Towards an Innovative Model in Wearable Expert System for Skiing

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Abstract. Mobile applications and portable devices are being used extensively in the healthcare sector due to their rapid development. Wearable devices having sensors can be used to collect, analyze, and transmit the vital signs of the wearer. In this paper, we have proposed a wearable expert system that supports and monitors the skier during his activity. This research work is motivated by the need to provide rapid assistance to skiers, especially during off-piste skiing, where its more dangerous, and seeking help is difficult with mishaps. Our approach mainly focuses on proposing an expert system that integrates wearable devices (helmet, goggles, digital watch) with the skier’s smartphone. We present an architecture model and knowledge artifacts to design a wearable expert system for skiing.

Keywords: Wearable expert system · Skiing · Knowledge engineering · Wearable devices · Internet of Things

1 Introduction

Health services and other organizations often find themselves faced with critical conditions. Collaboration, efficiency, and rapid reaction to changes are what these communities must pursue. Quality becomes a crucial pillar of healthcare and various technologies that allow for the mounting of people’s health are in development [16].

In the sports field, various technologies allow athletes to monitor their physical state and prevent possible injuries [9]. Even though the International Ski Federation (FIS) [6] provides guidelines, there are very few applications for the management of ski accidents. Sule Yildirim Yayilgan et al. [18] developed a new architecture for the management and registration of ski injuries effectively after an accident occurs. In this new approach, incident-related communications are made directly between the rescuer and the medical staff at the hospital (with
direct access to the patient’s condition) using mobile device interfaces and wireless technology.

Current technological innovations are less enhanced for skiing. Our research aims to monitor a skier, especially for off-piste skiing. We designed the **Wearable Expert System for Skiing** (WESS) that simulates the experience of human skiing in reasoning by applying knowledge artifacts [10,12], rules, and inferences. WESS supports ski athletes by providing: i) emergency support, ii) different operating modes, iii) suggestions and recommendations based on the situation iv) real-time analysis of performance.

### 1.1 Knowledge Engineering

Knowledge Engineering (KE) refers to all the technical and scientific aspects involved in the construction, maintenance, and use of knowledge-based systems (KBS) [4,13]. We define WESS as a hybrid system, as it implements the rule base model, the case-based model, and the non-case based model. The hybrid model helps to organize an interchange of knowledge between the various parts of the expert system knowledge [2].

The three types of Kinds of Knowledge are: i) **Functional Knowledge** consists of descriptions of the functionality of components (or (sub-) systems) and the relationship between them, ii) **Procedural Knowledge** is the understanding of how to apply the concepts learned in any problem solving situations and iii) **Experiential Knowledge** is the knowledge derived from experience [14].

### 2 Related Work

The most relevant problems in the community concern the field of health care using wearable devices [1,5]. Wearable devices collect and process real-time sensor information measuring the vital health signs of the wearer [17]. A study within the domain of pervasive mobile healthcare, performed by G. Sebestyen et al. [15] depicts protocols and communication models within the IoT healthcare systems.

The goal of using wearables in both medical and sports fields is the ability to continuously monitor the patient or athlete to receive real-time information on their state of health [7,8]. Hermes et al. [3] propose the detection of daily and sports activities with wearable sensors in a controlled and uncontrolled way. S Örüçü et al. [11] designed a real-time expert system for athletes comprising of an Expert System. Though skiing guidelines have been provided in the past to avoid possible accidents and relapses, the only existing expert system developed is by Sule Yildirim Yayilgan et al. [19] This project focuses on parallel on the design of interfaces for mobile devices and in presenting an architecture for the digital recording of ski system injuries.

To the best of our knowledge, there is no research or studies to develop an expert system capable of supporting the skier during his activity through continuous monitoring and analysis thanks to a wearable device.
3 Wearable Expert System for Skiing

As defined by Sartori et al. [4,10,13,14], “A wearable expert system (WES) is an expert system designed and implemented to obtain inputs and provide outputs to wearable devices.” One of its great distinguishing features is the direct collaboration between domain experts and users and the interaction with a knowledge maintenance system dedicated to the dynamic updating of the knowledge base, as taken care of by the evolution of the scenario [4,13].

3.1 Components of the Specialised Skiing Gear

The hardware components of the skiing expert system include sensors used for measuring the vitals of the athlete and other parameters like temperature, air pressure, and location. The skiing gear resides on the client’s arm or wrist like a smart band. The following sensors are ideal in designing a specialized skiing gear.

- **Display Unit:** The display unit allows the athlete to have a visual interface when placed within the helmet visor. Google Glass acts as an ideal display unit.
- **GPS sensor:** essential for tracking the real-time position of the athlete for an on-piste skiing event.
- **Compass:** to identify the direction in case the athlete gets lost.
- **Accelerometer:** measures the speed of the athlete during skiing. The accelerometer in the wearable device provides precise ‘g’ forces experienced by the athlete, even in extreme conditions making it better than the accelerometer in the user’s smartphone.
- **Gyroscope:** measures the tilt and rotation of the skier.
- **4G/5G mobile network with SIM module:** It is necessary for connecting to the expert system. The skiing hardware can also be connected to the Internet directly from the skier’s smartphone.
- **Heat Rate sensor/Pulse Oximeter:** helps to measure the heart rate of the skier. The pulse oximeter would also indicate the blood oxygen levels.
- **Temperature sensor:** measures the temperature of the skier; also measures the atmospheric temperature necessary for warning the athlete about hypothermia.
- **Pressure sensor:** measures the atmospheric pressure.
- **Speakers and mic:** needed in the unlikely event of a disaster when the skier’s smartphone is not reachable.
- **SOS Alarm buzzer and lights:** triggers an alarm when the skier has taken a hit and fallen or when the vitals signals are abnormal.
- **Personal Locator Beacon (PLB):** PLB is a passive component of the Wearable expert system. It is triggered only during an SOS emergency, where the network connectivity is absent.
3.2 Architecture

The Skiing Expert system is a wearable expert system that consists of a wearable device worn by the skier that communicates with the expert system through the user’s smartphone.

