics in this manner requires that a separate copy of each statistic be stored with every play in the game. There was some concern at first that this might create an unreasonably large annotation file whose download time would impact the functionality of the player. In practice, the annotation file is highly redundant allowing for excellent compression of the file. The compressed version of the annotation file containing the annotations for an entire football game is only 7KB, well within the limits of an easily downloadable file.

3.9 Live Game Viewing

TWF supports live viewing of a football game. Since the annotations required by TWF are easily generated in real time, viewers can watch the game live and take advantage of all of the TWF features just like they could if they were watching a pre-recorded game. One potential problem with a live viewing experience is people may try to skip to the next play when that play has not yet occurred. In this event, TWF shows an on-screen overlay to the viewer indicating they are watching live TV and cannot skip ahead.

4. EVALUATION METHOD

One important aspect of this work is to better understand how TWF will be used in the natural viewing environment of sports fans with entertainment being the only goal. Specifically we are interested in the following:

- Can we provide an interactive TV control system that is easy to learn without formal training?

- Can on-screen prompts effectively enable groups to watch an interactive sporting event without getting lost?
- Will TWF provide a successful interactive TV experience for fans watching an American football game?

4.1 Participants

The user study involved 11 groups using the system at home on their own TV. Groups were formed by asking 11 individuals (e.g., friends, past co-workers, and other acquaintances that had previously shown interest in the study) to invite 2-4 friends over to their house to watch a football game. All participation was voluntary and the only compensation participants received was free pizza while watching the game. Twenty eight males and 11 females participated in the evaluation with an age range of 18-55+. Interest in football varied among the participants with 5 participants watching 4 or more games a week, 7 participants watching 2-4 games a week, 14 participants watching one game a week, 12 participants watching one game a month, and 1 participant who never watches football.

4.2 Evaluation Setting

Groups gathered in the home of one of the group members to watch a football game using TWF. TWF ran on a standard PC connected to the home TV and used the home broadband connection to stream video content from servers several hundred miles away. An off-the-shelf wireless video game controller was connected to the computer for use as the remote control for TWF. The game controller and TV were the only hardware devices used by the participants.

Participants were asked to watch an old American football game from the 2004 college football season. We selected an older game for the evaluation because participants would be less likely to remember the details of the game and the final outcome. Video for the game started half way through the second quarter and continued until the end of the game. (The timing of the game was constrained by video footage available from our University Athletics Department.) Half time and all commercials were cut out of the game for a total playback time of 102 minutes. Three camera angles were available for this experiment. A TV view contained the actual TV broadcast of the game including the network commentary. A sideline view and an end zone view created for coaches were also made available. Each view used the audio track from the TV broadcast view to make switching between camera angles a smoother experience for the viewer.

For the evaluation, each group was asked to imagine they were sitting down to watch a live football game that was already half way through the second quarter. Even though all of the football footage was pre-recorded, TWF was configured to enforce an imaginary live time to get a better idea of how people behave in a live viewing experience. This imaginary "live" time was set to be 10 minutes ahead of real time which effectively gave groups 10 minutes of content they could skip before catching up to "live" time.

We logged all user commands issued during the sessions and videotaped the participants watching the game. Each videotaped session was reviewed and specific behaviors were coded. At the end of each viewing experience, an informal post game interview was completed to gather feedback from the individual groups.

5. RESULTS

5.1 Learnability

The first goal of the TWF system is to provide an interactive TV interface that is easy to learn and requires no formal training. TWF has two different command menu overlays that visually display what commands are available and how to activate those commands using the game controller. The only "training" that participants were given before watching the game was being shown where the menu buttons where located on the controller. Participants were informed that holding a menu button down displays the commands associated with that menu and that the upper right menu button contained the default commands which could be activated with or without holding the menu button down.

Figure 8 shows how often the default menu overlay was viewed per minute during each quarter compared with how often, on average, a default command was issued. Commands found on the default menu can be activated with or without the default menu overlay visible. Default control menu views are reduced by 63% from the second quarter to the third quarter, while at the same the time the usage of these commands increased by 64%. This dramatic decrease in menu views accompanied by an equally dramatic increase in commands shows that viewers were quickly able to learn the controls well enough that they rarely needed the visual prompts to be able to successfully interact with the system.

