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SMART SPORT

Survey report on smart sport technologies

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Justification of online courses

There already exist several studies which identified a higher level of stress in athlete students compared to regular students. Athlete students experience a double burden due to the extra amount of sports training and the pressure to perform well both in academics and in athletics. This leads to the conclusion that athlete students engage less than regular students in their education (Miller, Chen & Chiu, 2018). However, it would help athletes to have good and fast access to their education and the motivation would be even higher if they could choose the content themselves. This individual responsibility may also become advantageous in future life and in the sports training (Halem & Wahl-Alexander, 2018). Thus, online courses with free and open access can be a suitable solution to provide education for interested athletes and coaches, who can learn the content in an individual way. The provided content of technologies in sports can on the hand help in training immediately, on the other hand, the certificate of the online course can be a first step to motivate athletes for academic education in the future. Furthermore, such content could be used for injured athletes, or persons, who often travel, to use their time for self-reliant education.

Justification of the structure

The content will be given by use of images and videos and spoken powerpoint presentations. According to the guidelines of Mowling (2018), set inductions will be given to show the structure of the content, where the questions “what”, “how”, “why”, “by use of which means” and “for which purpose” will be answered. A closure will be made in form of a short review highlighting the most important points at the end of the content. Furthermore, (transfer) questions concerning the previous content will be asked to invite the participants to think deeper about the content. Also instructions for own experiments will be given. In additional sections, deeper knowledge shall be provided for interested participants and recommendations for further literature will be made. For the participants, a short introduction and possible application areas in sports will be given and pros and cons shall be provided as methodological critique. All components of the technology will be presented and (if possible) concrete studies executed with data acquisition and analysis.

Justification of the content

In many recent studies it is stated that technology comes more and more into sports (e.g. Colyer, Evans, Cosker & Salo, 2018, Ida, 2015). Thus, athletes and coaches should know recent technologies to make profound decisions about what they need in their daily training routines to increase the athlete’s performance. Therefore, recent technologies and their usage and importance in sports were screened, and the latest and most used technologies in sports science were chosen for content.

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Justification of feedback

Feedback is well known to reduce learning time (Covaci, Olivier & Multon, 2015a, Miles et al., 2012). Visual information is useful for spatial information. Acoustic information (e.g. by use of sonification) is appropriate for velocities, accelerations and regularities and might help to maintain the focus. Tactile information can be used for force feedback. Feedback should help to improve the learning process without making users dependent on it (Sigrist et al., 2015). Therefore, the feedback should be adapted both to the user's skills and to the task complexity.

It is an often used and very cheap instrument to film movements and give a feedback to the athletes to compare recorded movements to ideal movement executions. Additional visual information can be given by cueing (foreground relevant content), color coding and simulation of complex content (Plass, Homer & Hayward, 2009).

Different kind of feedback and current recommendations

Generally, there exist several forms of feedback - informative and guidance feedback-, and this feedback can be given during or after movement execution or delayed after execution. Users should not only rely on feedback, but also to their own kinesthetic feedback in order to learn correct self-assessment. Therefore, on the one hand, it seems appropriate to give a terminal feedback to support own motor learning, on the other hand, a real-time feedback seems to be better for complex tasks (Miles et al., 2012). Furthermore, it is recommendable to vary the kind of feedback to avoid that users get too familiar with certain feedback and refuse other kinds of feedback (Sigrist et al., 2015).

There are several forms of feedback. An informative feedback gives information about statistics or performance and a guidance feedback gives information about how to execute next actions (Covaci, Olivier & Multon, 2015a). A guidance feedback would be best during movement execution, while an informative

feedback would be appropriate after task execution. However, feedback should not be given too often and it is better to give feedback after a good task performance than after a bad task performance (Miles et al., 2012).
Plass, Homer and Hayward (2009) demand that only relevant information should be given. So, means of communication and adequate language are necessary. In general, feedback should be rich, but concisely, specific, and easy to understand. Feedback should contain task appropriateness; learning content should match the task (Plass, Homer & Hayward, 2009).
It is important not to overburden users with feedback. Especially beginners are not able to deal correctly with all feedback (Covaci, Olivier & Multon, 2015b). Thus, feedback must be shortened and reduced to improve only the most important part in movement execution, because humans have a limited cognitive capacity (Skulmowski et al., 2016).

To learn, reacquire or master a certain movement/motor function, giving the right technique and amount of feedback is playing an important role. Feedback can further be divided into two subfields. Task-intrinsic feedback and augmented feedback (Figure 1). Task-intrinsic feedback is everything the performer feels, sees, hears, smells or taste with his body sensors – feedback directly from the performer and not from someone or something else. Therefore, it cannot be guided or controlled as the augmented feedback (Edwards, 2011). The augmented feedback is feedback given to the performer of a motor function by an external source, as an observer, a video replay or a graph of some aspect of the performance (Edwards, 2011). This type of feedback can either be given verbal or nonverbal and is described as adding to or enhancing the task-intrinsic feedback. In some cases, the performer can detect the performance but cannot fully process the movement and needs assistance in fully understanding what happened (e.g. feedback from a trainer). On the other side, augmented feedback is adding information (from a trainer, video, etc.) that the performer could not detect with his own sensory system (Magill, 2016).
The augmented feedback is furthermore subdivided into knowledge of results (KR) and knowledge of performance (KP). KR is kind of an addition to the task-intrinsic feedback. It gives external information about an outcome of an action in terms of the goal of the action (what happened, what was the outcome, how successful was the attempt). This provides more information for beginners rather than elite athletes.

KP gives information about the movement characteristics (effectiveness) leading to the outcome which is important for beginners and elite athletes. This feedback tells the performer if the movement was correct or incorrect and if incorrect, how to adjust the movement to get a better outcome.

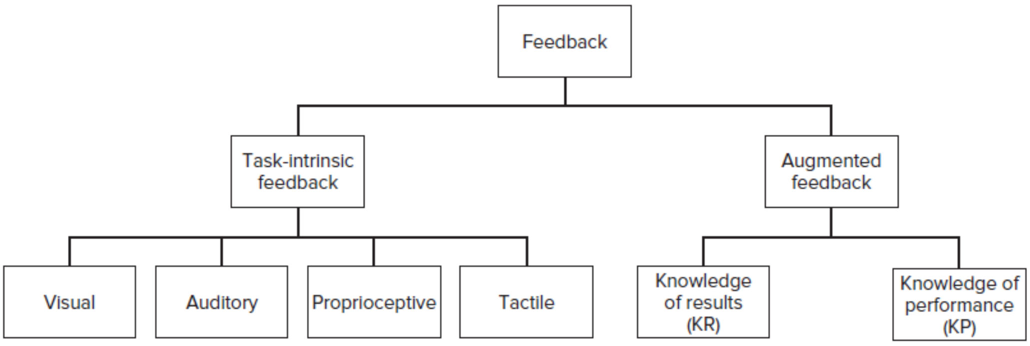

Figure 1: Dividing feedback into task-intrinsic and augmented feedback with all subgroups (Magill, 2016)

Feedback can be given in various forms (Figure 1), methods (descriptive or prescriptive), at various intervals (timing) and frequencies but it always has the same functions: information, motivation, reinforcement, and guidance. Information about the outcome of the performer's action and the correctness or incorrectness. Giving motivation, to encourage the performer to continue practicing. Reinforce correct behavior against the incorrect behavior. Guide the performer to correct actions. All this includes giving feedback with the variations of timing, frequency, and method and can be applied for elite athletes and beginners (Magill, 2016).

To give proper feedback it is necessary to understand all the principals of giving feedback. How precise should feedback be? When should feedback be provided? How frequently should feedback be provided? These are important questions for giving feedback and there are many more (Edwards, 2011). To fully understand and give proper feedback, it is necessary to understand all parameters and to understand when and how to use them. On one hand, the augmented feedback should not be the primary source of feedback for an elite athlete; the task-intrinsic feedback should be in most cases good enough developed so that the elite athlete only needs confirmation about his or her statement. On the other hand, a beginner needs more augmented feedback to also develop his task-intrinsic feedback to fully understand the motor skill (Magill, 2016). Many variables have to be considered when giving feedback.

Giving useful feedback is not something new or modern but is essential for beginners and elite athletes. Every coach, trainer or therapist should know the basics of giving good and necessary feedback in the process of learning a new motor skill or mastering a movement and should, therefore be included.
This topic can also be integrated in module 1.4 with an estimated online content of 1-3 hours.

Feedback in the online courses
It is planned to establish a test (e.g. multiple choice test) after each course (unit) or module. Thus, the user gets a direct feedback if he/she has well understood the content. In the single lessons, it is further possible to implement interposed questions which have to be answered correctly to get to the next lesson. Due to the nature of online courses, no personal feedback can be given, but we invite

athletes and coaches to do the courses in groups. This way the group members could help each other, and it would be easier to perform the proposed experiments.
To ensure multimodal learning, feedback should be given by many sensor channels (Miles et al., 2012). Therefore, it is planned to show powerpoint presentations with videos and images and the written text shall also be spoken by use of up-to-date computer programs.
Users should be allowed to influence the content, the velocity of information presentations and their order (Plass, Homer & Hayward, 2009). To satisfy the bespoken demand the online courses can be completed in a self-determined way: powerpoint slides can be skipped forwards and backwards or paused to e.g. analyze pictures more in detail or to look for further literature regarding the bespoken topic.

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Methods – literature search
The envisaged online modules in SMART SPORT will comprise 108 hours in total and are as follows:

1. Digital assistance systems / Online course module
2. Motion tracking and analysis / Online course module
3. Data analysis tools / Online course module
4. Innovative Sports Equipment and Technologies

Based on the top three module, according to the project description, the literature review and the web search have been conducted. During literature research, it became evident that module number four is also important and should be integrated into the planned content.
The search was performed using sports scientific databases (e.g. scopus, ACM, pubmed and IAT database) and scanning reference lists of already found articles and reviews. The keywords of the top three modules and further knowledge of the chosen content were used. For example, for searching literature in module 2 (motion tracking and analysis), we also used the keywords "motion capturing", "markers", "sensors", "force plates", "cameras" etc., and also a combination of several keywords. The literature search was conducted by the university of Vienna and university of Magdeburg in the time of February to September 2018. However, this search will go on during the process of the creation of the actual content for the project.

Those technologies considered as relevant current and future technologies are described. Following the premise of a neutral standpoint, several technical and scientific issues are mentioned, such as data security, accuracy of measurements, controversial research results, questioning of manufacturer promises, as well as a pro and con discussion (potentials and risks) of all applicable smart sport technologies.

Our definition of smart sports technologies is as follows:
smart = additional value to already existing item, mainly by electronic technology (e.g. sensor)
gadget = technology or device which is currently popular
wearables = anything that is light-weight and small enough to be worn on the body or carried with the person while doing sports activities
According to ([1]), wearables are electronic wireless devices with embedded sensors to receive data about a human or the surrounding environment. They send information to the processing unit (e.g. a server), and the user gets a direct feedback. The International Electrotechnical Committee divides the smart devices into the following types: near-body electronics, on-body-electronics, in-body electronics, and electronic textiles.

References

[1] Available online:: https://teslasuit.io/blog/wearables/detailed-wearables-classification-by-teslasuit-team (22.08.2018)

Each chapter (technology) is divided into the following sections: Introduction and application, Functionality, Cons and criticism, Justification, Estimation and References. The reference list is given at the end of each chapter.
We chose four modules (in bold in the table of contents). Each module will later consist of two to four courses (units, underlined in the table of contents) with several subsections. These subsections are set out in the following report based on previous scientific literature search.

1. Digital assistance systems

1.1 Smart devices

a) Eyewear

Introduction and application

Cognitive skills (e.g. anticipation and decision-making) are essential in sports and can be examined using eye-tracking and / or virtual reality (VR) or augmented reality (AR) to analyze anticipatory signals to which athletes respond to (Craig, 2013, Ida, 2015). Such new insights could be used in cognitive training, which is highly underrepresented in sports (Farrow & Raab, 2018, Harris, Wilson & Vine, 2018).

VR offers realistic, safe and standardized learning environments and provides manipulations which are not possible in reality. Furthermore, depth vision is given in contrast to video footage (Vignais et al., 2015). VR and eye-tracking can also be coupled by use of VR glasses with included eye-tracking device to analyze decision-making in sports.

Functionality

Using eye-tracking foveal vision can be analyzed with the following parameters: location and duration of fixations, quiet eye periods (QEs) and areas of interest (AOIs). It is assumed that QEs and AOIs contain relevant information which is processed by athletes to initiate their own motor response (Kredel, Vater, Klostermann & Hossner, 2017).

With VR natural, but standardized sports scenarios can be created to analyze motor and gaze behavior of athletes. Therefore, a virtual environment (VE) has to be developed by use of modern computers with adequate graphic cards, software and programming skills and / or 360° cameras. Virtual characters (VCs) have to be created using motion capturing data of expert athletes (Argelaguet & Andujar, 2013). To view and interact with a VE and/or a VC, the athlete is placed in a CAVE (CAVE Automatic Virtual Environment), a cube-shaped projection system that surrounds the athlete, or a powerwall (life-size canvas) or is wearing a Head Mounted Display (HMD), where the VR is directly projected onto the eyes.

With smart glasses, it is further possible to provide additional information concerning objects which can be seen in reality. This additional information can be written or colored information or information about route descriptions.

AR is a mixture of VR and reality. The athlete can see the real world through special glasses, where additional information (e.g. artificial objects) can be superimposed (Rebenitsch & Owen, 2016).

