# KUMITRON: A Multimodal Psychomotor Intelligent Learning System to Provide Personalized Support when Training Karate Combats

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**Abstract.** Martial arts discipline can contribute to build multimodal psychomotor intelligent learning systems due to the nature of the movements involved to learn the corresponding motor skills: they are predefined and governed by the laws of physics. In this context, we are developing KUMITRON, an artificial intelligence system to support Karate practice. In particular, KUMITRON monitors the physical activity of the karatekas during a *kumite* (Karate combat) in real time using diverse sensors (physiological and inertial) as well as a drone camera in order to provide multisensorial personalized feedback computed with machine learning and computer vision algorithms. This multimodal monitoring aims to anticipate the movements that a fighter is going to perform on the mat, providing added value for training and offering personalized advice on the type of strategy to follow in order to win the *kumite*.

**Keywords:** Wearable, IoT, *kumite*, drone, modelling human behavior, OpenCV, karate, Artificial Intelligence, Smart *Dojo*

## 1 Introduction

Bloom's taxonomy defines a series of educational purposes from the behaviorist perspective [1] identifying three domains: cognitive, affective and psychomotor. Recent research has shown that classical computer-based support systems for learning can be extended with sensors to provide formative assessment in those three domains, paying special attention to their use as feedback tools [2]. In our current research we focus on psychomotor learning which deals with physical movement, coordination and the use of the motor-skill areas [3]. In particular, psychomotor learning starts from the low level of motor ability (recognition, involuntary actions, imitation, etc.), up to the high level (internalized performance and automated, sophisticated choreography, creation of new patterns or art, etc.) [4]. The acquisition of motor skills could benefit from individualized personalized instruction and support [5], just as learning from cognitive skills.

Martial arts discipline can contribute to build multimodal psychomotor intelligent learning systems due to the nature of the movements involved to learn the

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corresponding motor skills: they are predefined and governed by the laws of physics [6]. The teaching methods that exist today in martial arts are based on attending a class with a teacher (or *sensei* in the martial arts jargon), who in many occasions performs some movements that must be copied and imitated by the learners. In addition, there are a large number of audiovisual media that allow individual training, but this type of material is of little use for collaborative learning (e.g., to support combat practice) and in no case this approach provides a guide to whether the movements are correctly executed or not by the learner, and how to improve them (and avoid injuries). In fact, there is an opportunity to delve into the personalization of motor skills learning for martial arts practitioners [7]. In that work several parameters to deliver feedback that helps the practitioner to improve the execution of the technique are identified, such as breathing, energy consumed, explosiveness, acceleration and correct position. Furthermore, that paper analyses the work done so far to personalize the learning of martial arts movements and highlights two challenges: 1) to improve the modelling of movements in pairs, for example, in combat, since currently research focuses on postural detection or striking movements, but not on the execution of techniques between two practitioners; and 2) to improve the interactive design to make the virtual environment more realistic, building intelligent environments that offer multisensory feedback that includes other channels beyond the visualization of the techniques, such as auditory (through voice commands) and tactile (through vibration or physically guiding movements directly).

Thus, there are already several scientific articles that discuss the need for intelligent tools applied to the teaching of psychomotor skills [4][5]. In the same sense, a recent systematic review [8] on intelligent psychomotor tutoring systems shows the lack of this type of tools, as only nine psychomotor intelligent systems were found. This outcome is being revised in an on-going review of the psychomotor learning field [9].

## 2 Related works

In our current review of the literature, no intelligent psychomotor systems have been found that are useful for martial arts training in pairs. On the one hand, there are video based applications to show how to perform Aikido techniques in pairs [11] and virtual reality based systems that presents physically simulated opponents [12]. In addition, the applicability of sensors for performance analysis in combat sports has also being reviewed [13]. On the other hand, there are educational approaches based on STEAM (Science, Technology, Engineering, Arts and Maths) education that uses sensors and computer vision tools to develop educational material for scientific teaching that involves the execution of martial arts movements in pairs, such as the *kote-gaeshi* (projection technique - or immobilization - by twisting of the wrist) defense in Aikido martial art to show the concept of physics torsion [14], but it does not directly support the learning of the motor skills involved. In addition, neural networks have been integrated in a mobile app to learn American Kenpo Karate movements on-line, but currently only serves for arm movements performed individually [10].