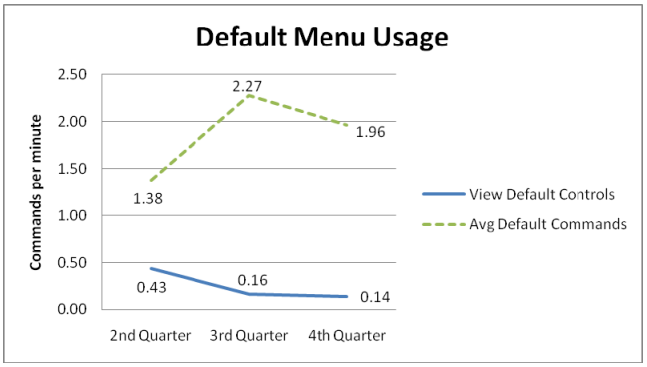

Figure 8. Control overlay view counts per minute.

Use of the commands on the secondary menu can only be activated when the secondary menu is visible. There was a 72% reduction in secondary control views from the second to the third quarter. These controls include the standard DVR style controls: play, pause, rewind, and fast forward.

Figure 9 shows how the use of these controls drops off over time. Of particular interest is the drop in use of the fast forward and rewind options. By the fourth quarter these options are almost never used. This suggests that as viewers become more comfortable with the new play-based controls such as Next Play and Previous Play, they begin to replace their use of old familiar controls like fast forward and rewind with the new, more precise, controls.

5.1.1 Game Controller Learnability

Figure 4 shows the wireless video game controller that participants used to control TWF. A total of 27 participants ranging in age from 18-54 actually used the controls themselves. Post game interviews showed that all 27 participants that used the controller felt like the controls were easy to learn and easy to remember once they learned them. Configuring the command

overlays to match the layout of the actual video game controller was an effective approach to creating an interface that was easy for people to learn without training.

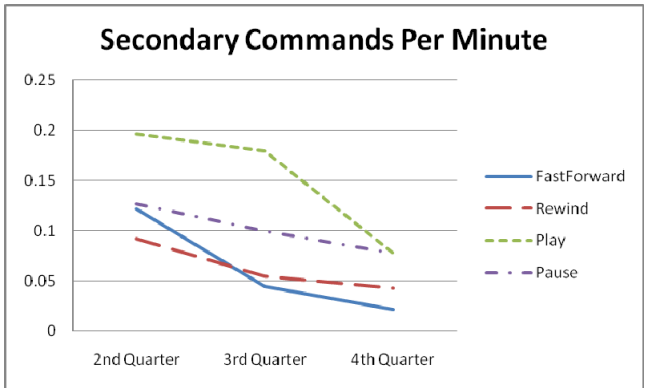

Figure 9. Secondary command usage counts per minute.

Twenty-four participants said that they would prefer using a game controller as their remote control over a standard TV remote control. One participant noted, "If you have content that is highly interactive, you're going to feel constrained by a remote control. You're going to want to feel like you are playing the TV."

Eleven people said that while they felt the video game controller was easy enough to use, they would still prefer a standard TV remote control for watching TV. While it is common for different people to prefer one control device over another and TWF could be configured to run with a standard remote control, it's worth noting that despite these user preferences, all participants were able to successfully control the system using the video game controller.

The main reason cited for favoring a standard remote control was the one-handed nature of a TV remote. Note that of the 11 participants that would prefer a standard remote control, 3 of them never actually used the game controller suggesting that there is some amount of user bias that exists against video game controllers, specifically among the older generation. This conjecture is reinforced by a comment made by the oldest participant (age 55+) when he said, "I wouldn't know that to do with that." In the end, this participant refused to even try the controller.

5.1.2 Control Usage

Another useful indicator that the system was easy to learn is how often participants actually used the controls. In our in-home evaluations, groups actively used the TWF controls. Over the 102 minute game, a command was issued on average every 24 seconds. Figure 10 shows the average command usage per minute for each type of command. The Next Play and Change View commands were by far the most frequently used commands. This corresponds directly with user feedback obtained in the post game interviews where all 11 groups said their favorite commands where Next Play and Change View.

In Figure 10, there appears to be a drop off in usage of the Change View command as the game goes on. To explain this behavior, Figure 11 shows the cumulative usage counts for the Next Play and Change View commands for every play in the game. The Next Play command usage is fairly consistent throughout the entire game. In contrast, the Change View command is fairly irregular with large spikes in usage as the game proceeds. Comparing these spikes with the actual plays in the game, there is a noticeable correlation between use of the Change View command and interesting plays in the game. The usage drop seen with the Change View command is because there were not as many interesting plays in the fourth quarter.