The skiing expert system interfaced with external systems like an emergency, disaster rescue system, or with medical emergency systems, help in the effective rescue of a skiing athlete in the unlikely event of an accident or a natural disaster. Figure 1 depicts the overall architecture of the expert system. The expert system need not be necessarily present within the skiing hardware, but can be deployed as a cloud service consumed by multiple skiing athletes.

3.3 Skiing Expert System Design

The skiing expert system is responsible for collecting real-time data from the wearable sensors of the skiing athlete. It processes the data received based on the rules stored, performs tasks.

The proposed system comprises of various functional knowledge subsystems. A Knowledge Base storing the rules and knowledge artifacts [14] form the building blocks of the expert system. The Database stores user information, preferences, and the events that occur while the skier uses the expert system. The Information Retrieval Interface is responsible for collecting real-time data and for retrieving the user information from the database. The Rules Processing Engine loads the procedural knowledge rules and the knowledge artifacts based on the user context and the mode of operation of the system. The Inference Engine receives the information from the Information Retrieval Engine and the Rules Processing Engine; checks if the data received matches a rule or a functional knowledge artifact by modeling the causal relationships among the knowledge artifacts using Bayesian Networks (Korb and Nicholson 2010), Influence Nets (Rosen and Smith 1996), Superposed-Automata Nets (de Cindio et al. 1981), Petri Nets or Causal Nets (Van Der Aalst et al. 2011). If the rules match, corresponding tasks get triggered for execution. The Execution Engine is responsible for executing tasks received from the Inference Engine. These tasks include monitoring if the skier is within the safe skiing zone, triggering an SOS in case of an accident, measuring and monitoring the vitals of the skier, and also assess the skier’s performance; providing recommendations to improve skiing. The Communication Interface is responsible for maintaining constant connectivity with the skiing hardware and with other external systems like the medical assistance systems, emergency rescue systems.

3.4 Operation Modes

The skiing expert system is design enables the athlete to operate in 2 modes: Piste Mode and Off-Piste Mode.

The Piste Mode (or track mode) allows the user to ski on the slopes indicated by the ski resort and, through the use of the integrated wearable display,
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Fig. 1. Architecture of the wearable expert system for skiing (WESS)

is guided from start to finish. If the skier veers off-course, the system navigates the skier back to the piste. This mode also allows the skier to have competitions with other skiers in real-time or based on the lap-time.

The **Off-Piste Mode** is a mode meant for advanced cross country/free-ride skiers. In this mode, the expert system continuously monitors the GPS location of the skier, checks for any weather warnings or avalanches, and ensures that the skier is in the safety zone.

In the event of an accident or a fall with rapid descent of the vital signs indicated by the sensor, the expert system activates the emergency mode. After activation, the expert system communicates with the nearest paramedic and rescue services available, sends the GPS location, and securely retrieves the patient health records for medical diagnostics. The SOS alarm is also triggered, which allows bystanders to locate the skier.

To handle the situation of the skiing gear losing internet connectivity with the Expert System, all the necessary instructions needed to complete the skiing, the map information, and piste rules would be prefetched before the skiing starts. In the unlikely event of the skier being caught in an avalanche or if the skier is out of the network coverage during an SOS, the skiing gear has a mobile network module that triggers SMS messages through the cellular network. The
SMS would contain the last active geo coordinates captured by the GPS module. In case the skiing gear is unable to send out SMS messages during an SOS, the PLB would be immediately activated to call out mountain rescue. The Expert system has the last GPS location of the skier that would help in narrowing the search.

Modeling the knowledge artifacts in the wearable expert system employs expert system languages [14]. The procedural knowledge representation of the expert system uses an extensible markup language (Fig. 2) with Influence Nets representing the Knowledge structure.

```xml
<MODE_CHOOSE>
  <UserLang name="jess" ext="clp">
    <name> WESS_MODE_CHOOSE </name>
    <description>Selection of mode</description>
    <input><element>onClick(CHOOSE_RIDE)</element></input>
    <body>
      <element>Selected_MODE</element>
      <if> Pre_cond_check </if>
      <do> update_data </do>
      <subtask> instruction(chosen_mode) </subtask>
      <output> wess_active(chosen_mode) </output>
    </body>
  </UserLang>
</MODE_CHOOSE>
```

Fig. 2. Sample XML representation of MODE_CHOOSE in WESS

4 Conclusions

To provide proper practice guidelines from skiing beginners to experts and to support the medical emergency, SOS in the skiing grounds, we have proposed a Wearable expert system for skiing. Wearable Expert System for Skiing is a system that comprises of wearable skiing gear and an expert system. The paper describes the various components within the WESS. An outline for modeling the expert system and the different modes of the expert system are also additionally explained. WESS aims to help skiers improve their skills and provides real-time monitoring to save human life in emergency cases, making skiing safer.

4.1 Future Scope

The future scope involves implementing the proposed architecture incorporating smart devices like the Alexa and Google Glass. The system would be enhanced to support skiing race among a group of skiers. A scalable cloud-deployed service would store the skier’s data. This data can further be processed using data mining, machine learning algorithms to identify the best skiing strategies for a
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The ability to incorporate the map information from various skiing organizations around the world would allow the skier to have access to a variety of skiing grounds.

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