Cons and criticism

There exist many studies which used eye-tracking, VR and AR in the domain of sports, but many studies have not been made with immersive VR or not with expert athletes (Donath, Rössler & Faude, 2016, Düking, Holmberg & Sperlich, 2018).

With eye-tracking only foveal, but not peripheral vision can be analyzed, what is a disadvantage, because athletes, especially in fast reacting sports rely heavily on

peripheral vision. Therefore, it makes sense to couple eye-tracking with further methods, such as temporal and spatial occlusions (removal of information), either in film material or in VR. Already Vignais et al. (2015) found that for perception tasks, VR is more appropriate than 2D video footage. Moreover, there also exist liquid crystal spectacles which can be used to provide temporal occlusions in in-situ or field studies (e.g. Müller & Abernethy, 2006).
VR is an often used tool in sports science. However, VR is a quite new technology and should be treated with caution, because there exist several unsolved problems. Due to technical delays symptoms of cybersickness can occur (Rebenitsch & Owen, 2016). Furthermore, there is too little evidence that VR is appropriate for training in high-performance sports because there is a lack of interventions, transfer and retention test (Düking, Holmberg & Sperlich, 2018, Petri, Bandow & Witte, 2018).

Justification
VR and AR are new technologies which gain more acceptance and availability since HMDs reached commercial viability. VR and AR provide a realistic tool for visualization and interaction in a sports specific way. VR was already used in several sports studies to support and analyze movement execution (Petri, Bandow & Witte, 2018).
Coaches can use VR and AR to teach tactical solutions more understandably and athletes could try to interact with virtual opponents or teammates and to learn new movements in safe conditions because real collisions are not given. Several studies using VR were made in sports and showed that VR can be suitable for anticipation research to detect relevant signal to which expert athletes respond (Craig, 2013) and for training (Petri, Bandow & Witte, 2018). Furthermore, VR can be used to visualize tactics, spatial tracks of athletes and e.g. balls can be shown from different perspectives (Petri et al., 2018).
Analysis with eye tracking devices can also be used in anticipation research and are a common used instrument to detect areas of interest and to measure attention (Kredel, Vater, Klostermann & Hossner, 2017).

Estimation
Four hours of content can be filled: two hours with virtual reality, a half hour with augmented reality and one hour with eyetracking.

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b) Activity tracker

Introduction and application

Activity trackers and fitness trackers are currently experiencing a huge upward trend. In times when health is more and more in demand, of course, it must also be recorded how much people move over the day. There is a direct link between the frequency of exercise and health (Mueller, Winter & Rosenbaum, 2010). Beside of the well-known companies like “FitBit” or “Jawbone”, there is also a particular device for the scientific use like the Actigraph, it is the gold standard, and other wrist-worn devices have to compare with this one.

Functionality

Activity trackers can now measure quite a few things because there is an inertial sensor inside. That allows measuring tiny acceleration. An algorithm can calculate the steps out of it, and this is a pendant to the travelled distance. Another algorithm enables estimating the overall activity. That means activity can be recognized without looking at the steps only, which makes it possible to monitor sedentary activities and sleep.

Based on the data obtained in this way, conclusions about the kilocalories burned are also drawn, taking into account the body size and the weight. Since the smart devices are now so small, they do not disturb even at night, which means they can tell how restful sleep is. Some bracelets also have some optical sensors to capture the pulse, which can be very interesting in certain training sessions. Over the entire course of the day, for example, the regeneration can be recorded. For example, an increased heart rate indicates overtraining and this together with the quality of the sleep is essential to know for athletes and trainer.

Cons and criticism

Different measuring devices calculate different values because each manufacturer uses their own algorithm. In the number of steps are now many models on the same level, since they rely on the data from the inertial sensor, and they use the software on the sensor to detect steps. The most significant difference in counting steps is the positioning of the tracker (Park, Lee, Ku, & Tanaka, 2014). Especially given the exercise of certain sports this should be taken into account. The pulse rate, however, has some serious problems when it is directly worn on the wrist and not via a chest strap. Especially with short-term stress, such as strength training for example. It is not possible to get accurate results (Porto, 2009), because in some sports the wrist movement is too high for good pulse detection. The values can vary significantly from each other, as in the measurement on the wrist average.

Values are measured over a more extended period are better, in endurance sports such as running that plays not an important role. Another problem is the attachment of the sensor to the arm. It can disturb the athlete during his training. Furthermore, the calculated calorie consumption has a significant fluctuation. Particularly in connection with the pulse measurement on the wrist, deviations of more than 50% can arise, which must be considered (Robertson, Stewart-Brown, Wilcock, Oldfield, & Thorogood, 2011).

Justification

Fitness trackers do not enjoy increasing popularity for no reason. They are small and provide hobby athletes to get quick access to interesting information. In addition, they also offer a practical benefit. For example, the smartphones can be left at home while jogging, as it can display things like time or forward the music to the corresponding Bluetooth headset. Also, the tool helps significantly to improve the training by tracking activity. It also displays pulse and accordingly the running speed or the corresponding breaks in strength training can be maintained.

After the training, the regeneration can be monitored, and overtraining avoided. Especially for athletes and trainer, it is affordable information. The last point that is affected is motivation. It already starts with the number of steps. Here you can set a daily goal that will be attempted to reach. This should usually be around 10,000 steps a day (Le Masurier, Sidman, & Corbin, 2003). If this value is not reached, the bracelet reminds the user to move. The results can also be shared automatically across social networks, providing more motivation to achieve that goal every day.

In our time there are so many people wearing wristbands to measure their activity. So it is important to know how they will be working and what they can do. It could play a prominent role in our health system because it will motivate so many to do more sport. As a result, hopefully a decrease of e.g. cardiovascular diseases and overweight can be seen.

Another positive point is the data that will be generated. It is possible to make comparisons all over the world and get some impressive results out of it.

Estimation

Four hours of content: the significant potential to make all the basics in sensor measurements, application, social media aspects

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c) Smart watches

Introduction and application

Smartwatches can replace smartphones in sportive environments and even fit on the wrist. Such a watch keeps persons around the world up to date without holding a smartphone in their hands. Read and answer e-mails and messages via a messenger, take calls, catch up on breaking news or find the right way in a foreign city are some possibilities. The current smartwatches operate via touchpad and also by voice (Komninos & Dunlop, 2014). More and more additional functions like GPS, pulse and height make it even possible to use it without a mobile phone. It will replace the extra fitness tracker and this is especially interesting for athletes who spend a lot of time with training. Now they have all the information they need on the wrist.

Functionality

The smartwatch has even a better performance than a normal fitness tracker. It is because of better processors and displays. It is required because it has a bigger functionality. But in general they are pretty similar. They use the same sensors as accelerometer, heart rate monitors and GPS-modules. Accelerometers measure small accelerations and can be used to count steps. Even at night it can detect the amount and intensity of movements and give a conclusion of the sleep quality (Vermaat et al., 2017).

The heart rate is measured by an optical sensor, which looks for the alternating volume of the arteries. These dates allow statements about the energy consumptions.

GPS-modules work in combination with satellites. They measure the time differences between several satellites and the trilateration will give the exact position. This is useful for tracking distance by running or cycling for example.

Cons and criticism

Not every watch is compatible with every mobile phone. Important here is the operating system. Samsung and Sony use their own operating systems. Apple Watches on iOS cannot be used with an Android phone.

With all the onboard functions and the displays, the watches get even bigger than a fitness tracker and this could be disturbing in sports where the arms are moving pretty quick (Volleyball for example). And sometimes it is not accurate enough. In sports with high wrist movements, the optical pulse measurement method is inaccurate.

Another problem would be the battery life. With all the functions it is normal to charge such a device every single day.

Justification

It is a big part of “IOT” (Internet-Of-Things) and important to know. It could also play a big role in the fight against heart disease, because it works as a long-term electrocardiogram and will alarm if there is an issue.

It also helps athletes with their training, because they can easily track all their activities, take lap times and set timers to improve their breaks.

Estimation
Four hours of content: like Activitytracker (see chapter above).

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d) Ear-based devices

Introduction and application

In the time of wireless connectivity, low power computing and small form factors, there is the possibility to put some devices directly into the ears. There are already some devices out. The most common are probably wireless headphones and hearing aids. New systems are now able to measure some interesting data, e.g. temperature, directly in you your ear the hole time. It is also possible to wear a mobile ECG (electrocardiogram) monitoring device on the ear. It is very useful to record the heart rate and electrocardiogram in such an easy way bus use of an optical sensor, which looks for the alternating volume of the arteries. These dates allow statements about the energy consumptions (Valenti & Westerterp, 2013).

Another scenario is to improve the productivity. That means it gives the ability to control the mobile device with a fingertip.

Functionality

Control of a device is given by an accelerometer. It is a tiny piece of technology enabling the user to detect several gestures like tipping on your headphones, e.g. to skip the music title or start the speech assistant to make a more complex order.

The customer can now decide which command he will do. The next level is to use capacity sensors. This allows to use different gestures and even gestures with more than one finger. Thus, it is possible to pinch in and out and use different areas of the ear to control several function on the device (Lissermann, 2013).

The other function is the temperature measurement, which can be measured by some small thermistors. Their electrical resistance decreases if the temperature increases.

In case of the device for the ECG some graphene-coated sensors are used. The ability as a highly electrically conductive material makes it possible to measure the small voltage (Celik et al., 2017).

Cons and criticism

A problem could be the connection between himself and all the wireless connections in the environment. In case of too many connections in the air, for example on exhibitions, there are often problems to connect with your device because it is so much traffic outside. In our lives it can also become a problem because we get more and more wireless devices. Another thing is the effect of all the electromagnetic fields on the human himself. At the moment, there are some short term studies out there and they cannot find an effect until now (Mandalà et al., 2014). Long term studies will show in the future if this is a problem.

Justification

All these devices can be helpful and it is necessary to understand these technologies more and more to improve daily living because the applications are manifold. It is also easy to build such devices, because processors, batteries and every other part become smaller and the interaction with it becomes easier. Also the point of intersection is even easier to connect with each other.

An important thing that plays a big role is the option that such a tool can be used without using the eyes. Operations work with cognitive maps in the user's head and hit areas or a specific point on the user's ear, which is very easy to learn in a few minutes. Even athletes and trainers can benefit from it. The pulse rate is a reliable factor for showing the state of the generation (Cole, Blackstone, Pashkow, Snader, & Lauer, 1999) after a training session and gives a good hint when to start the next session. Furthermore, the measurement of heart frequencies is more accurate with ear based devices compared to devices word at the wrist.

Estimation

Two hours of content can be filled: one hour different scenarios and one hour with how its function.

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e) Mobile voice control technologies

Introduction and application

Mobile voice control would probably play a major role in our future lives, because smartphones are worn the whole day near the human body. It is possible to organize the daily routines by setting an alert, make an appointment, call someone and so on. Set up the timer only with the voice is probably a nice support for athletes to keep their breaks in an accurate way. It is also possible to exchange data with further measuring instruments (Špale & Schweizer, 2016).
The key for this feature is the (automatic) speech recognition. This is a branch of applied computer science, engineering and computational linguistics. It deals with the investigation and development of procedures which makes a spoken language of the automatic data accessible. The speech recognition is to be distinguished from the voice or speaker recognition, a biometric method for personal identification.

Functionality

In the automatic speech recognition, there are several factors which influence things like accuracy, speed of detection and size of the application. This is important if this is a local service on the device. If it is a cloud solution the size doesn't matter.
The function will start with an analogue value from the voice himself. Afterwards the electronic will grab and change it with the help of an analog-digital-converter to a discrete signal. After this step the software applies a filter to decrease the signal noise. With the help of the fast Fourier Transform (FFT) it will be divided into different frequency components. This allows to see the whole spectrum of the voice. Nervousness for example will show up in higher frequencies in comparison with the baseline (Streeter et al, 1977). The last two steps are to logarithmic the signal and a reverse FFT to get the cestrum (Graves, Mohamed, & Hinton, 2013). After these processes the recognizing will start. The most popular one is the phoneme-based model together with the Hidden Markov Models (HMM). The software is now able to guess the right words and grammar with the usage of a huge database (Špale & Schweizer, 2016).

Cons and criticism

The main negative point of this technology is that mobile phones are "listening" all the time and this could probably be a problem with privacy.
The other point is the very complex content and this is the reason why different database can guide to different results. Due to the large data input by users, big companies like Google can improve their process in speech recognition.

Justification

There are two main leaders for mobile voice control application. This is "Siri" from Apple and the "Google Assistant" from Google. They develop more and more features for daily lives and one major point is the voice control and the field of usage is enormous.

The big advantage of such a hand- and eye-free tool is the efficiency and safety. It helps to make some shortcuts and work faster. The IOs-assistant will start by saying the magic words “Hey Siri”. Afterwards the command like “Set the timer to 5 minutes” is to tell. Another feature is to make a call by using the corresponding name.
Athletes can use it in the training to control their music and this will lead to a better learning process (Simpson & Karageorghis, 2006).

Estimation
Four hours can be filled: Most of the stuff would be the speech recognition (with three hours) and one hour for some example applications.

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1.2 Smart textiles

a) T-shirts and socks

Introduction, application and functionality

Smart wearable technology can be included into garments, i.e. pieces of textile clothing, such as T-shirts, trousers, bras or socks. Besides military, medical and health-care applications, this technology can be used in sports applications as well. The development of special manufacturing processes including conductive elements directly into the textile yarns and fibers of flexible knitted garments (Kumar & Vigneswaran, 2016) allows for increased comfort compared to classical electrical wires. Wearable garments are mostly multi-layer systems, consisting of at least an internal layer (in contact with the skin) and an external one, with connected electronics and circuitry (Kumar & Vigneswaran, 2016).

