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An Event-Driven Wearable System for Supporting Motorbike Racing Teams

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Abstract

Exploiting the latest information is very important for winning a motorbike race. However, it is difficult for a pit crew to acquire the latest information while working. The miniaturization of computers has enabled the creation of wearable computers which permit users instant, and hands-free access to information. Therefore, we propose a wearable system that supports motorbike racing teams. This system allows pit crew to browse for various race information easily and effortlessly.

1. Introduction

Motorbike racing is a popular motorsport. Some motorbike races have grueling conditions that include a number of rivals and many long hours to finish. In such races, there are two types of people helping the race; a team manager and a pit crew. The team manager makes decisions, and the pit crew implements the decisions that were made and make some decisions by himself. To win such harsh races, the team manager needs to plan strategies according to constantly changing circumstances, and the pit crew needs to acquire the latest information to produce their best work. For example, although refueling with a large amount of fuel decreases pit stops, it also causes poor acceleration because of the fuel weight. Moreover, the high-speed operation causes the rapid wear on the tire and it increases the number of tire-conversions. They have to consider such information as the difference of lap time with other teams and the number of remaining laps to determine the timing of the next pit stop and the amount of fuel. On the other hand, since the pit crew is doing its assigned duties, as shown in Figure 1, it is difficult for them to collect and to explore the most current information. Although the team manager can watch a television monitor that displays the race conditions, it is difficult for him to acquire desired information because the displayed contents are not personalized for his team. Consequently, the demands of a system are taxed to provide real-time information during a race without detracting from their work.

Figure 1. Working pit crew

In this paper, we describe an information delivery system for motorbike races that utilizes wearable computing technologies. Figure 2 shows a wearable computer. A head mounted display (HMD) provides immediate access to visual information. We exploit two characteristics of wearable computing; *Hands-free* and *Always on*, to support racing teams: These characteristics enable them to browse for information at any time. They are also helpful to highlight such important information as changes of rank.

The remainder of this paper is organized as follows. Section 2 explains the environmental assumptions and system requirements, and Section 3 describes the design and the implementation of our system. Section 4 describes the practical considerations and knowledge of our system, and Section 5 presents a conclusion and future work.

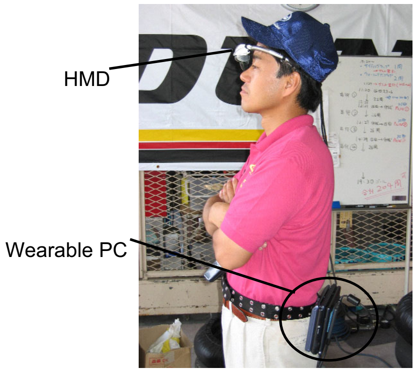

Figure 2. Style of wearable computing

Figure 3. Ranking monitor in pit

2. Requirements

In this section, we describe environmental assumptions and requirements for our system.

The motorbike races discussed in this paper take several hours and are called *endurance races*. Since such races feature several rider changes and pit stops, strategy is very important and complicated. Motorbikes are not allowed any communication devices except a transmitter that sends a motorbike ID to a receiver placed at the control line across the race track. The circuit control tower collects information on the motorbikes from the receivers and broadcasts it via radio waves. This means every time a motorbike passes the control line, the control tower broadcasts the motorbike information, such as the motorbike ID, the rider ID, the number of laps, and the elapsed time. The information of rider ID is attached manually by official observers on each pitstop. These assumptions are based on the FIM 2003 World Endurance Championship Round 6 ”Coca-Cola” Suzuka 8 hours Endurance Race, one of the most famous motorbike races. Suzuka Circuit has a 6km race-track, and motorbikes run through approximately 200 laps in the 8 hours. It has one control line at the goal line.

We also assume that each team manager and pit crew wears a computer with wireless LAN capability. In this research, we define three requirements:

1. No interference with work: wearable computer does not interfere with the work of a pit crew.
2. Information is continuously available: a wearable computer provides the latest information immediately whenever a pit crew wants to check.
3. Notification of incidental information: a wearable computer offers immediate information when an incident has occurred.

To insure that it does not interfere with works, the wearable computer should be free of input devices and it is equipped with an HMD as an output device[1]. Display information can be divided into two types: continuous and incidental. Continuous information refers to updates about information which changes every moment such as lap and remaining fuel. Here, the system calculates the remaining fuel based on the two information: the average fuel-consumption responsive to the motorbike speed, and the amount of refueling at each pit stop. This is because we cannot attach any device to the motorbike. A pit crew needs to gather the latest information immediately whenever they want. However, as shown in Figure 3, a ranking monitor cannot show information specialized to a particular team. Therefore, it is desirable to display such information completely and visually. Such incidental information includes the following events:

- The change of rank in the specific team.
- The rise/downslide of the lap time over the pre-set threshold in the specific team.
- Traffic accidents such as the crash, the obstacles, and the leakage of oil.

