Trade-off Analysis of Decision Support Systems for Time Sensitive Operations/Referee’s Assistant

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WHAT IS SOCCER?

Consist of:

• Official Referee
  • Runs Diagonal of field (To maximize Line of Sight)
  • Grants Final Decision(s)
  • Executes Laws of the Game

• Assistant Referees
  • Identifies Offside
  • Aids Official to identify infringements

• 4th Official
• Soccer Players
CURRENT REFEREE STATUS

Only 96.88% of Goal Decisions in 2010 World Cup were correct:
• 142 of the 145 goals awarded correctly
• 13 goals were correctly disallowed for offside
• Two more goals should have been allowed

In the League Managers Association (LMA) the Additional Assistant Referee (AAR) experiment concluded that:
• Only 78.8% for 5 types of decisions (Goal Kicks, Corner Kicks Free Kicks, Throw Ins, & Advantages) were Correct
• 10.2% were incorrect
• 10.9% was inconclusive.
Players are running faster and are covering more distances. 9 km in 1990’s, 11 km in 2004, and 15 km in 2010.

Based on our Subject Matter Expert, amount of decisions per game: 627 game situation decisions
Registered US Youth Soccer Players vs. Time

Number of Registered US Youth Soccer Players vs. Time

Virginia
Connecticut
Iowa
Florida
Utah
Total
• The importance of a goal being scored is increasing due to the decrease in average number of goals scored

• 17 teams won 1-0 out of the 64 matches during 2010 World Cup

• Spain, who won the 2010 World Cup, won 5 out-of 7 matches 1-0

Source: FIFA 2010 World Cup Technical Report
WHAT IS AT STAKE?

- Legitimacy of sport
- Fan base viewership (increasing popularity in other sports)
- MONEY: TV Revenue, Merchandise/Ticket Sales, TV Broadcasting rights, player trades

**British Sky Broadcasting TV Rights Value in English Premier League vs. Time**

- Total $ spent on games rights annually (Millions)
- Overall Revenue from Broadcasting rights

```
Total $ on rights deals 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
$ spent on games rights 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200
```

Overall $ Revenue from Broadcasting rights:
- 1992: $0
- 1993: $0
- 1994: $0
- 1995: $0
- 1996: $0
- 1997: $0
- 1998: $0
- 1999: $0
- 2000: $0
- 2001: $0
- 2002: $0
- 2003: $0
- 2004: $0
- 2005: $0
- 2006: $0
- 2007: $0
- 2008: $0
- 2009: $0
- 2010: $0
- 2011: $0
- 2012: $0
- 2013: $0
Referees are limited to:

• ONE line of sight
• Running Speed/ Degree of Fitness
• Limited ability to process event data (e.g. Offside: Flash-Lag effect; Referees can not simply see two events at the same time)
• Referee performance shows majority of the 2\textsuperscript{nd} half of a match outputting at 85-95\% Maximum Heart Rate

• Total distance covered by Referees must match players increased significant distance covered. 9 km during the 1990s, 11 km in 2004 and 15 km in 2010
WHY THIS IS A PROBLEM

- Physical Fitness
- One Line of Sight
- Processing Rate
- Biases
- Flash Lag

- Speed of the Game
- Number of Calls
- Popularity
- Prize Money
- TV Revenue
- Crowd Noise
- Country Pride
- Weight of Each Goal

Inaccurate Calls
• IFAB (International Football Association Board) are key holders of the “Laws of the Game”

• FIFA (Federation Internationale de Football Association) and IFAB are governing bodies of Soccer
PROBLEM STATEMENT:
Currently, the game has grown more complex, but humans are limited by their capabilities, creating a growing gap between the needed performance of the officiating system and the complexity. IFAB/FIFA (Governing bodies of soccer) have failed to identify and address this growing gap.

NEED STATEMENT:
There is a need to increase the percent accuracy of the Referee in game adjudication of a fair game.
• The system shall satisfy regulations and laws of the governing bodies of soccer
• The system shall reduce Referee workload
• The system shall relay information to the referee within 5 seconds of the game incident
<table>
<thead>
<tr>
<th>Utility</th>
<th>Cost</th>
<th>Accuracy (Percentage)</th>
<th>Usability (Learning Curve Rating)</th>
<th>Speed (Time to Result)</th>
<th>Time to make decision (seconds)</th>
<th>Time to transmit decision (seconds)</th>
<th>Implementation (Dollars)</th>
<th>Operation (Dollars, Annual)</th>
</tr>
</thead>
</table>

% Accuracy will come from model

Weights will be collected from stakeholder surveys
METHODOLOGY

• Simulate the effects of proposed Decision Support Systems on the Accuracy of a Soccer Official.