Vital signs like ECG or heart rate, EMG, respiration rate, skin temperature and moisture can be monitored by integrated sensors and live feedback can be provided. The first approach was a plug to attach a heart rate belt sensor directly onto T-shirts or sports bras (e.g. Adidas SuperNova Bra; Suh, 2015), followed by directly integrated HRM technology. The HeartIn smart t-shirt with ECG tracks heart rate with a sensor on the chest and transfers data to a smartphone app during workout and recovery (Heartin, 2018) (Figure 1). Hexoskin Smart Shirts combine cardiac and respiratory measurements (Aliverti, 2017) with the same purpose (Hexoskin, 2018).

Figure 2: HeartIn smart t-shirt

In addition to woven-in accelerometers, Nadi X smart yoga pants have live haptic (vibration) feedback at the ankles, hips and knees help in keeping proper yoga pose like a digital yoga coach (Wearable X, 2018). Although quite expensive ($179), the integrated sensors need a power pack attached behind the left knee (Caddy, 2018). The CuteCircuit SoundShirt features 16 micro-actuators embedded in the fabric of the garment, creating a haptic sensation of music to enable participation of deaf people in dance activities (Cutecircuit, 2018).

Surface electromyography (EMG) bipolar electrodes can be integrated into sports textiles, requiring perfect fit of shorts when assessing quadriceps muscle activity (Finni et al., 2007). With the Myontec Muscle Monitor EMG shorts, muscular actitvity, left / right and front / back muscular balance can be evaluated (Myontec, 2018). Clothing+ (2015) advertises the integration of skin temperature and conductivity sensing into clothing without giving specific examples.

In addition, technologies for flexible rechargeable batteries (Qu, Semenikhin & Skorobogatiy, 2015) and displays (Cochrane et al., 2011) are available as prototypes.

Cons and criticism

A common drawback of smart textiles is their limitation to the body region they are designed for, and their validity depends upon perfect fit. The debates surrounding smart textiles are just the same as for any other technical innovation. Scientific research, understanding of cultural, sociological and philosophical implications lags behind the rapid rate of technical innovation (Farrington, 2017). Startups and crowd-funded projects (e.g. KeenBrace EMG sensor; Indiegogo, 2017) constantly bring out new products to the market while others disappear (e.g. LifeShirt® by Vivometrics; Heilman & Porges, 2007), so there will never be a complete and up-to-date list of smart textiles. Most wearables have only been promoted by the manufacturers themselves and tested by influencers on the internet. Potentially negative aspects of their usage (e.g. surveillance and intrusion of privacy, digital addiction and corporate misuse of data) must be balanced out with positive aspects of their usage (e.g. capacities for personalisation, empowerment, and greater self-knowledge) (Farrington, 2017).

Justification and estimation of course hours

Wearables have the potential to monitor health to assist with improving sports performance (Kumar & Vigneswaran, 2016) without being restricted to costly, wired or invasive laboratory measurements. They are easy to use and don't require expert knowledge. The wearables market is growing quickly, so it is likely that wearables will assume an ever more prominent role in the everyday technological landscapes of the future (Farrington, 2017). Attempts to understand the future impacts of wearables (in sports) will need to balance utopian and dystopian polarities with theoretically informed and empirically grounded approaches (Farrington, 2017). This is exactly the way this project intends to inform future users.

This topic will fill estimated three hours of theoretical online content.

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b) Shoe insoles

Introduction and application

Force pressure can be measured by two systems: platform systems and in-shoe-systems. These systems are often used instruments in sports biomechanics for the analysis of the interaction between foot and ground surface to i) investigate gait, posture, balance, and foot wear design, ii) to detect lower limb problems, and to iii) conduct injury prevention (Razak, Zayegh, Begg & Wahab, 2012).
They can also be used in rehabilitation for patient groups, e.g. diabetes. Both systems measure forces and pressure (peak pressure and pressure distribution) at the feet (Hellstrand et al., 2014).

Functionality

The foot can be divided into 15 areas: heal (area 1-3), midfoot (area 4-5), metatarsal (area 6-10), and toe (area 11-15) (Fig.1). In in-shoe systems (shoe insoles) small sensors are horizontally and vertically attached to analyze pressure in the anatomical areas of the foot. Such shoe insoles have to be cost-effective, lightweight, energy efficient, and flexible (Razak, Zayegh, Begg & Wahab, 2012, Tan et al., 2015).
The sensors can be capacitative sensors, resistive sensors, piezoelectric sensors or piezoresistive sensors, where according to the induced force, electric impulses can be detected which are proportional to the force.
Sensors have to be small, and must provide linearity, low hysteresis, a pressure range for up to 3 MPa, a temperature sensitivity for only 20-37°, and an operating frequency of 200 Hz.
There exist both wired and wireless sole systems, but wireless systems are preferable to avoid the risk of falling (Razak, Zaegh, beg & Wahab, 2012). Often in-shoe systems are evaluated by comparison with platform systems, which are more accurate due to the greater number of sensors (Tan et al., 2015).

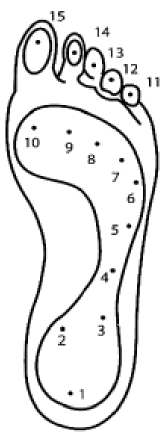

Figure 3: Foot anatomical areas according to Shu et al. (2009)

Cons and criticism

Important factors for both platform systems and in-shoe systems are spatial resolution, sampling frequency and thus, accuracy. Unfortunately, in-shoe systems provide a lower spatial resolution compared to platform systems, because of the smaller number of implemented sensors. Therefore, accuracy is decreased in in-shoe systems.

Furthermore, it is possible that the shoe insoles slip during movements and avoid precise data recording (Razak, Zayegh, beg & Wahab, 2012). An additional problem is that in-shoe systems are restricted to shoes, thus, it is not possible to analyze pressure during barefooted activities.

Justification

Although spatial resolution is lower in in-shoe systems, they can be used to analyze gait, posture and balance in natural conditions, because shoe insoles are not restricted to laboratories as it is the case with platform systems. Shoe insoles can be used with every shoes and every underground. And, compared to platform systems, tested persons can perform their activities in a normal way. No practice for e.g. gait for correct foot strike on the platform must be taken (Razak, Zayegh, Begg & Wahab, 2012, Tan et al., 2015).

Shoe insoles are also important in (high-performance) sports to analyze foot pressure during running, jumping and throwing (e.g. Salpavaara, Verhoe, Lekkala & Haltinnen, 2009) or distribution of body's center of mass (e.g. Holleczek, Ruegg, Harms & Troster, 2010). These parameters can be taken to analyze posture and balance, which are basic requirements for good performance. By use of such systems a direct feedback can be given to improve performance and prevent injuries (Holleczek, Ruegg, Harms & Troster, 2010, Razak, Zayegh, Begg & Wahab, 2012).

Estimation

Two hours can be filled: 30 minutes for platform systems and 90 minutes for in-shoe systems.

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1.3 Non-wearable technologies

a) Game assistance systems

Introduction, application and functionality

Game assistance systems have been introduced over ten years ago and are frequently used in today's sport events (Ryall, 2012; Ahmadi & Niloufar, 2014; Psiuk et al., 2014; Li & Shi, 2014; Carboch, Vejvodova & Suss, 2016). These technologies have to fulfill a variety of tasks during competitive matches. Most obviously, the application of these systems should reduce errors by referees and umpires to a minimum (Carboch, Vejvodova & Suss, 2016). Moreover, decisions made by referees should be visualized to ensure understanding by spectators and fans (Collins & Evans, 2008; Winand & Fergusson, 2016). Finally, participating players and external observers should experience fairer game with objective judgements (Collins & Evans, 2011; Nlandu, 2012).

"Hawk-eye" is based on the principle of triangulation using the visual images and timing data provided by several high-speed video cameras at different locations (Li & Shi, 2014). The system can track the ball and calculate the flight patch even if some cameras are being blocked. Moreover, the trajectory of the ball can be stored and used to create a symbolic image of the path and the area of impact of the ball to visualize the decision process (Collins & Evans, 2008). Since this technology bases on tracking technology no manipulation of the ball is necessary. This system is frequently used in tennis, soccer and cricket (Collins & Evans, 2011; Ahmadi & Niloufar, 2014).

Goal-line technology (GLT) is based on electric and magnetic fields which form a grid inside the penalty area as well as the goal. The ball has to be adapted by embedding a passive electronic circuit in it. Differences in the magnetic field around the goal or behind the goal line occur whenever the ball is placed at locations where the magnetic field is present. These changes can be measured by the system and used to determine the exact position of the ball. (Ahmadi & Niloufar, 2014; Psiuk et al., 2014). As soon as the system detects the ball being completely behind the goal line the referee receives a radio signal on their wristwatches. Another detection mechanism uses high speed cameras to track the ball while in play (Spagnolo et al., 2013; Ahmadi & Niloufar, 2014). GLT systems are mainly used in soccer.

Cons and criticism

Game assistance systems improve referees' decision making leading to more correct calls (Carboch, Vejvodova & Suss, 2016). The duration of analyzing a critical sequence and deciding is within seconds. Most commonly used systems are non-invasive, therefore not altering the critical objects of the games (i.e. balls) (Spagnolo et al., 2013). Moreover, statistical errors are possible for any system (Collins & Evans, 2008). Although game assistance systems are becoming more and more popular has to be stated that these technologies are primarily used at elite level (Ahmadi & Niloufar, 2014). This can be seen as an alternation of the game towards a more complex and less fluent variant (Ryall 2012).

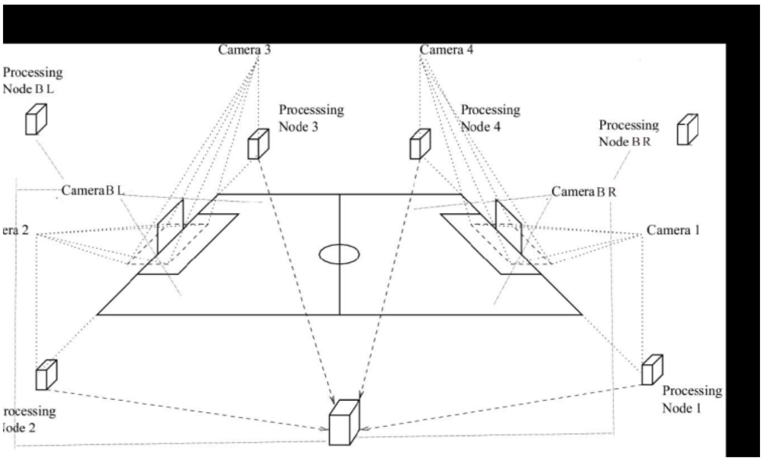

Figure 1: Scheme of a visual system (Spagnolo et al., 2013)

Justification and estimation of course hours

Game assistance technologies are implemented with the idea of supporting officials in order to reduce the amount of wrong calls to an absolute minimum. While it is proven that the mentioned systems are immensely reliant and therefore provide right decision-making in most of the cases, all systems are susceptible to statistical errors (Collins & Evans, 2008; Spagnolo et al., 2013). Thus, wrong decisions are not completely excluded but very unlikely to be made compared to decision-making processes without technical assistance. Moreover, the fundamental question whether wrong decisions made by referees should be extinguished completely to achieve an objectively correct game or if human errors are part of the game (Ryall, 2012; Winand & Fergusson, 2016).
Participants using the online subsection game assistance systems should be learning about the basic functionality of the technologies featured in the sections above focusing primarily on the different devices necessary (e.g. cameras, magnetic coils, antennas). In an application oriented section participants could be confronted with real game situations having to decide on the correct in-game judgment. First, they should decide using only video material or pictures from limited angles without any further assistance. Second, the technically supported decision-making process could be viewed, and the correct answer be given.

This topic will fill estimated three hours of online content.

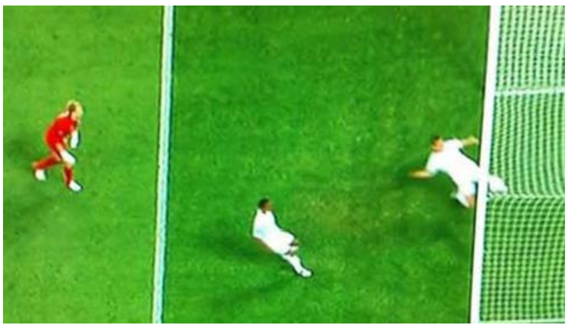

Figure 2: Decide: Goal or no goal? (Spagnolo et al., 2013)

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b) Stationary voice control technologies

Introduction and application

Stationary voice control would probably help to improve the life in the future because it saves time in order to do easy tasks like telling the weather forecast. It is possible to put it at home and have all the time access.
Several things like setting an alert make an appointment, call someone are only some of the features. The key for this feature is the speech recognition or automatic speech recognition. This technology deals with the investigation and development of procedures, which makes spoken language accessible for a computer.
The speech recognition is to be distinguished from the voice or speaker recognition, a biometric method for personal identification. However, the realizations of these procedures are similar.

Functionality

Devices like the "Amazon Echo" have several microphones on board for voice detection over the whole room. It is listening all the time for the initial word "Alexa". It is also called the buzzword and has to stay in front of a task. The user for example can ask for information without using the hands.
The functionality in detail is already explained in the mobile voice control report (Rabiner, 1989).

Cons and criticism

The main problem of the technology is that the device is not mobile. That means the user has to be close to the speech assistant.
The fact that a device is always listening could be critical for the privacy of a user. Even if the company does not want to, there is the possibility that hackers use this as a further possibility to access private data.
Another feature is the possibility to shop on Amazon only with the voice of a user. Other people can abuse this feature.