To win a race, it is important to be aware incidents and to react to them as soon as possible. When such an event occurs, it is necessary to immediately notify the crew.

3. Design and implementation

In this section we describe the design and implementation of our system. We employ a visual interface to display continuous information and an event-driven system called A-WEAR[3] to display incident information. Figure 4 shows an image of the proposed system. Because the control tower disseminates only lap information for each motorbike via radio waves and does not deliver information about rank, we established a server that receives and accumulates information, calculates the rank, and resends information to wearable computers via wireless LAN. These processings are fully automated. When an incident occurs,

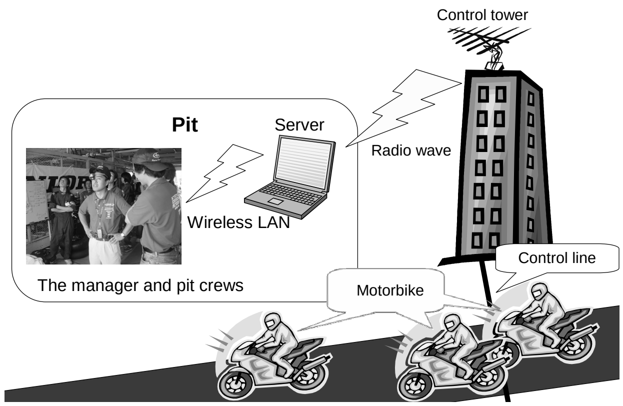

Figure 4. System image

```
DEFINE Rule-ID
    [IN List-of-belonging-groups]
    [FOR Scope]
    [VAR Variable-name AS Variable-type] *
WHEN Event-type [ (Target-of-event)]
IF        Conditions
THEN DO Actions
```

Figure 5. Syntax of ECA rules in A-WEAR

Common Plug-in

Type	Name	Content
EVENT	CMN_START	Initialize System
	CMN_TIMER	Timer expires
ACTION	COMM_EVENT	Generate specific event
	CMN_DISPLAY_MESSAGE	Display a message
	CMN_SET_TIMER	Set timer
	CMN_KILL_TIMER	Kill timer
	CMN_ADD_RULE	Insert rules
	CMN_LOAD_PLUGIN	Load a plug-in
	CMN_UNLOAD_PLUGIN	Unload a plug-in

Network Plug-in

Type	Name	Content
EVENT	NET_RECEIVE	Receive data
	NET_ FILE_RECEIVED	Finished receiving file
	NET_FILE_SENT	Finished sending file
ACTION	NET_UNICAST_SEND	Send data
	NET_BROADCAST _SEND	Broadcast data
	NET_FILE_SEND	Send file

IRC Plug-in

Type	Name	Content
EVENT	IRC_RECEIVE	Receive message
ACTION	IRC_CONNECT	Connect to server
	IRC_SEND	Send message

Table 1. Functions provided by plug-ins

```
DEFINE FIND-BUILDING
WHEN MOVE
THEN
  DO MAP_SET_CENTER (NEW.LATITUDE, NEW.LONGITUDE)
  DO QUERY ('SELECT * FROM GEODATA WHERE  (
    ABS (%NEW.LATITUDE%-X) < 0.005 AND
    ABS (%NEW.LONGITUDE%-Y) < 0.005) ')

DEFINE DISPLAY-WEBPAGE
WHEN SELECT (GEODATA)
IF ?MAP.EXIST (%GPS.X%;%GPS.Y%;%NEW.X%;%NEW.Y%;
  %MOTION_SENSOR.ALPHA_NORTH%;100.0;20.0)
THEN DO SHOW_BROWSER (NEW.URL)
```

Figure 6. Example of ECA rules

the server also delivers the information to wearable computers. The system can detect several incidental events automatically such as the change of rank and lap time by using the information from the control tower. On the other hand, the others are input manually based on the information from official announcements and reporters allocated in the circuit places, such as the traffic accidents (yellow/red flags) and the change in the weather.

Next, we explain an event-driven system called A-WEAR that is a platform of the proposed system and describe its design. Finally, we describe the implementation and practical uses of the proposed system.

3.1. A-WEAR

A-WEAR, a system platform for wearable computing, is a middleware that runs between OS and wearable services. In A-WEAR, we describe system behaviors with event-driven rules and use plug-ins to extend system functions. Service developers can easily construct various services by combining plug-ins and describing rules that use the functions of plug-ins. We can add, delete, or customize those services while the system is running by adding, deleting, or modifying the rules.