• Simulate the Factors that hinder a Referee’s ability to accurately judge an event

• Simulate the probability of an accurate decision based on the Decision Support System’s characteristics

• Perform a Trade-off Analysis comparing decision support systems to assist the soccer official
<table>
<thead>
<tr>
<th>Event</th>
<th>Affect</th>
<th>Freq</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>kicks or attempts to kick an opponent - in opponent's penalty area</td>
<td>Very High</td>
<td>10</td>
<td>10000</td>
</tr>
<tr>
<td>• trips or attempts to trip an opponent - in opponent's penalty area</td>
<td>Very High</td>
<td>10</td>
<td>10000</td>
</tr>
<tr>
<td>• jumps at an opponent - in opponent's penalty area</td>
<td>Very High</td>
<td>10</td>
<td>10000</td>
</tr>
<tr>
<td>• charges an opponent-in opponent's penalty area</td>
<td>Very High</td>
<td>10</td>
<td>10000</td>
</tr>
<tr>
<td>• pushes an opponent-in opponent's penalty area</td>
<td>Very High</td>
<td>10</td>
<td>10000</td>
</tr>
<tr>
<td>• tackles an opponent- in opponent's penalty area</td>
<td>Very High</td>
<td>10</td>
<td>10000</td>
</tr>
<tr>
<td>holds an opponent- in opponent's penalty area</td>
<td>Very High</td>
<td>10</td>
<td>10000</td>
</tr>
<tr>
<td>• handles the ball deliberately (except for the goalkeeper within his own penalty area)- in opponent's penalty area</td>
<td>Very High</td>
<td>10</td>
<td>10000</td>
</tr>
</tbody>
</table>

Importance Value = Frequency * Effect on Outcome
<table>
<thead>
<tr>
<th>Category</th>
<th>Freq</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Blind Angle</td>
<td>33</td>
<td>54.76</td>
</tr>
<tr>
<td>Horizontal Angle of Parallax</td>
<td>6</td>
<td>11.9</td>
</tr>
<tr>
<td>Visual Field</td>
<td>27</td>
<td>47.62</td>
</tr>
<tr>
<td>Speed</td>
<td>18</td>
<td>38.1</td>
</tr>
<tr>
<td>Distance</td>
<td>18</td>
<td>38.1</td>
</tr>
</tbody>
</table>

**Frequency of Difficulty Criteria for highest Expected Value**

- **Blind Angle**: 54.76%
- **Horizontal Angle of Parallax**: 11.9%
- **Visual Field**: 47.62%
- **Speed**: 38.1%
- **Distance**: 38.1%

26% Elsewhere
24% Penalty Area
52% Offensive 3rd
The **Distance** will be measured from the **Event Location** to the **Referee Location**.

\[
\text{Distance} = |\text{Referee Location} - \text{Event Location}|
\]
The **Duration** is defined as the amount of time an event takes to occur.

\[
\text{Duration} = \text{Finish Time} - \text{Start Time}
\]
The **Blind Angles** are defined as the angles that obstruct a system component view of the play.

\[
\text{Blind Angle} = |\text{Obstructed View}^\circ_{\text{Initial}} - \text{Obstructed View}^\circ_{\text{Final}}|
\]
The **Angle of Parallax** is defined as the degree of separation from the **Optimal Viewing Angle** and the **Actual Viewing Angle**.

\[ \text{Angle of Parallax} = |\text{Optimal Angle}^\circ - \text{Actual Angle}^\circ| \]
The **Visual Field** is defined as the area viewable by a single System Component.

\[
\text{Visual Field} = |\text{Visual Field}^\circ_{\text{left}} - \text{Visual Field}^\circ_{\text{right}}|
\]
The most important factors:
• Distance
• Blind Angles
• Angle of Parallax
• Duration
• Visual Field

Event’s Analyzed will be limited to the 42 calls with the most impact on the game:
• Fouls
• Goals
• Play Stoppage
• Disciplinary
SIMULATION DESIGN

Ball Position Function → Event Function → Probability of Accurate Call Function → \[ \sum \text{ Foul 1 – 40\%} \]

Ref Position Function → Probability of Accurate Call Function → \[ \text{Foul 2 – 60\%} \]

... → Total System Accuracy
SIMULATION DESIGN

Ball Position Function
Event Function
Ref Position Function
Probability of Accurate Call Function
\[ \sum \text{Foul 1} = 40\% \]
\[ \text{Foul 2} = 60\% \]
... 