Justification

There are two main leaders for mobile voice control application. This is "Siri" from Apple and the "Google Assistant" from Google. They both are easy to use and have pretty similar features. The user is able to ask for information or control his smart home (Graves, Mohamed, & Hinton, 2013). This could be the light that should change the color or turn complete of, the thermostat of the flat, the home entertainment system or play some music.
Athletes could get their own advantages from a speech assistant. This will save time and allow focusing on training and upcoming competitions.

Estimation

Four hours can be filled: Most of the stuff would be the speech recognition (with three hours) and one hour for some example applications.

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Graves, A., Mohamed, A.-R., & Hinton, G. (2013). Speech recognition with deep recurrent neural networks. 2013 IEEE International Conference on Acoustics, *Speech and Signal Processing* (ICASSP), 6, 6645–6649. DOI: 10.1109/ICASSP.2013.6638947

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c) Biofeedback

Introduction and application
By use of different sensors attached to the skin of athletes, a direct feedback concerning body parameters can be given. These sensors can be applied to detect muscular activation, sweat, body temperature, skin conductance, respiration and heart rate in studies with biofeedback and brain waves or blood flow in studies with neurofeedback. By use of the real-time feedback, which is in most cases an audio or acoustic feedback, the athlete can learn to understand and control these parameters to increase sports performance (Dupee, Forneris & Werthner, 2016).

Functionality
With the sensors attached to the skin, the athlete will be placed into a stressful situation. This can be made in a stationary way, e.g. the athlete is placed in front of a screen to monitor a sport specific situation, or it can be made in (quite stationary) sports situations, e.g. pistol shooting or free throws in basketball (Langner, Stucke & Edelmann-Nusser, 2016). A typical training session consists of twenty to sixty minutes, where athletes have to concentrate on the task. Using a training with biofeedback and / or neurofeedback, athletes can learn self-monitoring and self-observation about their nervous systems and become more aware of the connection between body and mind. They can learn to control bodily functions (Dupee, Forneris & Werthner, 2016).

Cons and criticism
Biofeedback and neurofeedback trainings are very time-consuming because each training has to be developed and performed individually. Additionally, only intra-person comparisons can be made (comparison to individual baseline values).
Such training was developed for clinical settings to treat diseases, such as concentration disorders and migraine headache. It is an often used instrument to decrease fear and anxiety. This psychological instrument can be transferred into the domain of (high-performance) sports, but more studies, especially with elite athletes are needed (Dupee, Forneris & Werthner, 2016).

Justification
There exist several studies, which confirm the advantages of biofeedback and neurofeedback training (e.g. Langner, Stucke & Edelmann-Nusser, 2016). Dupee, Forneris and Werthner (2016) found that athletes benefit from such training because they learn to identify, differentiate and control different body states, they increase their self-regulation for better management against distraction and to maintain better focus on relevant information, and they notice that the control of the respiration is an important factor. In sum, they receive a better comprehension for stress management; unconscious body processes become conscious.
The concrete feedback helps athletes because it supports a comprehension about the own body and the own behavior, which athletes often are not aware of. The real-time feedback helps to connect the concrete reasons for the own reaction.

Especially with subsequent self-talks (Galanis, Hatzigeorgiadis, Zourbanos & Theodorakis, 2016) the knowledge can be consolidated.
Furthermore, Marshall and Gibson (2017) detected that imagery training can also help to increase self-confidence, and Moen and Firing (2015) and Moen, Firing and Wells (2016) found out that attention training helps to increase the perception and to learn to deal with distractions in different sports. This way, such training can reduce stress in sports, and thus, increase performance.
To gain further insights into performance of athletes, it would be possible to couple such biofeedback and neurofeedback with other technologies, e.g. eyetracking or virtual reality to analyze attention strategies. Or such feedback systems could be connected to analysis tools of biomechanics, such as movement recordings (film material or 3D movement analysis), force plates or shoe insoles to analyze connections between attention and movement executions.

Estimation
Two to three hours of content to describe and explain such training and give further examples.

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1.4 Feedback and motivation

a) Gamification as a special type of giving feedback

Introduction, application and functionality

Gamification is a rather new approach to learning and engagement improvement using game-design elements and game principles in non-game contexts (Cugelman, 2013; Hamari, 2013; Wikipedia). Introduced roughly ten years ago it gamification is seen to have a positive influence on user activity, quality and productivity of actions as well as enhancing interactions between users (Hamari, Koivisto, Sarsa, 2014, Iosup & Epema, 2014). Gamification refers to the use of design, elements and characteristic for games in non-game contexts rather than using the full-fledged games in a specific gaming intention (Deterding et al., 2011).

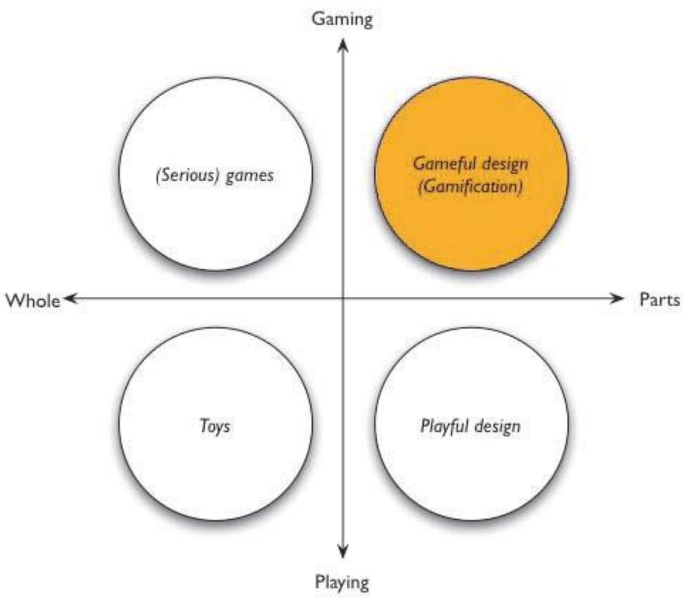

Figure 1: Gamification in the context of gaming and playing separated by the parts/whole dimension (Deterding et al., 2011)

The application of procedures and methods, commonly known from video games (e.g. console games, computer games, game boy), have a strong influence on users' motivation towards fulfilling various tasks. From a psychological point of view gamification can be defined as a process of enhancing services with affordances in order to invoke gameful experiences and further behavioral outcomes (Hamari, Koivisto & Sarsa, 2014). The psychological persuasion is achieved in three steps. First, the implemented motivational affordances. Second, the resulting psychological outcomes of this affordance. Third, behavioral outcomes due to the first two steps.

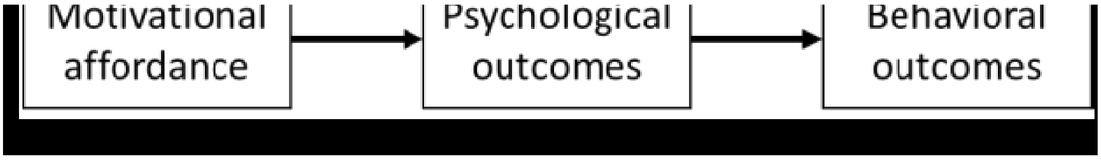

Figure 2: Three main parts of gamification (Hamari, Koivisto & Sarsa, 2014)

Cons and criticism

Gamification tools and game-like interfaces provide various possibilities for giving feedback. Progressing bars, increasing numbers, batches, tokens, amount of accumulated knowledge are examples for feedback systems used in serious games. These forms of quantitative feedback increase engagement in the action (Reevers, B. & Read, L., 2011; Jung, Schneider & Valacich, 2010).

Although being one of the most popular and trending topics regarding persuading and motivation people the simplicity of gamification is a big point of criticism. First, due to its simplicity, it can easily be used in a wrong manner when not understood fully. Second, every person has experienced game-like situations in some form or the other. Thus, other motivating architectures could be neglected or ignored unintentionally (Cugelman, 2013).

Justification and estimation of course hours

Gamification is a tool used in multiple disciplines and areas to motivate people and persuade users. Applications range across finance, productivity, health, education, sustainability and entertainment media (Deterding et al., 2011). Since gamification is a very flexible method to use it has to be considered in the application area of sports as well. Researches show the big potential of this approach in the educational context as well as in the area of e-learning (Lee & Hammer, 2011; Piteira, Costa & Aparicio, 2018; Shipherd & Burt, 2018; Pieteira & Costa, 2017).

Estimation

This topic will fill estimated **3** hours of online content. One hour for the theoretical introduction to the topic of gamification plus two hours of completing various tasks in order to earn some form of virtual reward.

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b) Calculation models

Introduction and application
Nowadays we need a precise and accurate measurement of the human energy consumption to fully understand how energy is regulated in order to develop interventions and evaluate their efficiency to protect the human for overweight.
Another important reason to calculate the consumption is the effect on the performance of athletes.

Functionality
There are many possibilities to calculate the energy consumption of the human body. The most-often used methods are laboratory based, such as ergometry plus respiratory gas analysis while running or cycling on ergometers. These methods served as the golden standard, but are also very expensive. Another method is to use certain tables. According to the load of activity and the body mass index, the energy consumption can be guessed. This method is quite cheap and easy to apply, but not that precise as the laboratory methods.

Cons and criticism
There exist many models for calculation. There is a distinction between two groups. The first one uses general tables. It is only necessary to enter a few parameters for a first impression of the energy consumption. The second method determines the exact and individual consumption in the laboratory by means of respiratory gas analysis (Livesey & Elia, 1988).
Of course it also depends on the possibilities and the requirements. The first method gives a guess of the consumption. It is cheap but not as accurate as it should be for elite athletes. The labor-method calculates the consumption on the basis of exact laboratory values. It will cost more money and need more time, but very precise if applied in an appropriate way. By using some biomarks for the metabolism it is possible to reach precise values (Trabulsi & Schoeller, 2018). The cost is also pretty high and it requires often invasive sampling like blood draw.
The problem is that the consumption depends on the human himself and his activity. Periodical movements like endurance cycling or running on a known level are easy to measure but in sports with a change in velocity, e.g. team sports like soccer, or racquet sports and martial arts, exact calculations are not possible.

Justification
It is very important to understand how the body work with your meal and how much energy you need for specific activities. Therefore, it is necessary to calculate the basic consumption together with the consumption under load. Good examples are athletes in weight orientated sport classes like boxing or weightlifting. If they want to lose or gain some weight, they have to track their meals and their energy consumption. This determines if more or less calories have to be taken.
The understanding of the topic can improve the performance of athletes and should be known also by each trainer. Good examples are sport categories where athletes have a weight limit for a special class to compete against each other.

Estimation

Four hours of content: explain different Models (1. Guessing Model and 2. Measure energy expenditure (EE)) and show some examples.

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2. Motion tracking and analysis

2.1 Single person

a) Apps and software for qualitative and quantitative motion analysis

Introduction, application and functionality

There is a lot of software for motion tracking and qualitative and quantitative motion analysis, from costly commercial programs (Simi Motion, Dartfish, utilius, TEMPLO) to cheap or even freeware programs. A well-known and increasingly scientifically used software (Barounig, 2018; Beato et al., 2016; Conte et al., 2015; Cristea, Dragoş & Pădure, 2014) is the open-source program **Kinovea** (Kinovea, 2018), a project launched in 2004 with regular updates (current version 0.8.26) and in different languages. Videos can be imported, displayed frame by frame or with different speed. Two videos can be compared, synchronized (using one key frame) and overlapped. Vantage points can be visualized directly in the video or screenshots using tools (e.g. angle or distance measurement, human model including centre of mass calculation), marker tracking includes velocity calculation (if calibrated). Results can be exported in spreadsheet format (*.csv).

Another freeware is **Tracker** (Brown, 2018), originally designed for physics teaching. It provides similar functions as the aforementioned program Kinovea, but it is not as appealing for visualization. Autotracker function is more sophisticated, and data is directly displayed in diagram and table format (Figure 1).

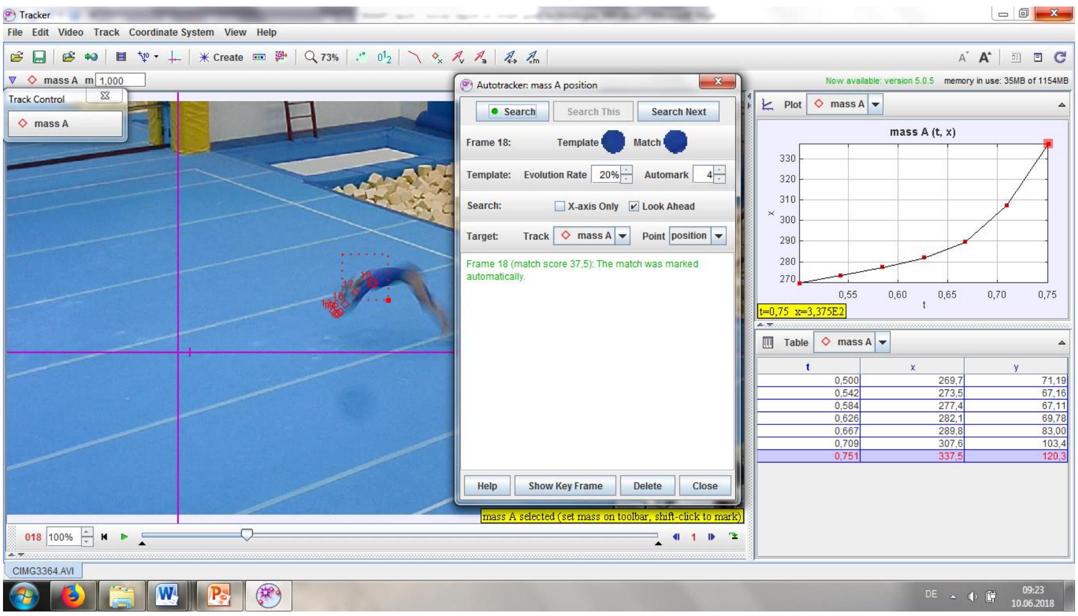

Figure 4: Tracker user interface including Autotracker function and data display

The increasing use of smartphones and tables operating on either Android, iOS or Windows led to an emerging market for apps. Throughout the last few years, there was a real boom of new and improved apps, which has now flattened out and left a number of useful apps. Besides fee-based light versions of well-known motion analysis programs such as **Simi Move** (iOS 7.0 or later, $ 9.99) (Yeo & Sirisena, 2017) or **Dartfish Express** (Android and iOS, € 6.99) (Figure 2). Yet free of charge apps such as **Hudl Technique** (formerly known as Ubersense) provide similar visualization tools (line, rectangle) (Agile Sports Technologies, 2018). **Coach's Eye** (Techsmith, 2018) on the contrary has a free trial, while the full version costs up to € 17 depending on the operating system.