All services are represented as a set of ECA rules, which were originally a behavior description language in an active database system that is a database technology. An active database processes the prescribed actions in response to an event arising inside or outside the database[8]. Each ECA rule consists of three parts: *Event*, *Condition*, and *Action*. The event part describes an event that occurs in the system, the condition part describes the conditions for executing actions, and the action part describes the operations to be carried out. Figure 5 shows the syntax of ECA rules for A-WEAR. In the figure, *Rule-ID* describes the name of the ECA rule, and *Event-type* describes the name of the event that triggers this rule. *Conditions* specifies the conditions for executing the following actions, and we can use AND

Type	Name	Content
EVENT	RACE_RANK_INFO	Ranking updates
ACTION	INIT_RACE	Initialize

Table 2. Functions of race specific plug-in

and OR operators in *Conditions* for describing complicated conditions. *Actions* specifies executing operations and their arguments. Events and actions that we can use are specified by plug-ins. Table 1 shows the functions of some implemented plug-ins. EVENT and ACTION describe events and actions that the plug-in provides.

Common Plug-in provides commonly-used functions such as timer functions and loading/unloading plug-in functions. *Network Plug-in* provides a function to send/receive data to/from other hosts via Internet. *IRC Plug-in* provides function to send/receive messages using Internet Relay Chat (IRC) protocols.

Figure 6 shows an example of ECA rules for a building information service that displays a web page of a building in front of a user. This service consists of two rules. *FIND-BUILDING* rule searches for the building nearby the user's current position when a *MOVE* event occurs. *DISPLAY-WEBPAGE* rule extracts the buildings, that the user is heading in, from search results and displays the web pages of the extracted buildings when *FIND-BUILDING* performs data retrieving.

We have implemented many plug-ins and applications as described in [2][3]. Using A-WEAR, we can describe services as a set of ECA rules, and users can easily customize services by modifying, adding, or deleting rules. We can also add new events and actions to the language specifications for extending system functions by adding plug-ins without modifying the entire system.

A-WEAR easily enables us to construct services for wearable computing. Even if existing plug-ins do not fulfill required functions, we only have to implement a plug-in that provides those functions. Therefore, the cost of service development using A-WEAR is cheaper than not using A-WEAR.

3.2. System design

Figure 7 shows the detailed structure of our system. As illustrated, A-WEAR runs both server and wearable computers. A-WEAR in the server uses the network plug-in and the race specific plug-in. On the other hand, A-WEAR in the wearable computer uses the network plug-in, the common plug-in, and the IRC plug-in. Table 2 shows the functions of race specific plug-in that accumulates information delivered from the control tower, generates RACE_RANK_INFO events after the calculation of rank, and transmits rank information to the *Display Information Calculator*. When a

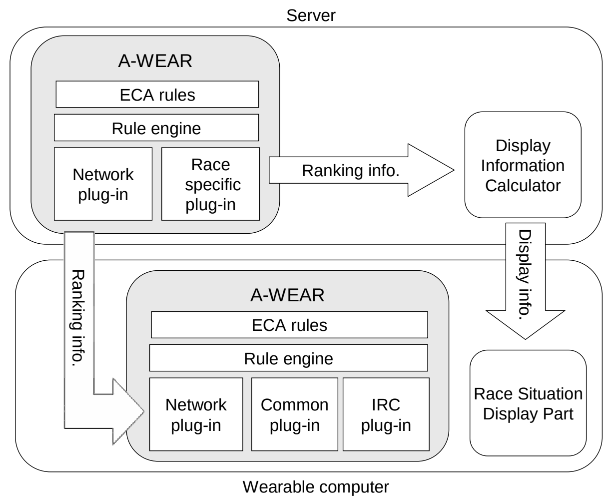

Figure 7. Detailed system structure

```
DEFINE OnRankInfo
WHEN RACE_RANK_INFO
THEN DO NET_BROADCAST_SEND('RankInfo', NEW.RANK,
  OLD.RANK, NEW.NUMBER, NEW.LAP, NEW.LAP_TIME,
  NEW.ALL_TIME, NEW.PIT_IN)
```

Figure 8. ECA rules for the server

RACE_RANK_INFO event occurs, the rule shown in Figure 8 sends the rank information to the wearable computers.

Figure 9 shows the rules for wearable computers. These rules are activated when A-WEAR receives a message via network. The rule *ReceiveMessage* shows the received message in a popup window. The rule *OnRankUp* and *OnRankDown* show the notification message in a popup window for five seconds when A-WEAR detects a change in race situation. The rule *TooFast* and *TooSlow* show the warning message in a popup window for ten seconds when the lap time is less/more than 130000/150000 ms.

