A Coaching CMS with Wireless Sensors using ANT+ Connectivity Solution

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Abstract: In this paper, a design of Content Management System (CMS) linking up with a mobile device (smartphone, tablet PC etc.) for transmitting, monitoring sensor data and feedback is proposed. The system is intended for fields of sports, rehabilitation promoting health and so forth. Users (athletes, rehabilitants etc.) are equipped with wireless sensors using ANT protocol in addition to the mobile device during training for the purpose of acquiring activity data including biomechanical, physiological parameters and so on. A mobile device buffers sensor data locally and forwards it via wireless network to a web server on the Internet. Simultaneously, the video streaming of activity scenes are recorded from camcorders and forwarded through another transmission line to a streaming service (e.g., Ustream). Principally, the CMS functionality comprises two services. As a synchronous/real time service, the server provides experts (coaches, physiatrists etc.) with analysis and feedback by remote access. In this way, experts are able to analyze the parameters which reflect users' performance and return the feedback in almost real time. Also for an asynchronous/subsequent service, after training users and experts can replay streaming video linked feedback triggers during the entire training on a time-series plots of the web interface.

Keywords: Bio-feedback, remote coaching, wireless sensor network, video streaming, content management system

Introduction

A proper amount of exercise in our daily life is recognized as a requisite human activity in order to keep us healthy. Current computerized and diversified society enforces our life to be sedentary and irregular. Therefore, some people tend to try to begin an easy exercise (e.g., running) by themselves when and where they can. However, those people might face dropout problems because of less motivation or lack of effective advice through communication with others (e.g., physical educator). In fact, the increase of diseases (e.g., obesity) due to such as lifestyle and lack of motivation to do physical exercising are reported [1]. On the other hand, in the field of sports athletes require effective methods to improve performance. Especially it depends on methodologies of monitoring and advising by coaches. Motor learning literatures reports that feedback combined with practice is a significant factor for affecting motor skill learning [2] [3]. Appropriate feedback derives remarkable improvements of sports skill performance and motivation as a result. Thus, exercises including sports under educational environment with coaching are essential regardless of athlete or non-athlete.

Bio-feedback (Feedback support by computer-based system with sensors for human who wears them) can facilitate improvements of the above mentioned problem and requirement. Feedback system assists users by monitoring their training and providing relevant specific information for the purpose of achieving better performance [4] [5]. However, one of the requisite factors regarding sensor system is to avoid excessive fatigue of users. Generally the complexity of a setup of sensor and application link including transmitting data is comparatively high. Therefore, difficulties regarding the sensor equipment and the application need to be managed in order to minimize interferences for users during exercise under realistic conditions like outfield activity.

Meanwhile the continuous progress in up-to-date technologies such as sensors and mobile device contributes to the development of current feedback system. Due to the diverse functionalities and the miniaturization of hardware, wearable feedback system is applicable for health monitoring [6] as well as sports activities [7]. In particular, wireless sensors allow a convenient setup and easier usage during the data acquisition on parallel with training. Therefore, interference which attached to the user can be reduced dramatically. In addition to the progress, recent sensor technologies have the advantage of low power consumption, allowing their use during long-term training sessions (e.g., Marathon).

Besides modern mobile devices (e.g., smartphone) provide not only the wireless communication tools in relation to the Internet technologies such as a social networking service, but also various wireless sensor protocols (Bluetooth Low Energy, Zigbee/IEEE 802.15.4 etc.). It enables a wide range of mobile training-applications. Therefore, such devices can be used for mobile data relay which realizes the reception of sensor data, storage and transmission to a web server like a position from Global Positioning System (GPS). For example, commercial systems and services (Nike+ [8], Garmin connect [9] etc.) are capable of recording training, thereafter allowing other users to monitor their training data via social networking services. The mobile system integrated with such wireless sensor network (WSN) could create the potential for the feasible remote coaching environment which prevents excessive fatigue.