Total System Accuracy

R = Random Number
ballPosition = bp
If (R == nextPositionCDF)
ballPosition = nextPosition

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SIMULATION DESIGN

If (Random Number == specificEventTypeCDF)
   EventType = specificEventType
   EventDuration = Random Number(0,X)

If(Random Number == specificLocation)
   Location = specific Location

return Event & Location

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Freq</th>
<th>%</th>
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<tbody>
<tr>
<td>Tripping</td>
<td>23</td>
<td>54.76</td>
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<tr>
<td>Out of Bounds</td>
<td>4</td>
<td>9.52</td>
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<tr>
<td>Goal</td>
<td>5</td>
<td>11.9</td>
</tr>
<tr>
<td>Push</td>
<td>20</td>
<td>47.62</td>
</tr>
</tbody>
</table>

Event Type
- Event Location
- Event Duration

26% Elsewhere
24% Penalty Area
52% Offensive 3rd
SIMULATION DESIGN

RefPositionY = RefereeDiagonalPosition(BallPositionX)

Return BallPositionX, RefPositionY

*Assume Referee will always be in position according to graph (No fatigue, No straying off path)
Accuracy Probability due to:
Distance + Blind Angles + Angle of Parallax + Duration + Visual Field

SIMULATION DESIGN

Ball Position Function
Event Function
Ref Position Function

Probability of Accurate Call Function

Total System Accuracy

∑
Foul 1 – 40%
Foul 2 – 60%
...

Probability that a single event will be called accurately
EX – Tripping Foul = 78% of Accurate Call

System Data
Location of Components (L)
# of LOS (S)
Processing Time (T)
Visual Field (V)
Accurate Range (R)

Input Data
Event Blind Angles (EB)
Event Type (ET)
Event Location (EL)
Event Duration (ED)
Referee Position

Excel
SIMULATION DESIGN

DISTANCE

Distance = |EL – L|

P(Accuracy) = P(Accuracy due to Distance)

System Data
- Location of Components (L)
- # of LOS (S)
- Processing Time (T)
- Visual Field (V)
- Accurate Range (R)

Event Data
- Event Blind Angles (EB)
- Event Type (ET)
- Event Location (EL)
- Event Duration (ED)

Ball Position Function

Event Function

Ref Position Function

Probability of Accurate Call Function

∑ Foul i – 40%
Foul 2 – 60%
...

Total System Accuracy

Distance = \|EL – L\|
SIMULATION DESIGN

Ball Position Function
Event Function
Ref Position Function
Probability of Accurate Call Function

\[ \sum \text{Foul 1} = 40\% \]
\[ \text{Foul 2} = 60\% \]
...
Total System Accuracy

System Data
Location of Components (L)
# of LOS (S)
Processing Time (T)
Visual Field (V)
Accurate Range (R)

Event Data
Event Blind Angles (EB)
Event Type (ET)
Event Location (EL)
Event Duration (ED)

BLIND ANGLES

Event Blind Angles
Location of Components

= P(Accuracy from Blind Angles)

P(Accuracy)
Angle of View

Blind Angles
SIMULATION DESIGN

**Angle of Parallax**

- **Optimal View Angle**
- **Actual View Angle**

\[
P(\text{Accuracy}) = P(\text{Accuracy from Angle of Parallax})
\]
SIMULATION DESIGN

Ball Position Function

Event Function

Ref Position Function

Probability of Accurate Call Function

\[ \sum \text{Foul 1} - 40\% \]

\[ \text{Foul 2} - 60\% \]

... 