Display Information Calculator in the server performs calculations for race situations and sends the results to wearable computers. *Race Situation Display Part* in a wearable computer continuously displays information from the *Display Information Calculator*.

3.3. Implementation and practical use

We implemented our system based on the design described in Section 3.2. We used A-WEAR with a common plug-in, a network plug-in, and an IRC plug-in that we had already implemented[3]. In addition, we implemented

```
DEFINE ReceiveMessage
WHEN NET_RECEIVE
IF NEW.COMMAND == 'Message'
THEN DO CMN_DISPLAY_MESSAGE(NEW.TIME, NEW.MESSAGE)

DEFINE OnRankUp
WHEN NET_RECEIVE
IF NEW.COMMAND=='RankInfo' AND NEW.RANK<OLD.RANK
THEN DO CMN_DISPLAY_MESSAGE(5,
  'Go up rank from %OLD.RANK% to %NEW.RANK%.')

DEFINE OnRankDown
WHEN NET_RECEIVE
IF NEW.COMMAND=='RankInfo' AND NEW.RANK>OLD.RANK
THEN DO CMN_DISPLAY_MESSAGE(5,
  'Go down rank from %OLD.RANK% to %NEW.RANK%.')

DEFINE TooFast
WHEN RACE_RANK_INFO
IF NEW.COMMAND=='RankInfo'
  AND NEW.LAP_TIME < 130000
THEN DO CMN_DISPLAY_MESSAGE(10,
  'Our motorbike is faster than our plan.')

DEFINE TooSlow
WHEN RACE_RANK_INFO
IF NEW.COMMAND=='RankInfo'
  AND NEW.LAP_TIME > 150000
THEN DO CMN_DISPLAY_MESSAGE(10,
  'Our motorbike is slower than our plan.')
```

Figure 9. ECA rules for wearable computer

a race specific plug-in, a *Display Information Calculator*, and a *Race Situation Display Part*. We used Microsoft Visual C++ .NET 2003 Enterprise Architect for the race specific plug-in and Macromedia Flash MX for the *Display Information Calculator* and *Race Situation Display Part*. We also used Macromedia Flash Communication Server MX for communication between *Display Information Calculator* and *Race Situation Display Part*.

Figure 10 shows a snapshot of the implemented system for wearable computers. At the top, the system displays team names, rider names, number of laps, latest lap times, and time behind the top team. The system also displays predicted times of pit stops calculated from fuel consumption and the amount of fuel added at a pit stop which we input manually. In the figure, a message of an incidental event (a change in rank) is superimposed on the main window. Ideally, we should provide individual information that is suited for the team manager and each pit crew. However, we cannot prepare individual versions for practical use. In future, we will prepare individual rules that filter information for the team manager and each pit crew.

Our system was actually used by two teams in the Suzuka 8 hours World Endurance Championship Race held in Japan in August, 2003[7]. During the race, two kinds of users used our system; pit crew and support staff. As we described in Section 2, the pit crew did not use any input devices. However, the support staff used input de-

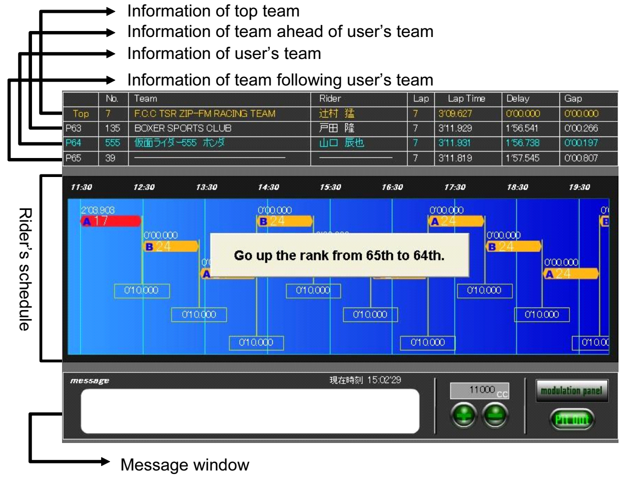

Figure 10. System snapshot

Figure 11. Servers and wearable computers

vices to monitor the system, fix problems, input refueling amounts, and send messages to other staff. As shown in Figure 11, we used three SONY PCG-U3s[6], one SONY PCG-U1, three SONY PCG-C1XFs, and one SONY PCG-C1VJ as wearable computers, and a SHIMADZU Data Glass 2[5] as a HMD of a wearable computer. Figure 12 shows a wearable computer in practical use. We prepared three servers; two were used for two teams as a server, and the other was a backup that dealt with system troubles. We set up a desk in the corner of the pit area and placed servers on the desk. The measured delay of data from control tower via radio waves was a few seconds, and the processing delay of the server was less than 100 ms. We think such delays are acceptable because they are almost the same as the monitor in the pit. Figure 13 shows the pit crew using the system. System support staff wore the same wearable computers as the pit crew and support operations.