For video recording, works that present advances in relation to the use of fixed cameras have been analyzed, which propose the use of drones. Drones (as in [15] and [16]) improve the video taking since i) they provide more flexibility to capture movements, either by fixing the recording point (for example, the front of the knee) although the user moves and turns, and ii) they can direct the point of interest to any part of the body at any time simply by moving the drone around the participant (at a sufficient distance that it does not disturb him or her) [17]. In this context, computer vision [18] is being widely used for facial recognition, identification of objects or identification of movements. There are computer vision algorithms [19] capable of recreating the movement that a human is performing, recreating the skeleton of the human body and imitating the movements that an individual performs during their activity. Some systems use virtual reality environments (as in [20] and [12]) to make the training experience of martial arts more immersive, but do not delve into the creation of intelligent training tools in real time.

Although there are works dealing with the monitoring and sensing of martial arts, the objectives set out in our research are not fulfilled: *to provide multisensory personalized feedback when training physical activity in pairs that is monitored with multimodal data coming from different types of capture devices*. For this reason, we have designed KUMITRON (KUMITe+dRONe), an Artificial Intelligence (AI) system for martial arts learning that supports personalized training in pairs during a karate combat (*kumite*) using drones for image capture (among other sensing technologies).

## 3 KUMITRON System

In this section we describe the system we are building to monitor the interaction between various practitioners and provide intelligent advice in real time in the combat practice of martial arts in general, and Karate in particular, where the combat practice is called *kumite*. The development of KUMITRON [21][22] was inspired by the state of the art: sensors to collect motion related data [13][23], existing karate systems [12][24] and sports [25][26], drones for dynamic video gathering [15][16][17], and computer vision algorithms that combine video and inertial information [19] [27].

### 3.1 Designing the KUMITRON system

For the design of the system, user centered design methods have been applied, that is, the system design has taken into account the information received from expert users (i.e., martial art teachers or *senseis*) and learners. In this way, the points of view of the training needs of both those who are going to receive the teaching of *kumite* practice and those who are going to teach it were gathered with a questionnaire (Learners: N=15; male=7/female=8; age range=10-65 years; Teachers: N= 5; all male; age range = +25 years). The main outcomes that were used as input to design the system were: 1) the majority (teachers = 100% and learners = 93.3%) of the respondents are positive about the use of new technologies in training, and 2) the following features were considered of interest: i) inertial, physiological and video data should be shown in real time; ii) demand analysis of the *kumite* in real time and its storage in a database for post-analysis; iii) learners want to get feedback in real time, and iv) both teachers and learners are interested in movements, technique, sensor data, and *kumite* strategy.

In addition to the questionnaire, the four stages framework proposed in [5] to build intelligent psychomotor systems has been applied in KUMITRON, as shown in Fig 1.