Furthermore, live video streaming service (Ustream [10], Livestream [11] etc.) which can now improve the utilization of broadcast because of a simple method and convenient equipment with only a few devices. Moreover, in the case of broadcast regarding training scene, it means that at least one of experts (coaches, physiatrists etc.) can monitoring user's training data at individual remote places. Monitoring sensor data synchronized with streaming video of training can enhance experts' analysis towards feedback.

Thus, our objective is to develop a coaching CMS system linking up with a mobile devices (smartphone, tablet PC etc.) which are capable of integrating the aforementioned WSN and live streaming technologies. We tackle to a remote coaching which makes use of a high compatible sensor platform named "ANT+" connectivity solution (extension of ANT protocol [12]). The system functionality comprises two services. As a synchronous/real time service, the server provides experts with analysis and feedback by remote access. They take advantage of data of ANT+ sensors and live video streaming. In this way, experts are able to analyze the parameters which reflect users' performance and return the feedback in almost real time. Also for an asynchronous/subsequent service, after training users and experts can replay streaming video linked feedback triggers during the entire training on a time-series plots of the web interface.

The number of existing ANT+ sensors is quite high. Some commercial products are released by major companies in fitness and sports equipment sales (Suunto, Garmin etc. [13] [14]) too. As the reason for this, the wireless communication distance of almost WSN needs a few meters around a body. In the communication field of a few dozens of meters enough to absolutely guarantee it, ANT protocol is lower power consumption than others (Bluetooth, Zigbee etc.). Therefore, at this time, it is the most suitable wireless communication for realistic long-sessions support. One basic idea is to integrate common sensors with standardized protocols that are used by the majority of the population. Based on these intentions, we adopt ANT+ as the standardized sensor platform.

To our knowledge, a server-based mobile coaching and feedback prototype-system using ANT+ has already challenged [15]. Besides broadcast live tracking for athletes who wear GPS, ANT+ sensors and a mobile device as commercial service in major sports events (e.g., Tour de France 2012) [16]. However, in comprehensive supports from training to after it, there is no approach available which combines monitoring of sensor data and a live video streaming. Furthermore, our system which is suitable to the needs of professional and amateur users (athletes, rehabilitants who improves their health etc.) coming from various sports or exercise is intended. However, our main focus, in this paper, is set on popular sports such as cycling, running and fitness.

1. Support Scenario of Coaching/Training Environment

The following passages describe a support scenario with the Coaching CMS (CCMS) by illustrating working process and tasks of relevant persons (users, experts, observers etc.). Figure 1 shows the conceptual diagram of the scenario. Basically, a flow using CCMS is conducted following stages:

(1) Definition of training-session plan from Expert-Client(s) (E-Client)
(2) Setup of User Client(s) (U-Client)
(3) Setup of Live-Video-Streaming Camcorder (LVS-Cam)
(4) Coaching/Training with E-Client/U-Client
(5) Reflective Learning on website

