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AN EVENT-DRIVEN WEARABLE SYSTEMS FOR SUPPORTING PIT-CREW AND AUDIENCES ON MOTORBIKE RACES

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Motorbike racing is one of the most popular motorsports and many fans visit circuits to watch races. However, since audiences and pit crews can only obtain limited information, it is difficult for them to get detailed information about teams except for high ranking teams and few popular teams. To solve this problem, we propose an information browsing system for pit crews and audiences who use wearable computers. This system allows pit crew to browse for various race information easily and effortlessly, and it can entertain audiences much more.

Keywords: Wearable Computing, Motorbike Race
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1 Introduction

Motorbike racing is one of the most popular motorsports. Some motorbike races have grueling conditions that include a number of rivals and many long hours to finish. In most cases, more than 70,000 people visit the venues for the circuits and enjoy watching motorbikes racing at high speeds. By watching a race at the actual circuit, fans can gain a sense of togetherness with

Fig. 1. Television monitor showing race information

Fig. 2. Uses of wearable computers

riders, pit crews, and other fans, unlike when they watch the race on television. However, they cannot obtain sufficient information to understand the current race situation at the circuit, because it only provides information about a few high ranking and very popular teams. Therefore, there is an increasing demand for information systems to provide the information that they want to know.

Pit crews who participate at races also have the same problem. Figure 1 shows a television monitor, which is providing current race information to pit crews. As we can see, since the monitor is only presenting information on 14 teams at a time, the crews cannot understand the race conditions when they want to. In response to this problem, we proposed an information-browsing system for pit crews and team managers by utilizing wearable computers, and applied the system to the Suzuka 8-hours-Endurance Race in 2003[1]. Figure 2 shows a team manager and his pit crew who are wearing the system, and Figure 3 shows a screen shot of the system. Since our previous system employed wearable computers, it provided managers and crews various information without interfering with their work.

Through this previous practical use, where we obtained knowledge from the team manager and the pit crew, we were able to improve our former system to support them in winning races. Thus, we clarify the requirements for our system in this research, improve the previous

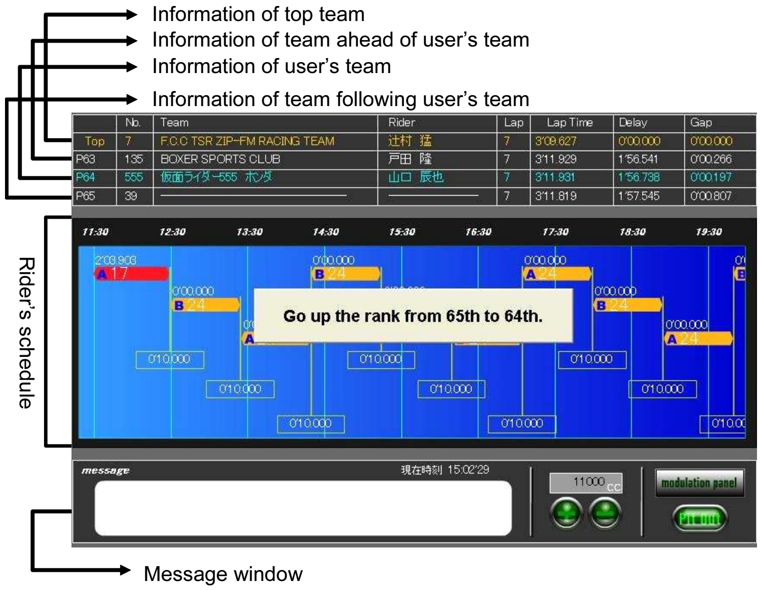

Fig. 3. A snapshot of the previous system

system, and apply it to an actual motorbike race. Moreover, as previously described, since fans at circuits need race information to enjoy the events, we also enhance our previous system to entertain audiences by presenting them with various information. The key to enhancement is the adding a function to post/share photographs among audiences. Using this function, they can post photographs they have taken with their digital cameras with their annotated comments, and they can browse them broadcast from the server on their wearable computers. These photographs enable fans to be aware of various situations such as crushes on the opposite side of the circuit, or riders making pit stops.