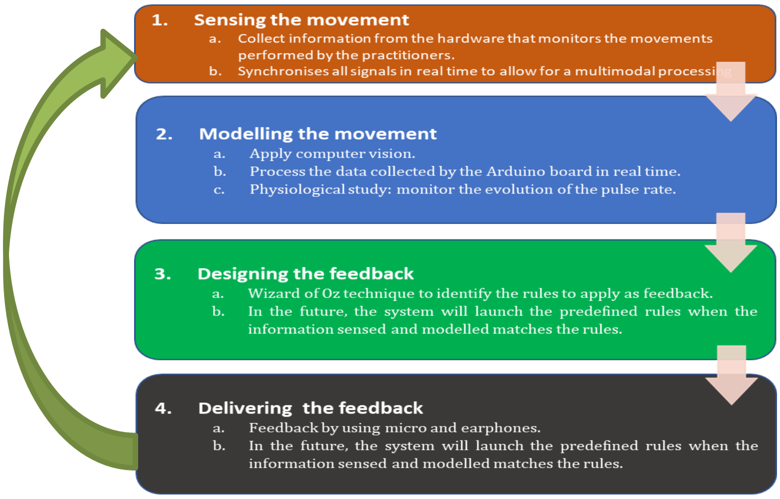


**Fig. 1.** Four-stage framework to build intelligent psychomotor systems [5] in KUMITRON

## 3.2 KUMITRON system current implementation

As shown in Fig. 2, KUMITRON uses a drone to capture the video with the best viewing angle of both karatekas, which is processed with OpenCV filters. Karatekas wear an Arduino board that collects inertial (accelerometer and gyroscope) and physiological (pulse meter) signals that are synchronized and displayed in real-time. The *sensei* visualizes this data in real time, so he or she can give audio instructions to the karatekas during the *kumite* training. The application is connected to WEKA data mining suit via sockets to generate automatic expert recommendations, but data collection (following the GDPR [28]) needs to be performed to train the algorithms.

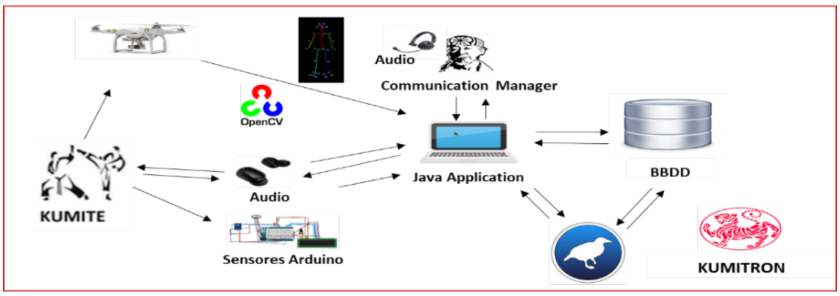


**Fig. 2.** Architecture of KUMITRON System

### 3.3 KUMITRON expected benefits

Karate has several benefits on the individual [29][30]. As discussed in [21], KUMITRON takes advantage of Karate practice and enriches it with intelligent support, which expects to provide the following benefits:

- **Innovation in martial arts teaching:** KUMITRON introduces new technologies in the *dojo* (the gym where martial arts are practiced), improving and transforming it into a “smart *dojo*”. In this sense, KUMITRON supports the analysis and evaluation of psychomotor learning through the collection of data from the sensors worn by the learner, comparing the learner’s current data with historical data and expert datasets, so that the activity and development of the learner can be measured. In fact, the application is supported by ubiquity and mobility capabilities to be able to track the motion activity in real time and thus provide appropriate formative multisensorial personalized feedback (currently visual and aural). In addition the *sensei* can use KUMITRON to record teaching material (both of the movements involved in the *kumite* to be learn as well as to learn physics concepts as in Phy+Aik [14]) using the services on the web to upload MOOC-type didactic material to support the learner.
- **Physical condition improvement and peripheral vision:** Physiological values (pulse and calculated effort) are tracked to improve fatigue management during combat. Applying analytics and AI algorithms can improve effort management on a mat. Despite the fact that KUMITRON is a tool for training in pairs, it also allows individual training to improve skills such as peripheral vision, as explored in [31].
- ***Kumite* tactic improvement:** KUMITRON applies computer vision filters in real time to the video captured with the drone in order to analyze the movements applied in the combat and provide multisensorial personalized feedback. The inertial data received from the sensors is visualized through a motion vector that illustrates the direction of movement of the practitioners, being able to generate warnings of change of direction and anticipate movements of the fighters. Thus, AI is used for the analysis of the video images in real time and to obtain expert advice through predictive algorithms. In addition, learners can access the recorded sessions to analyze the technical errors made during the *kumite* training.
- ***Kumite* strategy improvement:** AI applied to historical data can provide expert knowledge to select the strategy to be applied during the performance of a *kumite* based on various factors such as physical characteristics, type of the most effective technique, historical data of victories, etc.