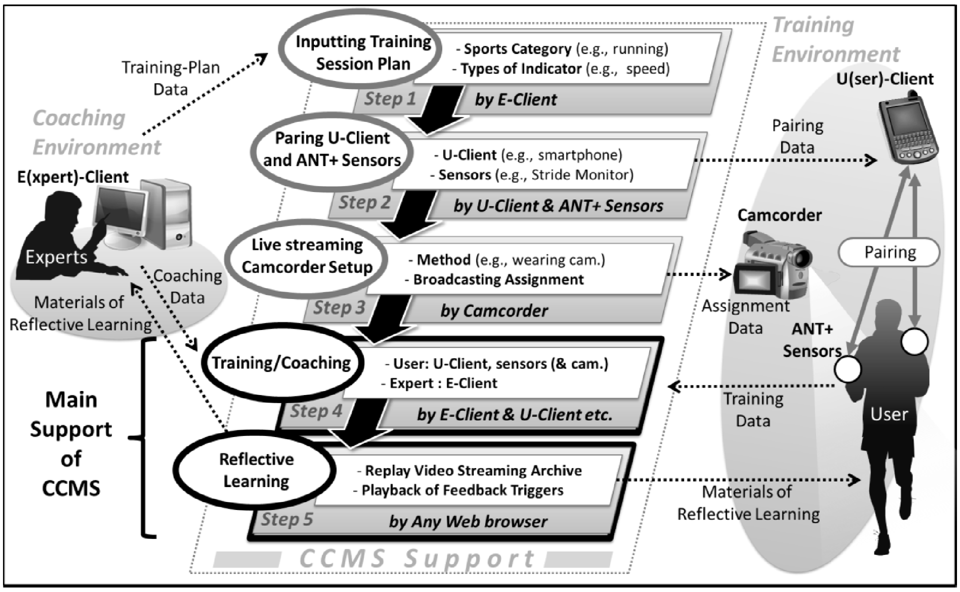

Figure 1. Support Scenario of Coaching/Training Environment.

1.1 Definition of training-session plan from E-Client

The types of sensors used in a specific training session depend on the activity domains. Such could be physiological and biomechanical sensors like Heart Rate Monitor (HRM) but also positional data from GPS for tactical/strategically goals. On the stage (1), Expert defines such a plan which comprises meta-data of monitoring parameters in training-session (e.g., sports category, types of kinematic indicator). After that, expert registers the content on the web page of CCMS. The client of experts available to web browser is called

E-Client.

1.2 Setup of U-Client

On the stage (2) in relation to setup of user's training environment, users can get the information regarding types of sensors which they need to wear during training. For example, if an expert coaches athlete's legs movement in running, User Client (U-Client) instructs the use of Stride Based Speed and Distance Monitor (SDM) as a requisite sensor preliminarily. At this time, the application software of U-Client can pair itself with surround sensors automatically because ANT+ compatible sensors can be registered according to their specification (network key, channel id, transmission and device type, etc.). In the case of group training with plural U-Client, users must place an enough distance each other to avoid collisions of pairing between U-client and sensors. The CCMS can support several types of sensors (accelerometer, HRM, SDM, bicycle speed/distance, Bicycle Power Sensor (BPS) etc.) that use the ANT+ connectivity solution.

1.3 Setup of LVS-Cam

Concerning setup of LVS-Cam on the stage (3), it is optional and not always required for individual coaching because sometimes only monitoring sensor data makes enough profit. Moreover, wearing LVS-Cam on user's body depends on the activity categories or training environment. For instance, in the case of coaching MTB athlete, it can be set up on the handle bar of the bicycle. On the other hand, if road cyclists train at exclusive training field (e.g., bicycle race track), fixed camcorder which is able to overlook them at the main stadium, takes a same role. Also, according to environment, expert may need observer who records a video. Therefore, whether user wears LVS-Cam or not is decided flexibly. On the basis, the assignment between CCMS and LVS-Cam is processed through web browser. This procedure is to avoid excessive fatigue as well as sensor pairing on the stage (2).

1.4 Coaching/Training with E-Client/U-Client

After the initial preparation stages from (1) to (3), a synchronous task (real time coaching and feedback) during training is conducted. For the training on the stage (4), bidirectional data flow based on sensor monitoring and feedback is constructed from data transmission between U-Client and the E-Client via CCMS. At first, CCMS offers U-Client to start training immediately following a request from E-Client. Thereafter user starts training. During training experts can monitor user's situation by browsing consecutively-updated sensor chart and live video streaming from LVS-Cam. Feedbacks provided as audiovisual information, are invoked by judgment of experts. Feedbacks give users triggers of awareness for the purpose of a breakthrough of improvement for implicit skills (posture, movement etc.).