Total System Accuracy

System Data
- Location of Components (L)
- # of LOS (S)
- Processing Time (T)
- Visual Field (V)
- Accurate Range (R)

Event Data
- Event Blind Angles (EB)
- Event Type (ET)
- Event Location (EL)
- Event Duration (ED)

DURATION

Event Duration

Processing Time

\[ P(\text{Accuracy}) \]

\[ T \]

\[ \text{Event Duration} \]

\[ = P(\text{Accuracy from Event Duration}) \]
SIMULATION DESIGN

**Ball Position Function**

**Event Function**

**Ref Position Function**

**Probability of Accurate Call Function**

\[ \sum\text{ Foul 1 - 40% Foul 2 - 60%} \ldots \ldots \]

**Total System Accuracy**

---

**System Data**
- Location of Components (L)
- # of LOS (S)
- Processing Time (T)
- Visual Field (V)
- Accurate Range (R)

**Event Data**
- Event Blind Angles (EB)
- Event Type (ET)
- Event Location (EL)
- Event Duration (ED)

---

**VISUAL FIELD**

\[ \theta = \text{acos}(V_1 \cdot V_2) \]

\[ = P(\text{Accuracy from Visual Field}) \]

---

\[ P(\text{Accuracy}) \]

- \[V\]
- \[0\]
- \[60\]
- \[180\]
SIMULATION DESIGN

Ball Position Function → Event Function → Probability of Accurate Call Function → ∑ Foul 1 - 40% Foul 2 - 60% ... → Total System Accuracy

PROBABILITY EQUATION

= P(Accurate Call for Event)

Probabilities due to

Distance + Blind Angles + Angle of Parallax + Duration + Visual Field

*Each will have different weights according to Type of Event

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SIMULATION DESIGN

Event 1 – 40%
Event 2 – 60%
Event 3 – 50%
...
...
...
AVG all Probabilities

Total System Accuracy

Ball Position Function → Event Function → Ref Position Function → Probability of Accurate Call Function → \[ \sum \text{Foul 1 – 40% } \text{Foul 2 – 60% } \text{... ...} \] → Total System Accuracy

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Must compare all Simulation Data against Actual Games

Sample Size needed to Achieve a C.I. of 10% with a 95% Level of Confidence:

$$\frac{Z^2 \cdot p(1-p)}{(CI)^2} = \frac{1.96^2 \cdot (.5)(1-.5)}{.1^2} = 96 \text{ games}$$
## HOUSE OF QUALITY

<table>
<thead>
<tr>
<th>WHAT</th>
<th>HOW</th>
<th>Multiple Lines of Sight (Technology)</th>
<th>Change Diagonal Path</th>
<th>Sensor (microchip in ball)</th>
<th>Global Positioning Satellite (GPS)</th>
<th>Sensors &amp; GPS</th>
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<td>Build Actual Simulation</td>
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BUDGET AS OF 12/1/10

Earned Value Management

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<thead>
<tr>
<th></th>
<th>EV</th>
<th>AC</th>
<th>PV</th>
<th>CV%</th>
<th>SV%</th>
<th>CPI</th>
<th>SPI</th>
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<td>18106</td>
<td>21000</td>
<td>0.0544</td>
<td>-0.088</td>
<td>1.0575</td>
<td>0.9118</td>
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</tbody>
</table>
Risk Mitigation

Risk:
- Data Collection

Mitigation Strategy:
- Allocate more resources to collecting Data
- Started Simulation Building a month ahead of schedule.
References

Figure 1.5; Courtesy of: (Jesse Chula; 27 Jun, 2010). Available: http://view.picapp.com/pictures.photo/entertainment/germany-goalkeeper-neuer/image/9233659?term=People%253a0.714%253a%2522Frank%2bLampard%2522+frank+lampard&scomp=pis & (Sophie Freeman; 29 June 2010). Available: http://www.dailymail.co.uk/news/article-1290538/World-Cup-2010-Sepp-Blatter-apologises-concedes-time-talk-technology.html
Questions?
ALTERNATIVES

Alternative 1:
Multiple Lines of Sight (Human) + Multiple Lines of Sight (Technology) around the Offensive 3rd of the field to monitor infringements.

Alternative 2:
Multiple Lines of Sight (Technology) around the Offensive 3rd of the field + Sensors (microchip in ball) to track ball (goals) and player activity (fouls)
Frequency of Effect on Outcome of Game

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Med</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect on Outcome of Game</td>
<td>0</td>
<td>30</td>
<td>15</td>
</tr>
</tbody>
</table>
Frequency of Affect on Outcome of Game

- Low: High frequency
- Med: Low frequency
- High: Moderate frequency
- Very High: Moderate frequency

Affect on Outcome of Game
OPERATIONAL CONCEPT