The remainder of this paper is organized as follows. Section 2 explains our environmental assumptions and system requirements, and Section 3 describes the design of our system. Section 4 explains its implementation and practical considerations, and Section 5 shows the related work. Finally, Section 6 is the a conclusion and discusses future work.

2 Assumptions and requirements

This section explains our environmental assumptions and requirements for our wearable system.

2.1 Environmental assumptions

Our system is designed for the FIM 2004 World Endurance Championship Series, the Round 5 "Coca-Cola" Suzuka 8-hours-Endurance Race held in Japan in July, 2004, which is one of the world's most popular motorbike races. At this race, motorbikes are not allowed to have any devices to communicate with pit crews except a transmitter that sends a motorbike ID to a receiver located at the control line across the race track. The circuit control tower collects the information from the receiver and broadcasts it via radio waves. This means every time a motorbike passes the control line, the control tower broadcasts individual motorbike information, which includes the motorbike ID, the rider ID, the number of laps, and the elapsed time. However, other important information to win races is not officially provided, such as ranking information, the distance between two specific teams, and detailed positions of motorbikes.

The Suzuka Circuit has a 6-km race-track, and motorbikes complete approximately 200 laps in the 8 hours. It has one control line at the finishing line.

2.2 Requirements from pit crew

In our previous work[1], we designed and implemented a system to support team managers and pit crews, especially taking the following requirements into consideration:

No interference with work: the wearable computer did not interfere with the work of pit crews.

Information was continuously available: the wearable computer provided the latest information immediately whenever a pit crew wanted to check this.

Notification of incidental information: the wearable computer offered immediate information when an incident occurred.

After practical use, we obtained five information requirements from users of our system.

Environmental information: the condition of the track surface is greatly influenced by the surrounding situation. Especially, a change in weather has the potential to change race conditions drastically. Therefore, the system should provide information about weather forecasts, temperatures, and humidity. Moreover, it is important to notify of changes in environmental situations.

Ranking table: users occasionally want to check all team information to understand the whole race.

Information on two following/leading teams: to improve their rank, the team manager needs to observe these teams carefully. Therefore, he needs to be able to watch this information ay any time.

Approximate positions of motorbikes: the team manager needs to know the approximate positions of motorbikes to devise a rough strategy.

Road surface after an accident: the team manager and pit crew want to check the condition of the track surface after an accident because there is a possibility this has changed after an accident.

To comply with these requests, we had to drastically enhance our system. In this research, we design and implement the system for team managers and pit crews, which had these five functions.

Fig. 4. Main display monitor (right) and ranking table (left) in front of grand stand

2.3 Requirements from fans

The fans at the Suzuka Circuit can only acquire information from the large main display monitor (Figure 4) and announcements via a public address system. This monitor displays the numbers of the top-5 teams, which do not even include the team names; thus, it is difficult for fans to understand the race situation. Moreover, this monitor is located in front of the main stand. Since many fans watch the race from many places around the circuit, they cannot even obtain such poor information from the monitor.

To solve these problems and entertain racing audiences even more, we provide a wearable system that gives various information to users and enables them to actively participate in the race. Since this system also employs wearable computers, fans can freely walk around the circuit using our system.

The system has two main functions to entartain racing audiences using it:

Browsing race information: the system provides information about races such as ranking tables, team and rider names, the lap times of the teams they want to access, and the approximate positions of all motorbikes.

Sharing photographs: to create opportunities for funs to actively participate in races, the system provides a function for them to share photographs they have taken with their digital cameras with their annotated comments. They can browse them broadcast from the server on their wearable computers. These photographs enable funs to be aware of various situations such as crushes at opposite sides of the circuit, and riders making pit stops.