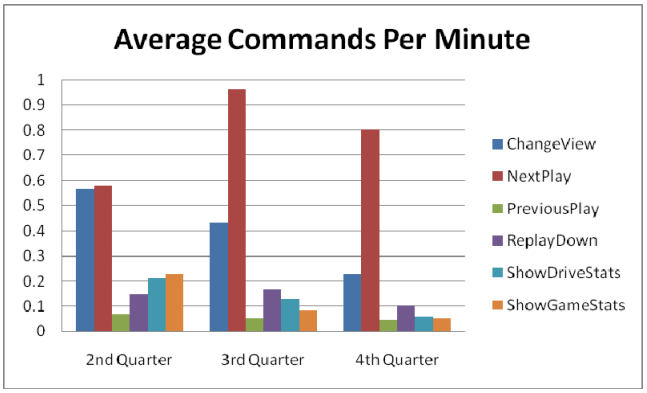

Figure 10. Average commands per minute for all groups.

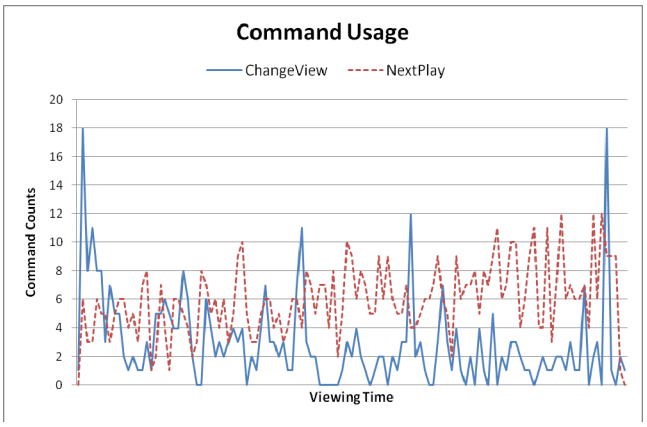

Figure 11. Total commands issued for every play.

Clearly, TWF's use of on screen command overlays whose layout closely matches that of the physical controller has proven to be an effective method for providing easily learnable yet powerful navigation controls. Participants were able to quickly learn the controls and actively used those controls throughout their viewing experience suggesting that they found value in having the extra interactive features.

5.2 Group Viewing Experience

The next goal of the TWF system was to provide an interactive system that enabled groups of people to watch a game together without getting lost.

5.3 Effectiveness of Transition Prompts

TWF uses visual overlays to signal when a command was issued, what the command was, and where in the game playback will resume by showing the current down and yards-to-go. Going into the evaluation, it was not clear if these visual prompts would be sufficient to enable viewers not holding the controls to follow what the person with the controls was doing.

In the videotaped sessions, an average of only 0.875 incidences of "navigation angst" where recorded per group. "Navigation angst"

was characterized by a comment or gesture indicating at least one viewer was confused by a navigation command. The frustrated viewer was not necessarily the one holding the controller. In the post game interviews, 35 out of 39 people commented that the navigation prompts made it easy to follow the game and to know what was happening even when they were not holding the controller. Participants especially liked the down and yards-to-go information in the prompts.

We also tracked how people not holding the controls influenced the game's navigation. On average, participants not holding the controls made 17.4 navigation requests per game. These requests included things such as wanting to move to the next play and asking to see a play again from a different camera angle. Many users expressed the feeling that physically possessing the controller was not as important as feeling like their navigation requests were being fulfilled. As long as the person holding the controller was responsive to other's navigation requests, it did not seem to matter who actually had the controller.

Providing visual feedback of control commands in the form of on-screen overlays is an effective way of helping people not get lost during an interactive TV experience, specifically those not holding the controller.

5.4 Successful Interactive TV Experience

The final goal of the TWF system is to create a system that would provide a successful interactive experience. We base the success of the experience on the user feedback obtained in our in-home evaluations.

5.4.1 Entertainment Value

In the post game interviews, all 11 groups said they liked the system a lot and would prefer using TWF over any other commercially available system to watch football games. Comments such as "This is so sweet," and "That was awesome" where frequently heard from all 11 groups.

Another common theme among all of the groups was the enjoyment of having more interactive control of the viewing experience. For example, one participant, speaking about the social implications of having interactive controls, said:

> *It made everyone want to help participate in it. Whereas, if we were just at a game, we would have cheered but we wouldn't have said, 'stop, let's talk about this.*

Having easy access to interactive controls enhanced participant's viewing experiences by increasing and facilitating social interactions.