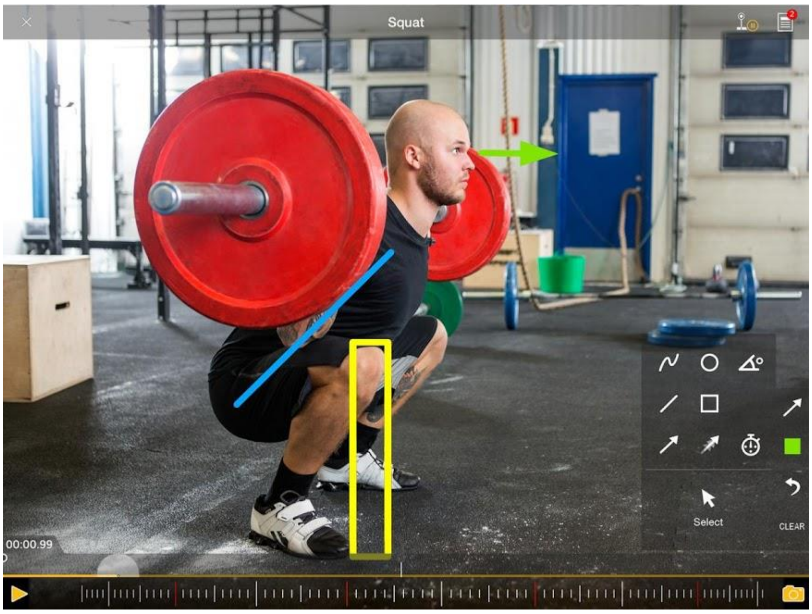

Figure 5: Dartfish Express user interface including visualization tools

Due to the lack of calibration, angles are the only quantitative measurement provided by motion analysis apps. **TrackIt!** (Google, 2018a) and **VidAnalysis** (Google, 2018b) (Android) or **iTrackMotion Lite** (Apple, 2018a) and **Viana Videoanalyse** (Apple, 2018b) (all free of charge) provide very simple marker tracking including the necessary calibration.

Cons and criticism

Drawbacks such as "3 free trial" versions, which can only be continued as fee-based, subscription, in-app buys, advertisements and upload platforms have to be mentioned. Potentials and risks in classroom use have been addressed by Drewes and Ziert (2014), Falkenberg et al. (2014) and Hebbel-Seeger, Krieger and Vohle (2014).

Justification and estimation of course hours

The invincible benefit of such apps is the easy use in everyday training process with fast feedback options. Therefore, this market can be expected to increase and further emerge in near future. The use of this mobile, intuitive technology in the practice of sport is highly supported and endorsed by Drewes and Ziert (2014), Falkenberg et al. (2014) and Hebbel-Seeger, Krieger and Vohle (2014).

This topic will fill estimated four hours of online content; one hour for the theoretical introduction plus three hours for completion of the study task.

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b) Apps including sensors

Introduction, application and functionality

Monitoring athletes has become very important in sports science. Movements, workloads and biometric markers can be recorded and analyzed and therefore maximize the performance and trying to minimize the injuries (Li et al., 2016). It is segmented into internal-load monitoring and external-load monitoring. Internal-load monitoring is defined as the physiological and psychological stimulations (e. g. brain function, blood assays, urine assays, skin and sweat sensors, etc.). As for the external-load monitoring, it is defined as the work completed by the athlete (e. g. duration, position, speed, distance, movements, etc.) (Cardinale & Varley, 2017). In the early stages of sports science, these parameters were only able to be gathered in a laboratory with fixed and static equipment. Because of the progress in technology, most of the monitoring of an athlete is now able to be captured in the field because of smaller and lighter sensors. This enables the athlete to naturally engage in his sport and also share important data with the trainer team or researchers (James & Petrone, 2016). In addition, sports sensor are affordable for hobby athletes as well and are heavily used in the health and fitness sectors (McGrath & Ní Scanaill, 2014).

Example on a golf sensor:
Golfsense is a small sensor unit, which is attached to the back of a golf glove. Data like club speed, club position, swing tempo and swing path is streamed via Bluetooth to a mobile device and can then be analyzed by an app (Figure 1.0).
Alternative approaches are attaching a sensor directly onto the shaft of the golf club (SwingSmart, SwingTip, Swingbyte).

Figure 6: GolfSense sensor with an app to analyze data (McGrath & Ní Scanaill, 2014)

Also, lots of other different sensors with other functions and different types of sports have been developed end reviewed (Chambers et al., 2015; Li et al., 2016; Magalhaes et al., 2015).

Cons and criticism

A big problem is that many manufacturers do not provide solid information about accuracy, validity, and reliability of their products and often do not give access to the raw data of the sensors (Cardinale & Varley, 2017).

On the one hand, the sensor technology continues to grow with lots of different approaches, techniques, and lower prices. On the other hand, those products might not be sufficient for elite athletes due to the above-mentioned lack of validity, reliability, and accuracy. Therefore, most of the fitness sensors are not 100% accurate, which might not be noticeable in the health and fitness sector but for elite athletes, this difference might be considered high (McGrath & Ní Scanaill, 2014).

Justification and estimation of course hours

The development of wearable sensors has been very successful and is still evolving. The reduction in size, better sensor techniques, and reliability make this field a promising tool for the consumer market as well for the elite athletes.

This topic will fill estimated two to three hours of online content.

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c) Marker and markerless motion capture

Introduction and application

Motion capturing is a technology to track all kinds of movements and transfer it into a computer language. That allows to save, analyze and process further the data. There are several points underneath this main topic. The most popular one is the tracking of the human body for 3D analysis. This will give important parameters like positions of the body or relevant segments, velocities, angles, trajectories and so on. This way, athlete's motions can be recorded and analyzed to further improve the motion execution and to recognize mistakes and potentials.

Other examples would be Head-Tracking and Eye-Tracking (for eyetracking see chapter eyewear). A more detailed version is "Performance Capture" that concentrates on specific human gesture and mimic. Nowadays a common usage is the computer game development. The characters should move like a real human. Therefore, the movements of expert athletes can be captured and implemented in video games, or other athletes could use this (perfect) movement execution to improve their own motor skills.

Functionality

There are two main ways to capture the motion. One way works with markers on anatomical landmarks (Moeslund & Granum, 2001) or marker clusters on body segments (Cheung, Baker, & Kanade, 2005). Normally several cameras track these markers. It is necessary because all markers has to been seen all the time for a robust tracking (but always at least to cameras have to capture the same point at the same time to create the 3D position). That is the reason for using 10 or more cameras in different heights. The infrared cameras work by sending out a signal, which is emitted by the markers. Now it is possible to detect the location and in addition with other cameras it is possible to calculate the exact position in a room. This method is best one and that is the reason why it is the gold standard and often used in scientific studies. An alternative is to use normal cameras. They work with passive or active markers. The last one is sending signals by himself that is detected by the cameras.

The second way and the newest one is marker-less tracking. It works with the silhouette of the human. The computer uses a normal video out of the camera and extracts the silhouette from the environment to calculate a virtual model. That allows to define also the exact points of specific joints and calculate all specific parameters like angles, velocity and so on (Colyer, Evans, Cosker & Salo, 2018).

Cons and criticism

The negative side is the aspect of the time. Getting people ready for motion capture takes quite a long time when marker- or inertial-sensor-based systems are used. This setup time can be prohibitive in the world of life sciences where many people are scanned or the patients are so weak that they cannot endure the entire procedure or have a low attention span like children. So most of the time it disturbs athletes in their routine. It is also pretty stressful because the preparation is time consuming and the temperature has to kept high for the

upcoming exercise.
These kinds of systems have also a problem with costs and portability. There are mobile systems out there but they have sometimes problems with the light outside. However, while marker-based systems serve today as the golden standard in sports science in biomechanics, because they are very robust and accurate, more and more marker-less systems exist and provide for some sports situations many advantages (no need to place marker on anatomical landmarks) with (in some situations, such as one only athlete being tracked) similar accuracy. But marker-less systems are still in the development. Both systems have the disadvantage that they are not portable (Colyer, Evans, Cosker & Salo, 2018).

Justification
These instruments allow to get such precise data and compare new measurement systems against this and give some valid information about the new ones. That is the reason why this technology is the gold standard in science and plays such a big role. It has such a big field of application for example the science and film industry.

Estimation
Minimum four hours of content because of so many different tracking types and methods. The cameras also take minimum one hour.

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d) Mobile 3D scanners

Introduction, application and functionality

Anthropometry is one sub-discipline of sports biomechanics, dealing with the measurement of human body segment parameters: lengths, circumferences, surface, volume and finally Body Mass Index (BMI) (Baca et al., in print). Digital anthropometry is done using 3D scanners. 3D scanning technology has evolved from large to handy and from costly to low-cost (Koban, Schenck & Giunta, 2016). This has widened its use in biomechanical and clothing applications as well as sport science research projects. Customization of biomechanical modelling and sports clothes relies on participant-specific body segment parameters.

In contrast to stationary 3D scanners, non-stationary 3D scanners allow their application in varying surroundings. Scientific and commercial non-stationary 3D scanning solutions range from portable multi-camera systems (Peyer, Morris & Sellers, 2015), Microsoft Kinect™ sensor (Bonnechère et al., 2014) and hand-held 3D scanners. Hand-held 3D scanners for full-body application cost from cheapest about € 200 to 500, e.g XYZscan Handy (XYZprinting, 2018) or Sense™ (3D Systems, 2017) (Figure 1) up to high-end products for € 5.000 to 20.000 and more, e.g. EinScan-Pro+ (Shining3D, 2016) or Artec Eva (Artec, 2018).

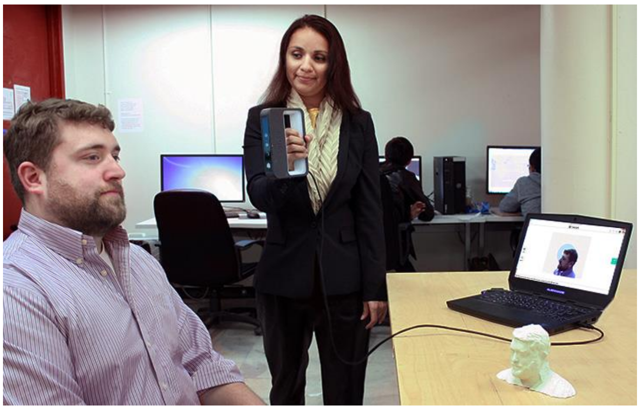

Figure 7: Sense™ scanner

The technology behind is either structured light (white light LED), laser triangulation (usually class I laser for human purpose) or infrared light (IR). From the acquired point cloud, a triangulated surface is created, which can be further processed. Open source software such as MeshLab (MeshLab, 2017; Cignoni et al., 2008) (Figure 2) or Blender (2018).

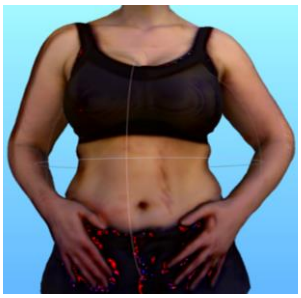

Figure 8: 3D scan in open source software MeshLab

Validation of portable 3D scanners is usually done in comparison to stationary scanners, e.g. to standard stereophotogrammetry (Bonnechère et al., 2014). Surprisingly, scientific experience reports with hand-held scanners are sparse. Koban, Schenck and Giunta (2016) compare three different mobile hand-held scanning systems: Sense, iSense™ mounted to iPad and Artec Eva for evaluation of plastic surgery outcome. The Sense™ scanner was found to be limited in more complex surfaces compared to the more costly Artec Eva scanner. Redlarski, Krawczuk and Palkowski (2017) calculated human body surface area using a hand-held Artec 3D Eva scanner.

Cons and criticism

The familiarization with 3D scanner handling takes several hours, and it has to be repeated for different size and shape of objects as well as lighting conditions (Hassmann et al., in print). The overall scanning procedure is more time consuming for cheaper scanners, and in the reproduction of more complex surfaces they are inferior to more costly scanners (Koban, Schenck & Giunta, 2016). Instead of moving the scanner, the use of turntables has established for objects as well as humans. Placing the participant on a turntable keeps the required distance between scanner and object, thus reducing scanning time and facilitating the participant to keep the same position (Hassmann et al., in print).