1.5 Reflective Learning on website

On the last stage (5), reflective learning as an asynchronous task (subsequent training) on the web site of CCMS. Though experts provide users with appropriate feedbacks, in fact, users cannot be always successful in improvement of problems which are revealed in training. The quality and quantity of information which user can get and understand them in training are limited because users have to concentrate on exercise while receiving feedbacks. Much the same is true on coaching of experts. Therefore, this stage helps users and experts to deepen their consideration of awareness from feedbacks based on the stage (4) in order to enhancement of upcoming training for both users and experts. From the viewpoint of effective feedback and reflect, it is significant for both user and experts to improve communication which they understand the intention behind sensor data and feedback. For instance, expert's intention is equivalent to indication contained in feedback. Moreover, user's intention appears as change action according to feedback.

CCMS gives them a web interface which they can replay streaming video linked feedback triggers during the entire training on a time-series plots in addition to sensor data. By showing such a synchronous video archive with the traces of feedbacks and the chart of sensor data concurrently, the system facilitate the reflective leaning that user and expert can remember the situation (e.g., biomechanical conditions) when feedback triggered. For this reason, they can check each other's intention surrounded by several conditions. Thus, this stage contributes to the improvement regarding quality and quantity regarding feedback and reflection.

2. System Configuration

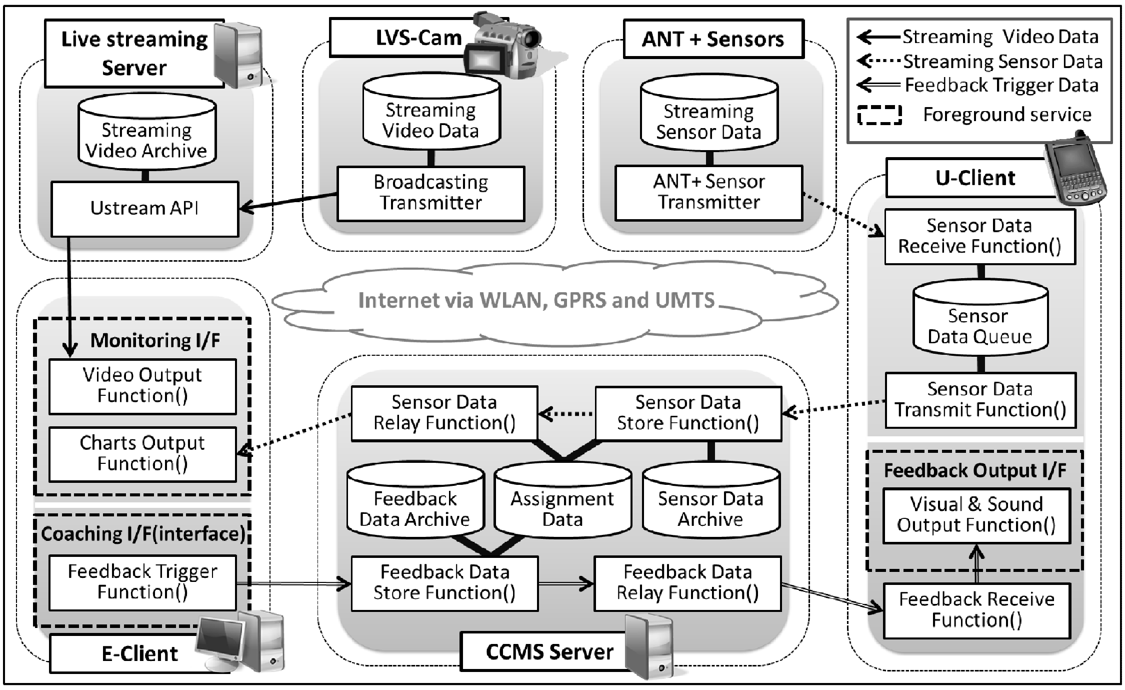

Figure 2 illustrates the system configuration of our proposal.