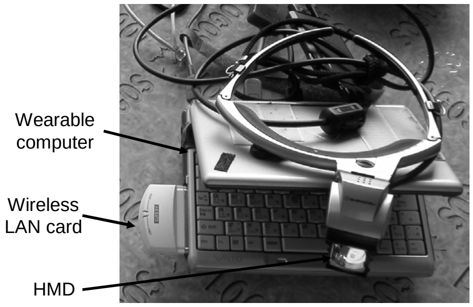

Figure 12. Wearable computer for practical use

Figure 13. Pit crew using the system

4. Discussions

4.1. Experiences

We received the following comments from the team manager after using our system.

1. Using the system with HMD was useful.
2. More detailed information on such factors as the distance to/from other motorbikes would be helpful.
3. HMD was useful for displaying secret information.
4. It was difficult to wear the wearable computer and HMD for extended periods because they are heavy. The cables got in my way, too.
5. Although initially I felt uncomfortable browsing information on an HMD, I got used to it and was able to watch without difficulty.
6. I want more freedom to operate the computer and zoom on information that I want to watch.

The first comment shows that our system can effectively support the team manager because he can browse information while he is watching the race, talking to other staff, and planning strategy.

From the second comment, although a wearable computer is effective to support motorbike races, the prototype system does not provide enough information for the team manager. Part of the reason is that insufficient information was delivered from the control tower. Therefore, our system will provide various helpful information in response to increases of information from the control tower. We were not able to investigate the requirements for planning strategies of a race. In the future, we plan to improve our system based of such comments and a detailed preliminary survey.

The third comment indicates that HMD is suitable for motorbike races because strategy and detailed information were not leaked to other teams. Using HMD was a good idea because our system displays secret such information such as remaining fuel and fuel cost.

The fourth comment shows that our hardware is too heavy to use for a long time. Although the total weight of the current system is only about 1300 g, in the future we plan to develop a lightweight PC specialized to wearable computing without displays and other unnecessary devices. The fifth comment suggests that if we can reduce the weight of the computer, users will get used to the system and actually use it.

The last comment shows the convenience to the team manager of an input device that operates his wearable computer. In this experiment, we used the same interface for both team manager and pit crew. We need to consider such user interfaces as creating different interfaces to answer users' requests.

The team manager and the pit crew may be able to use a big display screen instead of an HMD. This may be useful because they can discuss the strategy as they are watching the same screen. However, the manager said that this type of display was public to everyone, which includes a member of rival teams. Therefore, the system should not display the important information to this display, such as the team strategy and the average fuel consumption. From this standpoint, the HMD is suitable for displaying information required for winning a race. Moreover, he also said that if he used a fixed screen, it was difficult to check the pit crew because he might watch the screen at all time.

4.2. Durability

In endurance races, as we assumed, the system needs durability to work continuously for several hours. In this practical test, servers ran the entire race without any serious trouble. As for the wearable computers, although no trouble happened, we need a strategy to save power consumption because batteries had to be recharged every four hours.

Since we wore the system in the blazing summer sun, we felt that wearing the HMD became uncomfortable with time. We should consider the comfort of the system.

4.3. Related Work

F1-LIVE.com[4] provides real-time race information. This system is different in its purpose, because it is served for public audiences and it does not provide strategic information. However, our system can be enhanced to a public system if we implement the function of personalization. We can provide a new way to enjoy watching motorbike races with our wearable system. The realization of such function is future work.

5. Conclusions

In this research, we built and tested an event-driven system for supporting motorbike racing teams. It is based on an event-driven system called A-WEAR that provides incidental information to a pit crew immediately. Since the system displays continuous information visually using Flash animation, the pit crew can easily grasp the race situation at any time. Using our system, the crew can observe the latest updates without overlooking anything, the team manager is able to plan optimum strategy, and the pit crew is able to maintain peak efficiency.

We actually used the prototype system at the Suzuka 8 hours World Endurance Championship Race held in Japan in August, 2003. We acquired valuable knowledge about its practical use that will help us improve the system further in the future and enable us to support such races better in the future. In addition, we plan to apply our system to auto and motocross races, and create a system for audience.

Acknowledgment

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