Justification and estimation of course hours

The advantages of the hand-held 3D scanners can be summarized as follows: There are relatively cheap yet functional commercial 3D scanners available, which are lightweight and handy, and some include free software. They don't require any calibration before use. The Sense™ scanner provides quite good scan quality with high dimensional accuracy and repeatability if lighting conditions are optimal (Hassmann et al., in print). The market for cheap hand-held 3D scanners is not yet saturated, so further developments and improvements can be expected. Course participants will get information to decide which price segment is necessary for their specific application.

This topic will fill estimated three hours of theoretical online content.

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e) Full body suits

Introduction and application

The human motion capturing data is of increasing importance. It helps to understand the movement in order to the environment and connect it with the digital world. Even tiniest movements like small twitches could be detected. The areas of application are very diverse. A common area is in the clinical orthopedic environment (Morris, 1973). Nowadays computer games and movies use this technology to transfer real human motion to a virtual character. However, it is also common to apply inertial sensors in motion analysis, both in competition and training capturing the position, attitude, velocity and acceleration to improve the performance (Camomilla, Bargamini, Fantozzi & Vannozzi, 2015). Furthermore, it is used in clinical diagnosis, monitoring rehabilitation and investigating motor learning in medicine and sports (Wagner, 2018).

Functionality

Full body suits allow measuring the human motion without cameras, but only with inertial sensors. This is a collection of several individual sensors. One of them is the accelerometer sensor, which detects the acceleration of the unit. In many cases there are three in one housing, because it is necessary for each axis. It is possible to make a statement about which position the body has. For spinning movements, it is further necessary to use the implemented gyroscopes (Wagner, 2018). They are able to measure the velocity of the rotation and is better for some movements. In vehicles, for example, this is used to detect the swing off out during braking. The last sensor in the unit is the magnetometer. It has also three axes and detects the orientation in correlation to the earth magnet field. In combination of all these sensors, positions can be calculated. If you already combine several sensors with a model and take a suit to put all together, you are able to get a human body model out of the data (Roetenberg, Luinge, & Slycke, 2009).

Cons and criticism

The negative side of theses sensors would be some limitations, such as insufficient calibration, ferromagnetic disturbances and insufficient alignment between sensor axes and anatomical axes. Furthermore, sensors can drift and become inaccurate due to high dynamics in sports, although today's sensors provide at least ±2g and ±1500°s (Wagner, 2018). Another problem is the complexity of the topic. It isn´t easy to build or understand inertial sensors. Even the fusion of different sensors is so complicated, that a big company, or their software, is necessary for the work and this leads into high costs. On the other hand, companies and athletes can benefit due to co-operations. Athletes and coaches can get motivated and have better support during training and companies benefit from the reputation of experiences athletes. However, when applying inertial sensors, the user must have a profound knowledge in 3D kinematics.

Justification

Inertial sensors are used in biomechanics since 1920. And since 1995 with the market entry of MEMs gyroscopes, IMUs (inertial sensor units) became small, light and inexpensive. When attached to several segments of the human body, the above described parameters can be analyzed without interference of the athlete. Furthermore, interactions, such as between horse and rider in equestrian sports can be measured (Walker et al., 2016). Furthermore, IMUs are portable and can be used both in laboratories and in fields.

Estimation

Six hours of content: two for the main explanations, two for examples, two for self-experiments

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2.2 Team

a) Drones

Introduction, application and functionality

Drones have become cheaper, and therefore they are an affordable toy for anyone, which has made them very popular in the recent years. The advances in Unmanned Aerial Vehicles (UAV), commonly referred to as drones, has led to increasing interest and use in many fields, turning them from toys into tools (Giones & Brem, 2017). Drones are used in several businesses: virtual tourism, real estate and civil engineering, and their applicability as parcel delivery has been claimed by Amazon (Hern, 2016). Research examples can be found mostly for landscape and archeology purposes (Campana, 2017), agriculture (Kavoosi et al., 2018), bridge (Seo, Duque & Wacker, 2018) or solar power plant inspection (Kumar et al., 2018). Sports science examples are sparse so far, yet many challenges have to be met in order to use the vast unexplored opportunities of drones in sport (Suresh & Sundararajan, 2014). They are expected to assess and enhance athletic performance (Frey, 2014). So far, drones in sport are being used for filming purposes, e.g. in the 2014 Sochi Winter Olympics (Lecher, 2014), for which special algorithms are developed (Natalizio et al., 2012). In the 2016 Rio Summer Olympics, drones were used in organization, surveillance and TV broadcasting (Nadobnik, 2016). Not to forget that drone racing has become an independent sport with international championships (Nadobnik, 2016).
The application of drones in sport science will open new and exciting possibilities in many sports, such as track and field or team sports. In 2015, Akpa et al. presented the CuraCopter, combining an automated drone and a fixed video system that automatically follows an athlete to record his or her training session. Kljun et al. (2015) designed a concept of a drone projector for street exergames called StreetGamez. The most advanced approach was presented by Ferreira, Cardoso and Oliveira (2015) for indoor soccer player detection by two Parrot AR.Drones (see figure 1, left).
The advantage of drones over CableCams or fixed team sport systems is their price, versatility and mobility. Current systems are expensive and require a long time and expert knowledge to set up (Lecher, 2014). Drones are mostly quadcopters with four rotors such as the DJI Phantom 4 (DJI, 2018) (see figure 1, right), but there are also bi, tri, hexa or octo depending on the number of rotors.

Figure 9: Left: Parrot AR.Drone 2.0. Right: DJI Phantom 4.

These drones are equipped with a camera, which can be controlled and viewed via WiFi on the smartphone or tablet. In addition, traditional 2.4 GHz remote control is available. Video recordings can be transferred directly or stored on SD card inside the drone camera. Gimbal lock provides stability of flight and video even under wind influence. First person view (FPV) means to fly the drone not by sight, but by the live picture of the camera mounted on the drone.

Cons and criticism

The current restrictions in flight time (Lecher, 2014) and video quality depend on the price of the drone. Depending on the desired angle of view, the camera must be able to provide bird's-eye view.

The incident of Austrian skier Marcel Hirscher, who was almost hit by a crashing drone in a slalom race in Madonna di Campiglio in December 2015 (Thorpe, 2017), arose the discussion on the safety of drones. Legal regulations concerning drone weight, flight height, camera use and redundant drive are different in all European countries. In Austria, for example, unmanned flying objects with up to 79 Joule motion energy, not higher than 30 m above the ground, within range of vision (no FPV flight), not above people and without cameras do not require license. For any other purpose, the license has to be applied for and the drone pilot needs a special permission.

Justification and estimation of course hours

This topic will fill estimated four hours of theoretical online content, including 1 hour of research task on legal regulations of drone use in the course participant's home country.

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b) GPS technologies

Introduction, application and functionality

Global positioning system is a technology originally invented in the 1970s for military usage. In the 1980s usage for civilian purposes were allowed. It was the first global navigation satellite system (GNSS) to be introduced to the world. This system uses over 30 satellites in order to provide accurate tracking and navigation (Edgecom & Norton, 2006). Each satellite is equipped with an atomic clock constantly transmitting information about the exact time. A GPS receiver compares the signal and time stamp of multiple satellites and calculates the travel distance of the signal. By calculating the distance to at least four satellites, the exact position can be determined (Larsson, 2003; Edgecom & Norton, 2006). Today there are four different GNSS (BeiDou, Galileo, GLONASS and GPS) integrating a regularly increasing number of satellites to refine navigation and tracking (Li et al., 2015; Geng et al., 2018).

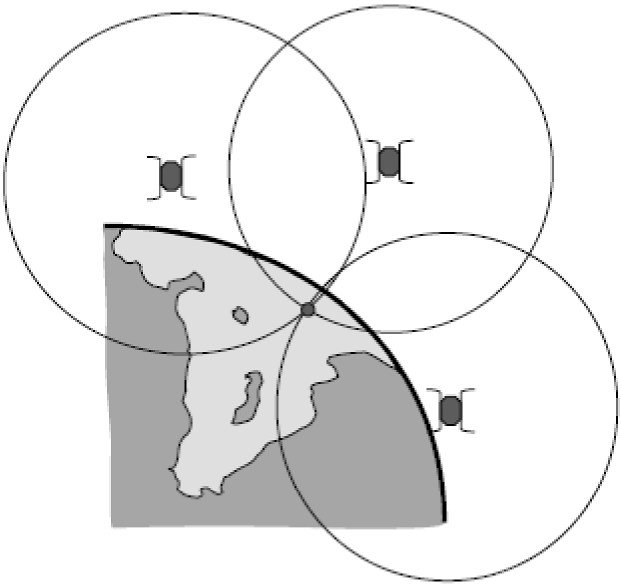

Figure 1: Triangulation method to determine position (Larsson, 2003)

GNSS are used in various applications in the field of sports including team sports, track and field, winter sports, and others at elite and amateur level (MacLeod et al., 2009; Edgecom & Norton, 2006, Aughey & Falloon 2010; Read et al., 2018; Polgaze et al., 2018).

Cons and criticism

GPS used in team sports shows an acceptable level of accuracy and reliability for total distance and peak speeds as well as for average speed during high-intensity, intermittent exercises. (MacLeod et al., 2009; Coutts & Duffield, 2010). Nevertheless, it can be unreliable for very high intensity activities (Coutts & Duffield, 2010; Aughey, 2011). Real-time analysis which is valuable in the field of sports can result in different values for performance parameters compared to post-game data (Aughey & Falloon, 2010). GPS technologies are rather simple to use and show easy usability. Especially at non-elite level where minor inaccuracies are acceptable these systems offer satisfying possibilities for tracking and performance analysis.

Figure 2: Route taken by an orientation runner (1-7) (Larsson, 2003)

Justification and estimation of course hours

GNSS are commonly used in the field of sports research, coaching and performance analysis (MacLeod et al., 2009; Edgecom & Norton, 2006, Aughey & Falloon 2010; Read et al., 2018; Polgaze et al., 2018). These constantly evolving systems (Witte & Wilson, 2005) are state of the art and will be for a long period of time.

This topic will fill estimated three hours of theoretical online content. Participants should learn about the different global navigation satellite systems and their basic functionality as well as their accuracy and validity under certain circumstances. This knowledge should be applied by selecting and justifying an appropriate system for a given research task.

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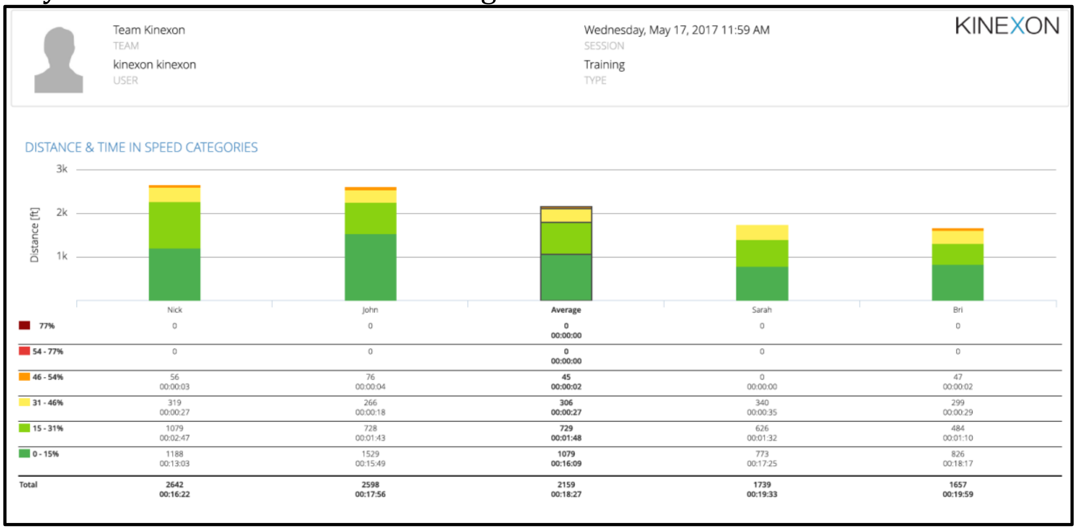
c) LPM systems

Introduction, application and functionality
Cons and criticism

Local **P**ositioning **M**easurement (LPM) systems enable the acquisition of X-, Y- and (in some cases) of Z-coordinates of athletes and sports devices (ball etc.) within spatially limited fields like soccer pitches or athletic tracks. These positions are measured, depending on the system, up to 5.000 times per second with high precision. With this, LPM systems are able to describe and visualize spatio-temporal properties of human movements and sports devices very accurately. By means of exact and high frequent time and location data a couple of kinetic parameters (speed, acceleration etc.), relevant to describe and quantify sports performances, can be directly derived. Figure 1 shows a typical physical analysis sheet of a basketball training session.



	Nick	John	Average	Sarah	Bri
77%	0	0	0 00:00:00	0	0
54 - 77%	0	0	0 00:00:00	0	0
46 - 54%	56 00:00:03	76 00:00:04	45 00:00:02	0 00:00:00	47 00:00:02
31 - 46%	319 00:00:27	266 00:00:18	306 00:00:27	340 00:00:35	299 00:00:29
15 - 31%	1079 00:02:47	728 00:01:43	729 00:01:48	626 00:01:32	484 00:01:10
0 - 15%	1188 00:13:03	1529 00:15:49	1079 00:16:09	773 00:17:25	826 00:18:17
Total	2642 00:16:22	2598 00:17:56	2159 00:18:27	1739 00:19:33	1657 00:19:59

Figure 1: Distance and speed analysis of the smart Kinexon® system (Kinexon, 2018)

The by far largest application fields of LPM systems in sports are match analysis and training monitoring. All 22 players of a soccer match, for instance, can be tracked in real time, and the gathered data is used to evaluate the physical performance (e.g., covered distances, peak speeds, mean intensities; Leser, Baca, & Ogris, 2011) as well as tactical issues (e.g., distances to team mates or opponents, area covered by a team; Lames, Siegle, & O`Donoghue, 2012). By means of accurate location data of all players and the ball, events like passes, shots or duels can be automatically detected (Kapela, McGuiness, Swietlicka, & O'Connor, 2014). In the past these events were gathered by human observation for the purpose of tactical analyses. Positioning data is nowadays also more and more used to model complex parameters like the "pressing index" or the "space control index" (Memmert & Raabe, 2018), which claim to have high validity for success in game sports.