5.4.2 Total Viewing Time

A common concern among broadcasters with interactive TV systems is loss of viewing time. Actual game time for a football game is 60 minutes but a typical broadcast of a football game takes around 3 hours. If viewers can skip all of the content between plays they might easily watch a 3 hour broadcast in as little as 60 minutes. This represents a definite problem for broadcasters who need to sell 3 hours of ads to make their money back.

Total playback for our sample game was 102 minutes with 29 minutes being actual game play and the remaining 73 minutes being "skip-able" time between plays. In our scenario, we started people 10 minutes behind "live" time which effectively meant that groups could watch the game in as little as 92 minutes. In all but two cases, groups spent more time watching the game than they had to if they had skipped everything the system would have let them skip and finished with live time. On average groups finished the game 5.6 minutes behind live time meaning that even though there were 73 minutes of "skip-able" content, participants filled in most of that time reviewing plays and interacting with the system. At the extremes, two groups finished right with live time and essentially skipped as much content as they could and one group spent 114 minutes watching the game which was 12 minutes longer than the actual playback time of the game and 22 minutes longer than they had to watch.

One participant commented, "I just like that you can watch the game so much quicker." Interestingly, this group never actually caught up to live time. Though they could go faster and thought they were going faster, the reality was quite different. Their use of the replay and multiple camera features consumed all of the time they might have saved skipping from play to play. Another participant said, "You just take out the stuff that makes it feel like it takes forever." Allowing the viewer to spend less time watching video that does not interest them and more time watching and re-watching the parts of the game they are really interested in not only keeps people's interest for longer, it also gives them the impression that they have spent less time watching. This is most likely because they are spending the time focused on things important to them rather than feeling like they are wasting time between plays.

In the post game interviews, 38 out of 39 participants said they wanted more camera angles. Participants felt that with more camera angles they would have spent even more time re-watching plays. The additional camera angles that we had were created for coaches. They allowed us to create a valid experience but the sideline, goal line, and close-up shots available to the broadcast team would have been much more interesting to the viewers.

5.5 What was Missing?

TWF is a prototype of an interactive football viewing system that provides a number of unique and powerful features to football fans. As well received as TWF was, participants noted a number of features they would like to see added to TWF to further enhance the experience.

None of the following requests were directly solicited outside of a general question of, "was there anything missing that you wanted?"

- All 11 groups wanted more camera angles. (Ultimately this is not a limitation of TWF as TWF can support any number of alternate camera angles but it is worth noting that this was one of the most desired additions to TWF.)
- 7 out of 10 groups wanted a slow motion option (easy).
- 5 out of 10 groups did not want the current play to restart when they switched camera angles (easy). The other 5 groups liked having the auto-replay. This feature would be a good candidate for a user configurable option.
- 4 out of 10 requested some visual indication of how far they were from live time (easy).
- 4 out of 10 groups wanted the option to select alternate audio tracks. Listening to the other team's announcers or allowing

individuals to post their own audio tracks commenting on the game was thought to be desirable (doable).

- 5 out of 10 groups requested the ability to zoom in on portions of the screen (hard).

The addition of slow motion along with providing more camera angles would likely have led to even longer viewing times.

6. CONCLUSION

Overall, participants were excited by the idea that someday they could be watching football using an interactive TV system like TWF. Precision navigation controls and the option to switch between alternate camera angles engages users and increases satisfaction with the overall viewing experience.

One key success of the TWF system is the notion of providing on-screen navigation overlays that closely resemble the physical layout of the control device. Presenting navigation controls in this manner enables users to easily learn how to use the system and makes them feel comfortable with the controls more quickly.

Watching football is typically a shared experience among a group of friends or family. Paying attention to the needs of viewers not holding the controls is essential for having a successful shared viewing experience. TWF's visual transition prompts successfully enable these viewers to follow the game and the navigation commands of the one holding the controls.

While TWF is focused on American football, it is easy to see how fans of a variety of sports would benefit from many of the same interactive features. It is clear that sports fans want more control over their viewing experience. More camera angles, precision navigation options, and easier access to statistics are all features that increase viewer satisfaction and enable viewers to take control of their own viewing experience. TWF provides an unparalleled live game viewing experience that has been enthusiastically received.

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