The system consists of four principal parts: U-Client, LVS-Cam, E-Client and CCMS. U-Client is a mobile device system which is both wearable (e.g., on body in running) and externally-mounted (e.g., on bicycle in cycling). LVS-Cam is a camcorder with a broadcasting mobile device which has both video streaming and capturing functions. E-Client is a monitoring and coaching system in a web browser at a remote place. Individual parts are connected with the Internet via wireless network (Wireless LAN (WLAN), General Packet Radio Service (GPRS) or Universal Mobile Telecommunications Systems (UMTS) etc.). Sensor data from U-Client and feedback from E-Client are directly transmitted through CCMS in opposite directions. In contrast, live video streaming from LVS-Cam is uploaded to streaming server (e.g., Ustream). Thereafter, live video streaming including its archive is called from CCMS through an exclusive Application Program Interface (API) of streaming service.

2.1 U-Client: Mobile Device with Data-relay Functions of Sensors and Feedbacks

For the current ANT interface into mobile devices, USB interface (ANT USB STICK [12]) in combination with Windows Tablet PC or Wahoo Key [17] with iPhone/iPad or built-in Android smartphone supporting ANT+ (e.g., Family of Sony Experia [18]) is used. If the mobile devices do not have wireless function connected to the Internet, a Mobile WiFi (Pocket WiFi) is used together. Moreover, ANT+ wireless devices have the following features related to advantages in practical use:

- Coin-cell battery use during several years (low power consumption)
- Theoretical data rate up to 1 Mbps
- Wide network types (peer-to-peer, star, tree and mesh)

That is to say, the devices are capable of long-term use and network formation according to training style (e.g., group-oriented training). On the basis, ANT+ devices in our focus (cycling, running and fitness) are as follows (also shown in Figure 3.).

- HRM: Garmin Premium Heart Rate Monitor (sampling rate: 4Hz)
- SDM: Garmin Foot Pod (sampling rate: 2 or 4Hz)
- BPS: SRM Training System Edition Track [19] (sampling rate: 4Hz)

In training, the U-Client application software automatically establishes HTTP connection which means HTTP request and response between U-Client and CCMS. U-Client buffers received sensor data in a queue structure. The all stored data are combined into one packet and sent to the server at regular time interval. A parameter of interval time is set by considering communication situation (approx. from 10 to 20 sec. [4] [15]). The HTTP responses from the server contain feedbacks.

2.2 LVS-Cam: Camcorder and Broadcasting Mobile Device

The live video streaming is done in combination with the following devices (also shown in Figure 4):

- Camcorder: Sony PJ760V or Wearable Camera (Contour+, GoPro HD etc.)
- Broadcasting Device: Cervo Live Shell [20] (resolution: Max. approx.. 1.5 Mbps)
- Pocket WiFi: NTT DoCoMo L-04D (transfer speed: Max. approx. 75 Mbps)

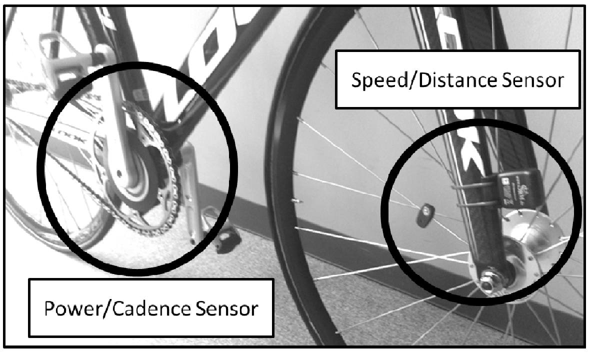

Figure 3. ANT+ Sensor Devices (in cycling).