Besides the benefits of tracking data for training evaluation and game analysis, position information is also intensively used in TV coverage, internet and print media. Viewers and readers are informed about the performance data of players such as covered distances, speeds etc.

There are two main types of LPM technologies: radio wave based (electronic) tracking and image/video based tracking:

Radio wave based tracking systems work similar to GPS (Chapter 2.2 b) but locally restricted to the sports pitch or other sports facility. The players wear transponders at their bodies, which answer to a conventional radio signal with an ultra wide band pulse (UWB). The UWB signals are received by basis stations (sensors) mounted around the observation field and are then transferred to a computer. By means of time-difference-of-arrival and/or angle-of-arrival measurements of the UWB signals at the basis stations, the location (x-, y-, z-coordinates) of the transponders can be calculated. These electronic systems have sample rates up to 5.000 Hz, which have to be shared among all active transponders. The accuracy is much higher than for GPS systems (Ogris, Leser, Horsak, Kornfeind, Heller, & Baca, 2012) and some systems also enable good measurements for momentary speeds, accelerations and deceleration. Similar to GPS a full automatic operating mode is possible. Besides the relative high costs, the main drawback of this type of system is the obtrusiveness of the transponders, which prohibited using the systems in many competitions under official rules (e.g., soccer) in the past. Nowadays, as miniaturisation of the sensors prolongs, this restriction is more and more removed.

Image based tracking is performed via calibrated video cameras. Due to no devices are required to be worn by the players, this method can be used for tracking in all game sports in training as well as for competition. Although also moving cameras can be used, most tracking approaches apply fixed cameras, which saves a couple of calibration problems (Beetz et al., 2009). Depending on the size of the pitch 1 to 16 cameras are mounted heightened at a central location or around the sports court. Each camera covers a certain section of the field and is usually calibrated in 2D by means of the field markings. If objects (like players or a ball) move into the calibrated pictures they can be detected, thus assigned to the regarding video pixels. Due to the calibration, the pixel coordinates can be converted into real world coordinates (location on the pitch). This is mostly done via player segmentation from the background (Figure 2) and temporal correspondence. The centre-bottom coordinates of the detected foreground object, respectively the player, are taken as the position of the corresponding player. This method is working very well as far as two or more players are not too close to each other. But, due to the interacting character of game sports, collisions between players occur frequently. These occultations prohibit automatic player tracking down to the present day. In the future, this problem will be solved by a combination of better hardware (higher image resolutions etc.) and smart algorithms, which use specific player features (e.g., hair colour, shirt number) to definitely identify single athletes.

Justification and estimation of course hours

(Automatic) LPM systems are the most important technical innovation for performance analysis in sports in the last decades. This is in particular for (invasive) sports like football, where positioning is probably the most important factor for the overall performance in competition (Kannekens, Elferink-Gemser, & Visscher, 2011). Besides the automatic analysis of physical factors position data also enables tactical analyses in depth – above all in future, when more and more algorithms based on artificial intelligence will be integrated and applied.

Figure 2: Color image and corresponding background image with segmented foreground (VisTrack®)

This topic will fill estimated three hours of online content.

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d) Quasi 3D-Visualisation

Introduction, application and functionality

Visualising key factors of sport performances has become an important part of applied game analysis and for sports broadcasting (Hilton, Guillemaut, Kilner, Grau, & Thomas, 2011), which was the driver of this technology. TV stations nowadays do not only entertain people and send images from sport events but also provide in-depth information of athlete´s and team´s performances (Thomas, G., Gade, R., Moeslund, T., Carr, P., & Hilton, A., 2017). The requirements for proper visualising systems are very high, because they have to handle professional video footage, should work very efficiently (the analyses are often used immediately post-event or even live) and produce attractive graphics (Figure 1). Derived from these broadcast technologies also downgraded systems developed for the use of team sports coaches or analysts. Here, the focus of the visualisation systems does not lie on entertainment but on the assistance of the conveying process. Concretely, coaches can use these tools pre-event to communicate their ideas, plans and strategies how to play (tactical behaviour) to their players and post-event to analyse their own matches and those of their opponents.

Figure 1: Football visualizations with the Viz-Libero® system and available visualization elements (bottom)

Simple visualisation tools using common figures (line, arrow, rectangle etc.) are part of nearly all analysis programmes in team sports (see chapter 2.2 e) Annotation systems). However, this kind of visualisation can only be applied for still pictures and is not considered here. The requirements of smart visualisations, as discussed in this chapter, are the option of pitch calibration and the application in moving images (video). Currently, there are a couple of such systems available on the market (e.g., VizLibero; Piero; Coach Paint).

In fact, all these systems apply a 2D-calibration in due consideration of 3D-objects (players, ball, goals) as basis of the visualisations. First, the colours of the background (pitch/playing field) and the foreground (3D-objects) are defined – similar as it is done for video-based tracking (see Figure 2 in chapter 2.2 c) LPM systems). Second, the video is calibrated to the pitch (Thomas, G., 2007) by means of the playing field lines (Figure 2). In a first step, this is done for one single video frame very accurately. Thereafter, this calibration information is put over all other frames of the video sequence, which is visualised. Due to the calibration all graphical elements (Figure 1) can be visualised foreshortened and are related to the field or objects, even during camera pans and zooms. In other words, and for the example in Figure 1, the striped yellow rectangle stays at the same position related to the pitch and the blue circular markings move accordingly with the players. 3D-visualisations, like shifting players to other positions as they are in real world or producing free viewpoint video perspectives (Angehrn, F., Wang, O., Aksoy, Y., Gross, M., & Smolic, A., 2014) have to be prepared separately. For this, each 3D-object has to be detected in each relevant frame. This detection involves colour definition and the pixel based cutting out of the object. Normally, this work-intensive task is done only for single frames of interest and therefore real 3D visualisations are only used very restricted.

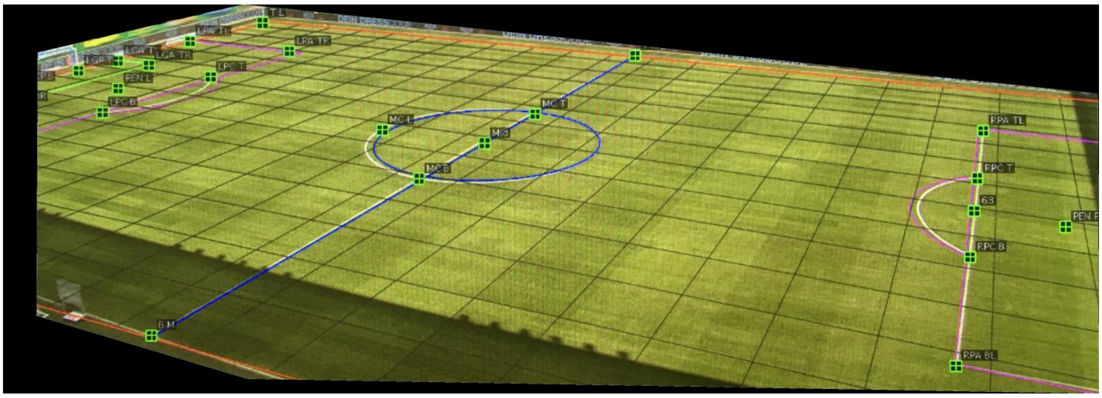

Figure 2: 2D-calibration of the playing field in the Viz Libero® system: once the lines of the field model are aligned to the real world lines in one video image, the software calculates the calibration for each other video image automatically.

Cons and criticism

Due to its origins in the broadcast business and its hence related requirements Quasi 3D-Visualisation systems are very expensive. As of this writing appropriate systems are priced with 5.000 to 30.000 € license costs per year. However, in virtue of the fast technological developments in this area and a massive growing consumer population (smart visualisations get more and more popular by means of media presentations and thus there are more and more coaches and teams who are interested in these systems) significant decreases for the systems are to be expected. However, compared to standard analyses systems the effort to apply Quasi 3D-Visualisation in the everyday training work is very high and time consuming. Therefore, substantial improvements on the side of the visualisation programmes are necessary. In addition, we have to wait and see, if the additional value of Quasi 3D-Visualisation systems compared to conventional standard analysis tools is justifiable.

Justification and estimation of course hours

Without doubt, there is a strong tendency to information dissemination and presentation in our society and thus also in sports. In particular, the young generation (of athletes) claims smart and attractive channels to receive this information. Quasi 3D-Visualisation systems satisfy to some extent this urge regarding team sports analyses.

This topic will fill estimated three hours of online content.

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e) Smart tagging

Introduction, application and functionality

Collecting relevant data of sports performances is a key issue of sports diagnostics in general and of match analysis in game sports in particular. Whilst in the past some rough data was often captured live during a sports competition via simple notation techniques (Hughes, & Franks, 1997), detailed analyses of sports behaviour (e.g., Leser & Baca, 2008) could only be managed by means of post-event observations and by using conventional video and annotation methods (Lames, 1994; Hughes, & Bartlett, 2002). Nowadays smart tagging1 tools enable live as well as post-event analysis of game sports competitions in each conceivable level of detail.

Game analysis software packages using interactive video are available for the mainstream since about the year 2000. Since then a high number of commercial software (e.g., Holzer, 2001), systems for the academic context (e.g., Gabin, Camerino, Anguera, & Castaner, 2012) and freeware tools (e.g., Alastruey, 2008) were developed. This progress resulted in a high standard of functionality and userbility of game analysis systems. Contemporary tagging systems comprise up to four environments: annotation, dashboard, analysis and presentation. All environments are directly linked to each other, which means that all modes access the same data base, and tasks that are done in one environment can be used in another.

At first relevant match data has to be collected in the annotation environment. This can be done a) live without video capture (the timecodes for the relevant events are taken from a live-watch; the tags can be synchronised with a match video post event; the numbers of tags can be used for simple quantitative analyses); b) live with video capture (the tags are directly linked to the appertaining video scenes, which means that immediate video feedback is possible); or c) post-event with an existing match video (detailed video annotation and analysis can be performed without time pressure). For means of data acquisition an observation system is needed, which is manifested as buttons template in the software (Figure 1). Each time a relevant action is observed the corresponding button is pressed. In this way the sequence is stored in a database with a pre-defined pre- and post-time-interval and additionally labelled with descriptors.

The *analysis environment* usually consists of a couple of sub modes (Figure 2) to watch the annotated video sequences. Additionally, the scenes can be qualitatively analysed by experts (coach, analyst) and certain aspects of the performance can be selectively visualised directly in the video by means of drawing tools.

The *dashboard environment* enables to visualise the tags quantitatively by means of tables, charts and other tools of conventional spread sheet software.

The *presentation environment* is a platform to perform video presentations, typically to give classes or hold player meetings.

[1] Basically, "tagging" means to address specific video sequences of match videos and in its wider sense to collect relevant data thereof.

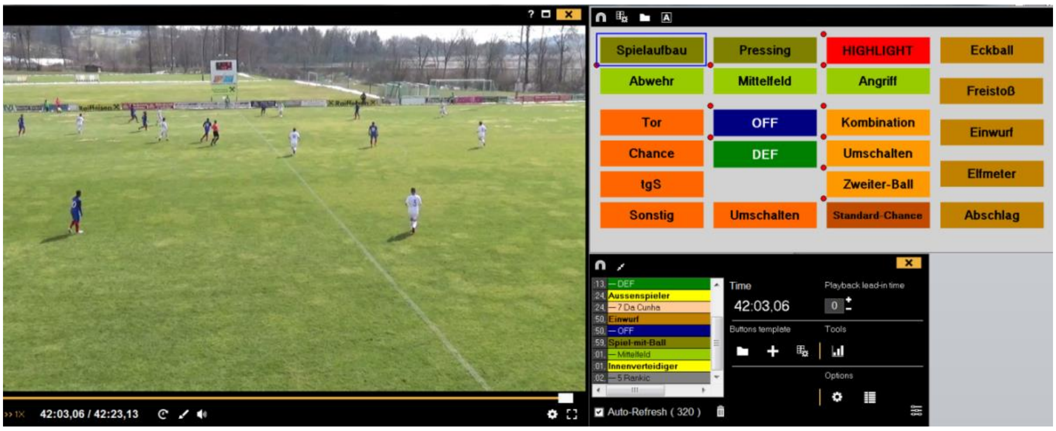

Figure 1: Exemplary buttons template for tagging standard actions in football with the Nacsport® system (buttons with a red dot are descriptors for the main categories)

Figure 2: Analysis environment in the Nacsport® system with timeline- (down), matrix- (upper-right) and visualisation-mode (upper-left)

Smart tagging systems enable comprehensive qualitative video analyses as well as quantitative evaluations. They have functions to give video and data feedback, to share its output with others (in particular with players and within the coaching staff) and to organise and store videos and data for the long-term. Furthermore, they are adaptive to the needs of the user and therefore allow rather rough analysis, if only little time is available, up to in-depth analysis including detailed quantitative data.