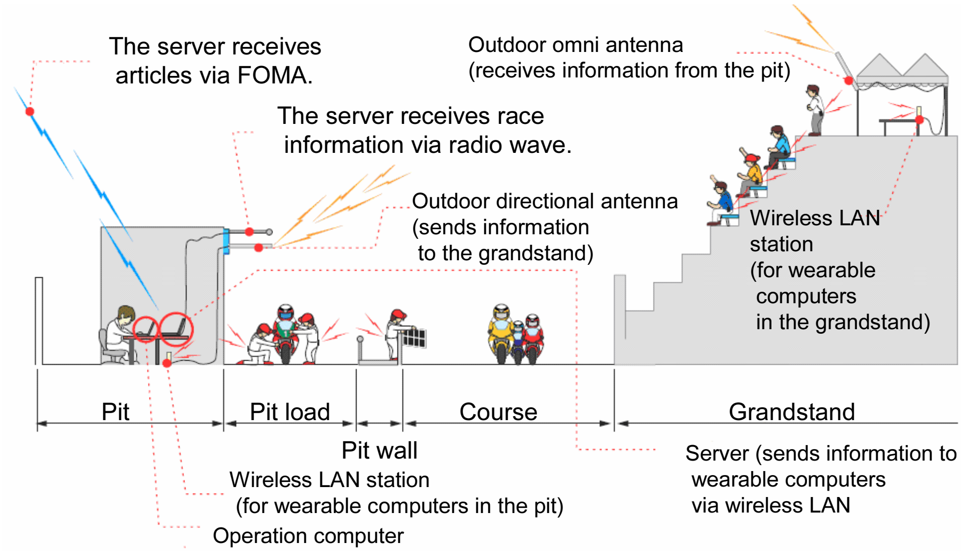

Fig. 5. System sketch

3 Design of the system

This section describes the design and implementation of our new system. Figure 5 shows the proposed system where pit crews and fanss are using it. Pit crew can also use our system inside the pit wall to be informed about instructions from the team manager. For managing the photograph-sharing functions, our staff determine whether the posted articles are suitable for broadcasting.

Since the control tower only disseminates lap information on motorbikes via radio waves and does not deliver information about rankings, we provide a server that receives and accumulates information from the control tower, calculates the ranking information, and broadcasts this to wearable computers via a wireless LAN. These processing is fully automated. Moreover, the server plays the role of the WWW and an email server for the photograph-sharing function. The server receives articles including photographs via an email and a WWW page. We locate operators in the pit lane, who determine whether posted articles are suitable for delivering to users. Fans receive information a wireless LAN station located in the grandstand. The server connects to internet using 3G mobile wireless network called FOMA (Freedom Of Mobile multimedia Access), which is a name of mobile phone service provided by NTT DoCoMo, Japan.

We employ an extended version of an event-driven system called A-WEAR[2] as a platform for the proposed system. To achieve system robustness corresponding to a large number of fans, we change the communication model from connection-oriented to broadcasting. When wearable computers detect a lack of information, they individually request lost data from the server.

```
 [FOR Scope]
 [VAR Variable-name AS Variable-type]*
WHEN Event-type [ (Target-of-event)]
IF  Conditions
THEN DO Actions
```

Fig. 6. Syntax of ECA rule

3.1 A-WEAR

A-WEAR, a system platform for wearable computing, is a middleware that runs between the 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 these 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 one of database technologies. An active database processes the prescribed actions in response to an event arising inside or outside the database[5]. 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 6 shows the syntax of the ECA rule for our rule engine, where *Rule-ID* describes the name of the ECA rule, and *Event-type* describes the name of the event that triggers this rule. *Conditions* specifies those for executing the following actions, and we can use AND and OR operators in Conditions to describe complicated conditions. *Actions* specifies executing operations and their arguments. We can also use three system parameters: *NEW*, *OLD*, and *CURRENT*. NEW and OLD are provided for each occurring event, and they store a snapshot of information after/before the event occurs. The system provides current information as CURRENT in response to a request from services. Events, actions, and system parameters are defined by plug-ins, which are extension modules for the system. In other words, we can use new events and actions in ECA rules by adding plug-ins. By employing such a plug-in mechanism, we can enhance functions such as adaptation to a new device by adding a plug-in for it. Table 1 lists parts of the already implemented plug-ins, and Table 2 lists the detailes of some implemented plug-ins. EVENT and ACTION describe events and actions that the plug-in provides.

When we constructed the previous system to support the motorbike racing team, we only implemented one race-specific plug-in, since we could use many conventional plug-ins. All functions of the system were described as several ECA rules. In this way, A-WEAR enables us to easily and rapidly.