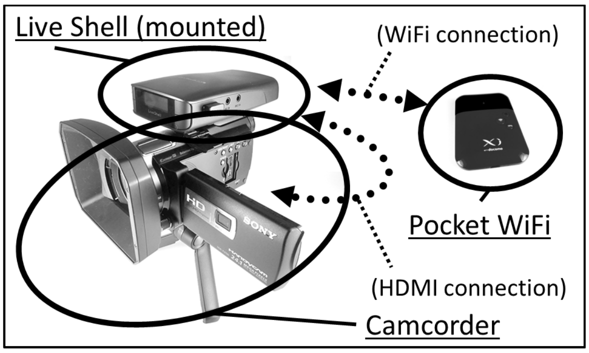

Figure 4. LVS-Cam System.

Recording video and audio from camcorder are transmitted to broadcasting device by connecting an HDMI cable. Moreover, streaming data is transferred to a streaming server via Pocket WiFi on the Internet. The broadcasting device has functionality of both encoding and streaming. Furthermore, all operations (e.g., resolution change) of the device can be done from web browser.

2.3 E-Client: Monitoring and Coaching System in a Web Browser

A graphical user interface (GUI) enables experts to monitor real-time sensor data and to interact with users through feedback. Experts can look at the parameterized time curves visualized by dynamic chart and streaming video. After training users and experts can replay streaming video linked feedback triggers during the entire training on a time-series plots of the web interface.

2.4 CCMS: CMS for Coaching and Reflective Learning

CCMS Server is responsible for data administration, device management and web interface functionalities. The server is constructed by Cent OS Linux, Apache HTTP Server, Oracle MySQL database and Symphony as web PHP framework in a desktop PC consisting of Intel Atom processor. The server takes a role in the permanent storage except for video streaming data. The server archives assignment information between U-Client and ANT+ devices in database and authenticates individual data transfer between E-Client and U-Client. All the sensor data and feedbacks are stored into CCMS database. Conversely the streaming data is managed distinctively from CCMS for the purpose of load distribution. While the server receives all the sensor data from U-Client in almost real-time including a slight communication delay, it also accepts feedback from E-client. The storage module runs in the background during the entire training, forwarding the monitoring/feedback data to E-Client/U-Client. Moreover, CCMS provides GUI for E-Client as foreground service. The server generates the interface combined with JAVA script-based dynamic chart and video called by streaming API.

3. Conclusion and Future Work

This paper describes a design of server-based system which provides real time coaching in training and reflective learning after it. On the stage of training, bidirectional data flow based on sensor monitoring and feedback is constructed from data transmission between a mobile device and the server via wireless network and the Internet. Experts can monitor user's situation by browsing consecutively-updated sensor chart and live video streaming. Feedbacks during training are invoked by judgment of expert. On the stage after training, experts and users can reflect their coaching/training through a time-series plots of the web interface.

In this framework, users are equipped with wireless sensors using ANT+ protocol during training. Our main focus in this paper is set on cycling, running and fitness. Therefore, we chose HRM, SDM, speed/distance monitors and cadence sensors as such examples of WSN device. Of course, there are several kinds of sensor function and extension including analog input in this sensor series. Therefore, it is sufficient to cover many activities. Thus, our system has the potential to be capable of supporting a wide range of skill acquisition and so on.

Our future work concentrates on the implementation and experimentation. For implementation, we have a plan to develop the system, in particular software on mobile device, in several major platforms of mobile devices (iOS, Android etc.) in order to meet practical demands. Moreover, for experimentation regarding improvement skill, we will obtain knowledge for knowledge-based and expert systems for the automatic generation of feedback [5]. Therefore, we aim to investigate the identification of movement patterns like cross-country skiing from the viewpoint of coaching by experts [21].

On the other hand, we will establish our own streaming service for exclusive use. Our approach in this paper makes use of a commercial live streaming service as a part of monitoring function. However, in the case of top athletes (e.g., Olympians) supports in our affiliation, a highly reliable and flex system which guarantees storage and provision concerning confidential and instantaneous information is required. We are currently developing a mobile streaming camcorder which has both real-time encoder and server functionalities. Our concept will be adapted as the extension function of such a camcorder which can show both streaming video and sensor data synchronously.

Acknowledgements

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