### 3.4 Outcomes from studies using KUMITRON

KUMITRON brings multiple improvements not only to *kumite* training, but also to combat skills. As an example, in [31] we report an intra-subject study exploring if KUMITRON can support individual peripheral vision training using OpenCV motion filters. The experiment was carried out with two subjects, a female (46 years old) white belt and a male (46 years old) green belt. The experiment was performed through the analysis of video images, comparing the filtered images with OpenCV (using the Tracking Mode algorithm) with the raw images recorded with the drone.

The experiment was as follows: one of the karateka threw *tsukis* (fist punches) from either left and right sides in several series of 60 blows from a room while recorded by a mini-drone that sent the image (using KUMITRON infrastructure) to the computer in another room, where the other karateka watched the videos (either raw video or filtered) and had to anticipate the origin of the attack/blow (left or right) in the shortest possible time. The order of raw and filtered videos was changed among series and between the participants to avoid effects in the order of the data collection.

The results (shown in Fig. 3) suggest that the use of some motion filters of OpenCV library can increase the success rate and decrease the time required to detect the direction of the opponent's punch. As discussed in [31], this findings are of relevance since the training of body reading in anticipation of the opponent's movements is not only useful in Karate performance but it is likely that peripheral vision ability can be trained with this practice.

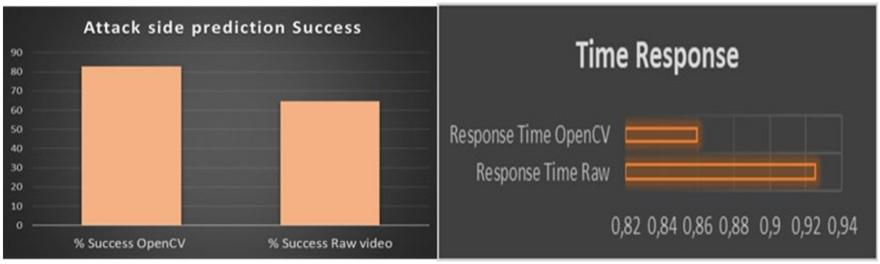


**Fig. 3.** Time response (seconds) and attack (side from it is launched) guessing success (%) (obtained from [31])

## 4 Exploring Personalized support using Multimodal Data

In Karate there are three main forms of *kumite* [32]: i) *Jihu Ippon kumite*, which consists in a preset match, ii) *Jihu kumite*, which is a free combat, and iii) *Shiai kumite*, which is a regulated or competitive combat. KUMITRON is a tool mainly aimed at preparing karateka for *Shiai kumite*, or regulated combat. With this objective, KUMITRON is being designed to analyze the strategies of the karatekas and try to give expert advice during combat at a physical, tactical and strategical level, as commented in section 3.3.

In turn, there are three main strategies in a *kumite*: i) *Sen no Sen* (Taking the initiative) where both karatekas initiate movement simultaneously, ii) *Sen Sen no Sen* (Superior Initiative or Anticipate Initiative), where both karatekas are ready and determined to attack, and iii) *Go No Sen* (Defense Initiative), where each karateka remain calm and carefully observe the opponent.