3.2 System design

The detailed structure of our system is shown in Figure 7. We employ A-WEAR in all systems as the fundamental engine, and we achieve the services by adding new functions to the race-

Table 1. Implemented plug-ins

Name	Function
Common	Providing basic functions such as timer processing
GUI	Managing user defined GUI
Database	Supporting database queries
GPS	Detecting moving position
System info	Providing PC information
Multimedia	Playing multimedia content
Serial Com	Transmitting data via serial port
Camera	Capturing images by camera
Network	Transmitting data via Internet
Mail	Sending/retrieving email
Browser	Controlling WWW browser
Map view	Showing a map
VCode	Recognising a visual marker
RF-ID	Recognising an RF-ID tag
Direction	Detecting current direction
IRC	Providing IRC-based communication
Skype	Controlling Skype function

specific plug-in of the previous system and describing ECA rules to provide the services.

The server also functions as a WWW/email server to receive articles. The user interaction part in a wearable computer is constructed with Adobe Flash content because of its rich visual animation.

The server only broadcasts differences in information with revision numbers to wearable computers to reduce the network load. When a wearable computer detects a lack of information by referring to the revision number, it asks the server to send all data via an HTTP connection. Our system achieves the robustness in this way.

The race-specific plug-in on the server receives information from the control tower via radio waves, calculates the ranking, and generates a ranking-update event and a pit-stop event when it detects these events happening. When a ranking update event occurs, the server broadcasts the ranking information to wearable computers. Moreover, when the server receives an article submitted from an email or the WWW page for submitting articles, the network plug-in generates a data-receiving event. The A-WEAR on the server sends the notification of the new article to the operators' computers, and these computers update the list of article candidates for broadcasting. When the server receives a request to deliver a specific article, it broadcasts the article to wearable computers.

When A-WEAR on the wearable computer receives the ranking information from the server, it processes the information using the race-specific plug-in to generate a ranking table and update information on its screen. When it receives other information such as an article and a message from another wearable computer, it also updates the information on the screen. In addition, the race-specific plug-in periodically predicts locations of motorbikes according to the previous lap times, and displays them on the display.

3.3 Interface design

We determined the displayed information and the interface design based on the requirements previously described. Figures 8 – 13 show snapshots of all five windows for the system.

Table 2. Functions provided by plug-ins

Common Plug-in

Type	Name	Content
EVENT	CMN_START	Initialize System
	CMN_TIMER	Timer expires
ACTION	COMM_EVENT	Generate specific event
	CMN_ADD_RULE	Insert rules

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 data
	NET_BROADCAST	Broadcast data
	NET_FILE_SEND	Send file

Race specific plug-in

Type	Name	Content
EVENT	RACE_RANK_INFO	Ranking updates
ACTION	INIT_RACE	Initialize

Figure 8 shows the strategy window, which displays the estimated times for pit stops. Figure 9 illustrates the track window, which displays the current predicted locations of the motorbikes. The upper part of the strategy window and the track window display information on specific teams that includes rankings, laptimes, team names, and rider names.

Figure 10 shows a report window for fans, which displays posted articles. Users can operate the system by using at least three buttons to change the window, scroll, and select. When a user selects an article, the system shows him/her detailed information of this as shown in Figure 11. Figure 12 shows a screenshot of the ranking-table window.

Figure 14 shows a screenshot of a PC for operators. They select articles suitable for broadcasting, and send them using this window. This function is also used to provide weather forecasts to wearable computers. Users can see this at any time they want as shown in Figure 13.

4 Implementation and practical use

We implemented the system based on the design described in Section 3.2. We developed new functions for the race-specific plug-in, and described 19 rules for the server, 21 rules for the operation computers, and 87 rules for the wearable computers.

Figure 15 shows an example of a rule for the server. When this rule receives the pit-stop information correctly, it updates the ranking information and the strategy window. Figure 16 shows an example of rules for weather forecasts by wearable computers. When the computer receives information on weather forecasts, *ReceiveWeather* stores this. *ShowWeatherForecast* is activated when the user pushes the select button, then the rule shows the weather forecast.

We used the Microsoft Visual C++ .NET 2003 Enterprise Architect to implement the

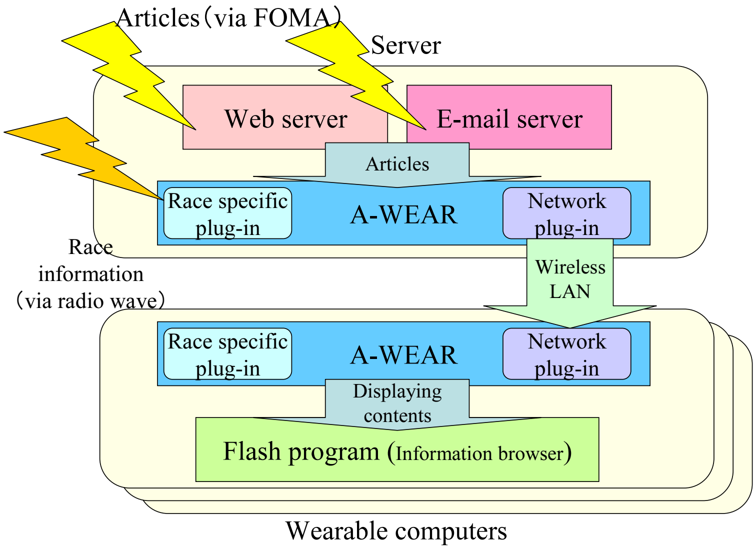

Fig. 7. Detailed system structure

race-specific plug-in and Macromedia Flash MX for the information browser.

The system was actually used by a team in the Suzuka 8-hours World Endurance Championship Race held in Japan in July, 2004[4]. We also established a booth to demonstrate our system to audiences, and approximately 100 fans experienced our system. We allocated several reporters to post articles, and they posted 69 articles during the race.

Figure 17 shows snapshots of our system actually being used, i.e., (a) the team manager using the system, (b) a reporter, and (c) a demonstration in the booth. Figure 18 shows one configuration for the wearable computer. We used the Sony VAIO Type-U and Sharp Muramasa CV as wearable computers, which were covered with our handmade carry-bag and fixed to users' waists. We employed Shimadzu Data Glass 2[3] as the HMD, a Sony VAIO R505R/DK for the server, and a Sony VAIO Z505NR and an IBM ThinkPad X31 for the operation computers. We provided three types of input devices for user operation, i.e., a small hand-made input device that had two buttons, a Sony Jog-dial controller, and a Mevael Keiboard for users who needed to input texts for chats.

In total, we used 30 computers, 17 HMDs, and 20 digital cameras. The wireless LAN network was composed of IEEE 802.11b devices. We achieved long-distance wireless communication by using Buffalo's outdoor directional antenna, the WLE-HG-DYG and their outdoor omni-antenna, the WLE-HG-NDC. The reporters posted their articles via wireless LAN and PHS networks.

4.1 Experiences

We demonstrated our system to approximately 100 fans. In conjunction with the demonstration, we sent out questionnaires about the system and received 33 responses. This questionnaire had 6 questions and a space for free comments. The results are listed in Table 3, where questions 2-5 require an answer on a scale from 1 to 5 (1: worst, 5: best).

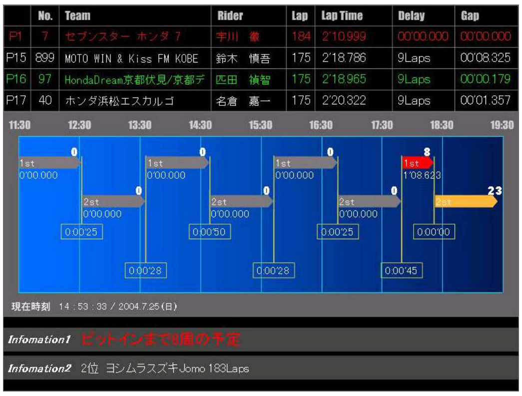

Fig. 8. Strategy window

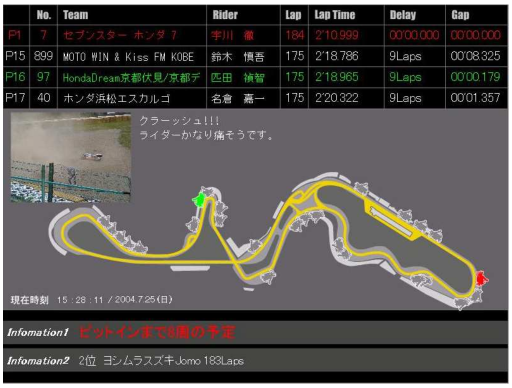

Fig. 9. Track window

Fig. 10. Report window

Fig. 11. Detailed article

From the results, most fans attended this race several times, and they were interested in our system and felt that the system was useful. This means that even experienced fans feel the information provided by the circuit is insufficient and our system can resolve this problem. They enjoyed using wearable computers and felt HMDs and wearable computers were sophisticated although it was difficult for nearly half of them to watch information on the HMDs.