Different tactics [33] are developed on these general strategies, which should be trained by learners according to their psychomotor abilities. A specific tactic that can be implemented in KUMITRON is counterattack, a very effective technique [34] as it can be seen in Fig. 4. The idea is that when a learner is training against a defensive karateka, KUMITRON warn the learner when he or she is going to receive a counterattack from the opponent.

| | Winners | | |
|---|---|---|---|
| | Total | Point | % |
| Attacking punch | 71 | 19 | 27% |
| Counter punch | 43 | 8 | 19% |
| Throw | 11 | 1 | 9% |
| Attacking kick | 27 | 2 | 7% |
| Counter kick | 27 | 3 | 11% |
| Total | 179 | 33 | 18% |

**Fig. 4.** Winner points statistics in competition (obtained from [34])

To predict a counterattack, KUMITRON can process the inertial and physiological data obtained from the sensors. For this, we are exploring the heart rate and heart rate variability during training [35][36]. An example of heart rate variability processed with KUMITRON is shown in Fig. 5, where it can be seen the distance between beats.

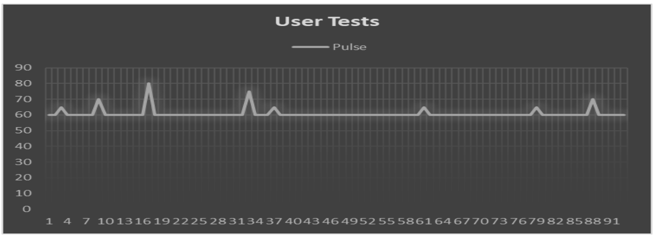


**Fig. 5.** Heart rate variability (obtained from KUMITRON)

Moreover, KUMITRON can analyze the opponent's direction through a direction vector (shown in Fig. 6) obtained from the inertial sensors. In this way, it can show both the directions of the karateka who is following a defensive strategy (backs away) represented by the blue vector (left image) and, the directions of the karateka who is tackling (advances) represented by the orange vector (right image).

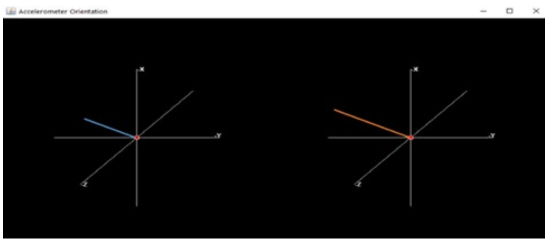


**Fig. 6.** Fighter direction during *kumite* (obtained from KUMITRON), the left one in blue is following a defensive strategy (backs away) and the right one in orange is tackling (advances)

With the above information, the feedback in KUMITRON can be implemented to warn that a counterattack is about to be launched. In particular, we hypothesize that a counterattack is being prepared when the karateka goes backward and at the same time a pulse change occurs (since stressful emotional parameters and sudden movement changes can cause the pulse to increase, so a counterattack is expected to generate a spike in heart rate). Currently we are designing a user study to validate this hypothesis. For the experiment, KUMITRON will launch an on-screen message of "Warning!!!" as shown in Fig. 7 and speak it aloud to the practitioner by synthesize voice through the earphones. In the user study we will also explore if these are the most appropriate multisensorial channels to deliver the feedback.

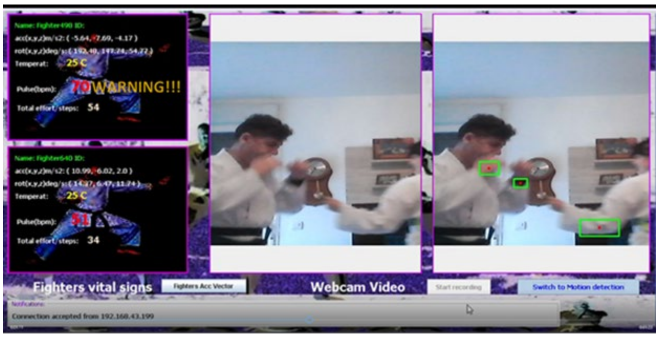


**Fig. 7.** Warning alarm in KUMITRON system to advice of a possible counterattack

Finally, in order to predict the movement of the opponent in the counterattack, we are also exploring (see Fig. 8) how to combine deep learning computer vision algorithms such as OpenPose [37] that builds a skeleton of the movement, with motion indicators trained with Weka. Moreover, we are adding OpenPose face detection algorithms to analyze the change in the emotional state of the opponent during the *kumite* as we hypothesize that this change might also reflect the intention of the opponent regarding the next movement to be executed.