More than 90% of them felt that our system fulfilled their needs and several respondants said that they wanted to rent this system even if it cost them tens of dollars per day. This means our system is effective for business use at racing circuits.

The open comments in the questionnaire included opinions that stated “I want to watch real-time videos from in-vehicle cameras,” “I want to know rider profiles,” and “the system should provide local information such as the locations of stores and lavatories, and maps.” Since these comments are valuable for improving our system, we intend to enhance it based on these.

Fig. 12. Ranking-table window

Fig. 13. Weather forecast

Fig. 14. Snapshot of operation window

4.2 Durability

Since the venue with the circuit was very large, wireless LANs, cellular phone networks, and PHS networks occasionally lost their connections when photographs were submitted. However, the servers and PCs for operators worked well for the eight hours without any problem. However, the laptop located at the pit wall became a runaway fifteen minutes after the race started because of high temperature. We have to adopt measures to avoid rises in temperature and direct sunlight.

The team manager used our system for almost eight hours without any major problems and as a result the team reached a record 18th ranking, despite their start from 43rd position.

4.3 Differences from previous system

There are many advances compared with the previous system [1] in which we could only provide a strategy window as in the current system. Since it was difficult for pit crew and

```
DEFINE ReceivePitin
WHEN NET_RECEIVE
IF NEW.TYPE == 'PITIN'
  AND NEW.REVISION == GLOBAL.REVISION
THEN
  DO RACE_CLIENT_PITIN(NEW.RANK)
  DO CMN_EVENT('UPDATE_STRATEGY',
               'RANK',NEW.RANK)
```

Fig. 15. ECA rule for pit stop

```
DEFINE ReceiveWeather
WHEN NET_RECEIVE
IF NEW.TYPE == 'WEATHER'
THEN
  DO GLOBAL.WEATHER_XML = STR('<Weather><Visible>
   True</Visible><Picture>http://%NEW.ADDRESS%
   %NEW.LARGE_PHOTO_URL%</Picture></Weather>')
  DO GLOBAL.WEATHER_FORECAST = BOOL(1)

DEFINE ShowWeatherForecast
WHEN SELECT_ITEM
IF GLOBAL.CURRENT_PAGE != 3
  AND !GLOBAL.WEATHER_FORECAST
THEN
  DO NET_XMLSOCK_SEND(GLOBAL.WEATHER_XML)
  DO GLOBAL.WEATHER_FORECAST = BOOL(1)
```

Fig. 16. The ECA rule for weather forecast

fans to obtain detailed information such as ranking tables, the system could only be used for planning the timing of pit stops. However, our new system has functions to show the complete ranking table and the track window. These functions not only help pit crew and fans to understand the race situation but also the team manager to devise strategies from diversified viewpoints.

Moreover, we provided photographs with sharing/posting functions that enabled fans to obtain various information and enjoy the race. These functions have the potential for enhancing the way fans of watch races and it can be applied so that pit crews and agents exchange information at the circuit to obtain even more information.

Since our system provides the team manager and pit crew with information on winning the race and also provides various information for the entertainment of racing audiences, it provided enormous support to people concerning motorbike races.

5 Related work

Recently, as well as our proposed system, there are many researches and actual systems on multimedia services using wearable computing and mobile computing technologies, such as a conversation support system[6], helthcare systems[7, 8], an advanced mail processing system for wearable computing[9], A nurse's routine activity recognition system[10], a maintenance task support system[11], a mobile social network system[12], and a dancing support system[13]. For example, a conversation support system[6] analyzes conversation content in real-time, and retrieves information related to ongoing conversation from the Internet to make users more interesting and beneficial. A dancing support system[13] creates new performance