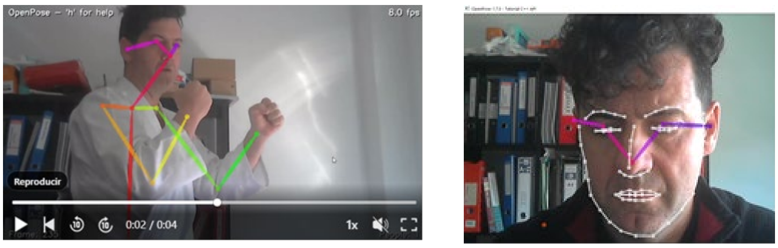


**Fig. 8.** Integrating OpenPose in KUMITRON videos

In this way, we are working on processing the multimodal data collected using diverse sensors (physiological and inertial) as well as a drone camera in order to provide multisensorial personalized feedback computed with machine learning and computer vision algorithms. This multisensorial feedback currently combines visual and aural information and is aimed to anticipate the movements that a fighter is going to perform on the mat, in such a way that it can provide added value for training and offer expert personalized advice on the type of strategy to follow in order to win the *kumite*.

## 5 Conclusions and On-going works

KUMITRON is an AI-based tool that aims to provide personalized intelligent support in Karate training. Computer vision algorithms are being explored to train peripheral vision and thus, help to improve the anticipation of the opponent's attacks during a *kumite*. In addition, the different sensors send information (inertial and physiological) to be processed in combination, and thus can provide expert knowledge about the reactions of the human body during high-demand exercise that is being performed in pairs. In particular, we have explored the personalized support that can be provided with the multimodal data collected to prepare for a counterattack in a regulated *kumite* considering the physiological information obtained with the pulse meter (i.e., heart rate and heartrate variability) and the opponent's direction obtained with the inertial sensors. Moreover, we are also exploring OpenPose deep learning computer vision algorithm in two ways: i) to predict the movement of the opponent in the counterattack by considering the motion indicators trained with Weka within the OpenPose processing, and ii) to analyze the change in the emotional state of the opponent's face during the *kumite* as this change might reflect the intention of the opponent regarding the next movement to be executed. In this way, warning signals are to be identified to train karatekas in anticipating to the opponent's movements. In this context, the integration of virtual glasses could extend KUMITRON for individual combat training with imaginary and simulated opponents, where learners could train without the supervision of the *sensei*, but with the personalized intelligent support provided by the system.

Besides the on-going developments mentioned previously and the consideration of other computer vision algorithms and machine learning techniques to obtain more relevant information for the feedback (as well as to consider tactile feedback in addition to visual and aural) and build the corresponding models for the adaptation purpose (i.e., user, expert and domain), we are also interested in extending the sensors of the system with a chest wearable that includes a breathing sensor to measure the respiratory rate and hence, enrich the physiological data obtained in KUMITRON (which currently only includes data collected with a pulse meter). This sensor can complement the affective information obtained with OpenPose face detection algorithms. The rationale behind is to extend the personalized support to consider another Bloom's domain (i.e., the affective one) in addition to the psychomotor and thus, analyze the impact of emotions during the *kumite* training. In this way, it could be possible to model certain emotional states such as concentration and relaxation, or at least, changes between different emotional states that provide relevant information to be used in the feedback delivery.

Moreover, we are also exploring the technological support provided in psychomotor teaching in other arts such as dance where technologies for motion analysis such as motion capture and whole-body interaction have been applied and provide some annotation mechanism that helps to define a ground truth against to which compare the results of different implementations ([38], [39] and [40]). In addition wearable technology has also been used in dance systems to build user models that can personalize dance learning [41].

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