(a) Team manager

(b) Reporter

(c) Demonstration to fans

Fig. 17. Snapshots of system being used

that enables a dancer to make music while dancing with sensor-equipped shoes. Moreover, one of the most important applications is mobile navigation[14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25]. P-tour[15] shows the route satisfying user requirement so that the user can go round in time if the user sets some points they want to visit, and a navigation system of Expo Memorial Park using wearable computer[17] shows information about pavilions and guidance automatically without manipulation. The navigation system that has a route planning algorithm to satisfy the purpose of the event manager[18] recognizes the situation of the users' behavior and fulfills the requirement such as the time-restriction and the equalization of congestion. There are wearable navigation systems that have achieved autonomy and provide high-quality services such as displaying virtual objects and annotations that overlap the real world on a HMD, such as MARS[23], TOWNWEAR[24] and VizWear[25]. Although each system has a mechanism to fulfill the requirements for each application, the requirements of our system is high-level; (1) handling secret information, (2) no interference with work, (3) information was continuously available, (4) notification of incidental information, and (5) durability in harsh environments. Therefore, it is difficult to realize our proposed application on previously proposed systems. In addition, previous systems are specialized to one purpose and it is difficult to apply them to our purpose. Our system has enough flexibility to modify functions and apply to other applications by our rule-based mechanism.

Fig. 18. Wearable computer for practical use

Table 3. The results of questionnaire

Question	Avg.
1. How many times have you come to see the endurance race?	4.80
2. Does HMD look sophisticated?	3.69
3. Are you interested in shown information on HMD?	4.50
4. Do you think that HMD is useful?	2.88
5. Did you enjoy our system?	4.63
6. Does information our system provides fulfill your needs?	4.34

These related researches have another characteristic as same as our system; the services are provided based on monitoring. For example, a health-care system[7] recognizes situations of life habits in real time using a heat sensor, GSR sensor, accelerometer, electric sphygmograph, GPS, geomagnetic sensor, and gyroscope. The system recognizes contexts and advises the user about how to make improvements in one's life. A nurse's routine activity recognition system[10] supports his/her routine work. They have to memorize what they did in a day to communicate with each other and not make a mistake such as giving a dose of medicine needlessly. However, the system seems messy and mistakes might occur. This system recognizes nurses' activities with an accelerometer and their locations with RF-ID receivers. These systems are called context-aware systems, and there are many researches on context recognition device[26, 27] and algorithm, and power saving techniques[28]. The system must adopt various contexts for our purpose. Our rule-based approach enables programmers to construct context-aware applications easily because they only have to describe ECA rules to execute various actions in response to occurring events. It means our system has enough flexibility and capability to use longer time with repetitive improvements.

There are several service platforms for wearable computing. MEX[29] constructs an application by combining modules that provide various services and extends its functions by adding modules. NETMAN[30] is a service platform to construct applications by collaborating with other systems via a network. The system by Henk[31] is an event-driven system, which handles an input from sensors as an event. This system has power saving functions when no event occurs. Context Toolkit[32] is not for wearable computing, but it can simplify construction of application that uses context information. In Context Toolkit, since context widgets collect various information from environments and translate the information to a unified format, developers can construct context-aware applications without concern for the difference in sensors.

Although MEX, the system by Henk, and Context Toolkit provide functions to describe autonomous services, NETMAN lacks this function. Moreover, not all of these systems can change the service configuration during execution, and only MEX can add/delete services while execution. Although MEX can also change devices dynamically, it cannot change devices that are directly attached to the computer because devices need to communicate with MEX via the network. Consequently, these systems do not have enough flexibility. The system by Henk has a mechanism for power saving. However, attached devices consume much power in wearable computing environments because this mechanism is only designed for the efficient use of a CPU. In addition, services of these systems are implemented using programming languages such as C and Java, which are not easy for general users.

6 Conclusions

In this research, we built an event-driven system that supported audiences and racing teams in motorbike races. Moreover, we carried out a practical test at the Suzuka 8-hours Endurance Race 2004. Since our system employs an event-driven system called A-WEAR, it can provide various information on the race with sufficient immediacy. The system also enables racing audiences to post/share/browse photographs and leave their comments. Using these functions, fans can easily comprehend the race situation at any time and they can enjoy the race much more by posting/browsing articles.

We acquired valuable knowledge from its practical use, which should help us to improve the system further. In the future, we intend to apply the acquired knowledge to our system for better support, and we also plan to apply this system to other speed events, such as auto mobile and motocross races.

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