Cons and criticism

In addition to a couple of smaller methodological issues, there is one very important aspect that has to be considered by all means but is often neglected in practical applied work: The output of match analyses is at the maximum as good as the quality of the gathered data. Therefore, it is obligatory to test the objectivity of the applied observation system (Hughes, Cooper, Nevill, & Brown, 2003).

Justification and estimation of course hours

Contemporary game sports practice cannot be imagined without match analysis in order to gather feedback for the own performances and to prepare for future opponents. The increasing importance of this area can be documented by a couple of coaches in football, who gained the highest level of their profession based on a strongly related analytical background. Pep Guardiola, Jose Mourinho or Jürgen Klopp, for instance, used video based match analyses as jump starts for their careers but also as indispensable tool for their day-to-day-work. Smart tagging (tools) enable all necessary tasks they needed to perform live and post-match analyses.

This topic will fill estimated three hours of online content.

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3. Data analysis tools

3.1 Life logging

a) Social platforms for data sharing

Introduction, application and functionality

Online social networks and platforms such have extensive reach, and they can be used to receive social support and status in order to enhance physical activity (Cavallo et al., 2012). Social networks and platforms are a fast growing market with steadily increasing numbers of users and participants (Kernot et al., 2013). Sport equipment producers as well as start-ups and sport related companies (e.g. Suunto™, Polar™, Strava™) provide platforms where users and customers can interact with each other and compare their performances (http://www.movescount.com/de/; http://www.suunto.com/Worlds/Training-World/Community-powered/; https://flow.polar.com/; https://www.strava.com/login).

These platforms provide a variety of interaction opportunities with the community. Users can save their performances and compare them with past exercises as well as with other people's performances. A trend over a longer training period can be computed and will be displayed in form of raw data and graphically. Training sessions, routes and routines can be planned with direct access to further useful information (e.g. weather condition, opening hours). Moreover, these platforms provide information on training methods, physiological data and nutrition of other participants who have reached a specific goal (e.g. specific marathon time).

Figure 1: Movescout™ – Average Parameters of users who successfully ran a marathon in 3h 30mins (http://www.movescount.com/de/traininginsights?sporttype=running-duration&metric=marathon&target=12600)

Cons and criticism

Social platforms and networks have big influence on social norms and personal expectations. Thus, these systems hold great potential to influence user's perception and improve individual and public health (Morris et al., 2011). Obesity, one of the most dangerous global disease causes several serious health problems. Since regular physical activity is critical to maintaining fitness, reducing weight, and improving health, social platforms are a key factor through their potential to increase motivation (Consolvo et al., 2006). People with varying social and economic background are in range. Motivational changes can influence users in an individual and private manner (Kernot et al., 2013; Newman et al., 2011).

The growth of social media platforms and networks is not uniformly distributed across age groups. Therefore, health communication programs have to consider their target group and ensure proper messages, pictures and interface. Otherwise the primary function of these systems which is building up a motivating and persuasive environment is corrupted and may have a contrary effect (Chou et al., 2009).
People in social platforms tend to post only trainings they consider successful and show only photos and health parameters, which view their health status and activities favorably (Newman et al., 2011).

Justification and estimation of course hours

The combination of reach and functionality makes online social networks a promising intervention platform for increasing physical activity. Applications and smart phones can be connected to these platforms to update software, share training sessions, communicate with others and get feedback as well as granting access to new training methods.

This topic will fill estimated three hours of theoretical online content.

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b) Running apps

Introduction, application and functionality

Smartphones are ubiquitous tools incorporated in people's daily life routines. In the fitness area, they have become a useful technology for activity tracking (see Chapter 1.1b). The upturn of this field started with the development of running apps (e.g., Martinez-Nicolas, Muntaner-Mas, & Ortega, 2016), which is hitherto the largest sector of fitness based life logging (Meyer, Fortmann, Wasmann, & Heuten, 2015).

The basic principle of running apps is to collect fitness data by a smartphone, which is worn during the physical activity (nowadays, initially for running developed apps can also be applied to many other sports like walking, cycling, swimming etc.). This data is evaluated during and after the activity by a mobile app (Figure 1).

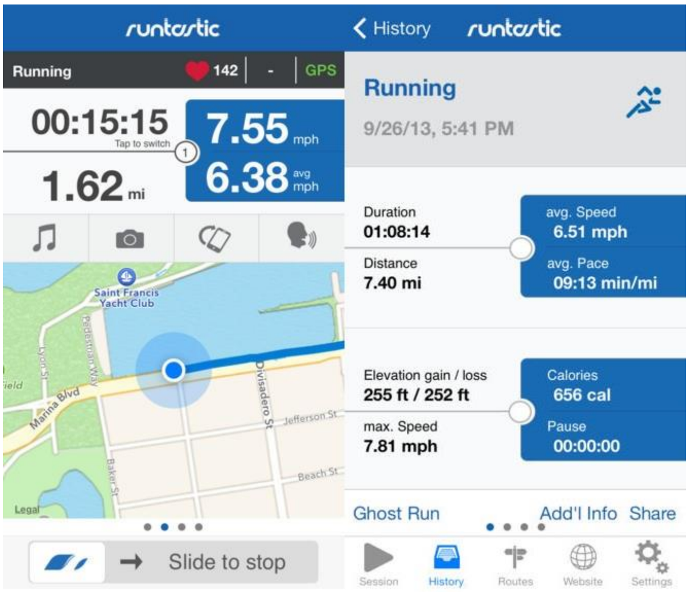

Figure 1: Runtastic® running app user interface and dashboard

Up-to-date running apps are highly functional and expandable, whereby the basic functions are most often free, whereas the advanced functions are part of payable software versions (Reisinger, 2013). Table 1 gives an overview of the most important running app functions.

Table 1: Most important functions of contemporary running apps

Function	Explanation
Export/Import	Possibility to export the running data for the use in other applications (e.g., MS-Ecxel®); import of data from other applications (e.g., training schedule)
Analysis at the desktop PC	Possibility to use the recorded data in desktop applications for more detailed analysis; direct export/import of the data or data transfer to the desktop PC via cloud
GPS recording	Possibility to use the GPS sensor of the device (smartphone)
Footpod assistance	Possibility to link the smartphone to a footpad and to use the footpad data in the app
Individual Training	Possibility to define workouts with time and/or distance targets
Intervals	Possibility to define intervals (duration, length, intensity, recovery, repetitions) and to exercise according to this
Audio-Coaching	Possibility to receive audio instructions or information (e.g., current speed, split times)
Heartrate monitoring	Possibility to use heartrate monitors, which are linked via Bluetooth, ANT+ or other wireless protocols
Statistical analysis on the smartphone	Possibility to evaluate the most important parameters (distance, speed etc.) directly on the smartphone – live or/and post-event
Music player	Possibility to hear/receive music direct via the app during exercising; thus, all other functions are coupled with it (e.g., interruptions for audio instructions)
Maps	Possibility to use street or terrain maps for orientation purposes and to record the track
Training schedule	Possibility to prepare or import training plans and to compare the recorded data with this
Gamification elements	Possibility to use gamification elements (e.g., leaderboard, ghost running, visual story telling) for the purpose of higher motivation or to persevere

Cons and criticism

There is a wide range of different running apps products, which don't require any other equipment than a simple smartphone. Many studies (e.g., Beldad & Hegner, 2018) confirm that they can increase the motivation to continue with or take up physical activity. On the other hand, contemporary running apps also offer many features for advanced runners. Most often they provide functions for scheduling training or expert feedback, and they can be combined with additional hardware like heart belts, smart shirts or footware. The demand of wearing smartphones during exercising is intrusive and disturbing for most of the users. However, special running belts or armlets can reduce this constraint significantly. The most critical issue dealing with running apps is its validity. A couple of studies show big deviations in the output of different products (Bauer, 2013) and also critical values concerning their absolute accuracy (Watzdorf &

Michahelles, 2010). However, the reason for inaccuracies of measured values with running apps may be more an issue of the hardware (smartphone model, sensors) than of the running apps themselves.

Justification and estimation of course hours
Running apps were one of the initial software products, which belong to the field of smart technologies and they are still among the most popular and most used sports apps.

This topic will fill estimated three hours of online content.

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c) Training routines sharing

See 3.1.a)

d) Nutrition sharing

Introduction, application and functionality

Mobile Health (mHealth) has become a very popular area since the introduction of mobile phones. Health and fitness apps have been developed for the tens of thousands for different target groups and use cases (Hingle & Patrick, 2016). The field of nutrition is one particular area of mHealth and is necessary for normal growth and development, maintaining health and well-being, reducing the risk of illness and injuries and also for optimizing sports performance (Capling et al., 2017).

On one hand, the most commonly used dietary assessment method is the so-called food record (FR), where all food and drinks of a person are recorded for a specified number of days. On the other hand, this method seems to generate errors because the people have limited knowledge of the nutrition contents, limited willingness to manually record every meal and are unable to accurately estimate portion sizes (Hongu et al., 2015). With this leading to an underreported energy intake by 4 – 37 % (Boushey, Spoden, Zhu, Delp, & Kerr, 2017).

Therefore, image-assisted and image-based nutrition assessment have been introduced to better manage the above-mentioned limitations. Easier and faster use and better estimation of energy intake should provide a better nutrition assessment for athletes (Capling et al., 2017).

Taking a picture of a food or meal will give basic information like macronutrients, micronutrients, kilocalories, and grams of all the ingredients. There are two different approaches for image nutrition assessment. Firstly, the image-assisted and secondly the image-based approach. The image-assisted approach is for example just an assistance for the FR approach to remember the food, size, and portion to get better results for the energy intake. The latter approach, the image-based, works only with taken pictures of the food.

There are different solutions on how to get data out of this picture (Boushey et al., 2017). For example, Pouladzadeh et al. (2014) use image processing and segmentation to identify food and the user can also manually give information to help the identification process.

As for Zhang et al. (2015), the taken image of the food is compared to a repository of different images of different meals and can therefore automatically detect and recognize food via mobile phones and give nutrition estimation.

Cons and criticism

Due to the fact that this approach only works with images, it is very important to have lots of different pictures of different foods and meals and also diverse angles. Therefore, the downside is that this approach needs good preliminary work and a user who understands how to use the app properly. Different angles and lighting might affect the nutrition estimation from the picture.

Also, it seems essential to support the image-based approach with additional user information to achieve optimal estimation because not all ingredients can be identified with this method and lead to some errors.
At last, the image-based nutrition assessment needs further time, research and high-quality studies to give detailed information about all strengths and limitations. At this time the validity of image-assisted methods seems limited (Gemming et al., 2015).

Justification and estimation of course hours

Nutrition assessment is an important factor for athletes and can make a difference between winning and losing. Accurate nutrition is very complex to achieve due to the influence of many different (sport-) specific factors.
For a sports team, professional dietary assessment is expensive and time-consuming and therefore, undertaken less often (Capling et al., 2017). With the image based nutrition assessment, it is an easier way to get solid information about the consumed foods and is less time consuming than the FR method. With the right app, a good database of images and a professional nutritionist team, athletes will be able to assess their nutrition with only a mobile phone and therefore save lots of time.

This topic will fill estimated one to two hours of online content.

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3.2 Machine learning

a) Simple regression-based systems

b) Feature detection

c) Classification

In the following part, the subitems a), b) and c) will be presented in sum.

Introduction, application and functionality

Machine Learning (ML) has been applied in many different fields of applications over the past few years. It is an essential tool for tasks with a large amount of data to extract major information. Areas like economics and business, scientific applications, and the World Wide Web have all been using the advantages of ML and would otherwise not function properly anymore (Shalev-Shwartz & Ben-David, 2014). All those areas have two things in common. Firstly, large amounts of data have to be analyzed (mostly) in very few seconds and secondly, the amount and complexity of the data prevent it from being explicit programmed. For this reason, ML has been introduced to these areas, to learn from loads of data to improve, describe and predict outcomes in a few seconds. With this adaptivity, ML has a big advantage over explicit programming (Hurwitz, 2018).
In the field of sports science, more and more data from athletes and teams are being gathered and stored. Therefore, it has become an interesting field of research for ML applications as well. More and more valuable information can be analyzed and thereby gather further insight into the sport (Pfeiffer & Hohmann, 2012), training (Novatchkov & Baca, 2013), recruiting/scouting (Ivankovi et al., 2010; Ofoghi et al., 2013; Park et al., 2017; Taha, et al., 2018) and performance testing (Erdogan et al., 2009; Etxegarai et al., 2018; Maier et al., 2018) for organizations, teams and athletes. In addition, organizations, which collect, predict and provide sports relevant data have become popular over the last few years and will have more impact in the future (Schumaker et al., 2010).

The goal of ML is to program a computer so that it is able to “learn” from a given input (experience) and create an appropriate output (expertise). Normally, algorithms are explicitly programmed to solve a specific problem. In scenarios where this is not possible (due to the lack of knowledge or the massive amount of data), the computer has to learn from the data (input), adapt and create an algorithm according to the problem at hand. In this case, to create an efficient algorithm the computer needs a lot of experience (input) to learn from so that the task can be solved as required. Problems might not be able to be identified completely but with the right model and data, a useful approximation should be able to be constructed. In some applications, the data is too complex, and the computer is not able to identify the whole process, but certain patterns and regularities might still be detected and used for further understanding of the underlying problem or task (Alpaydin, 2010).
As described above, data plays an essential role in the process of ML. The learning and prediction performance is affected by the quality and quantity of

the dataset. A learning algorithm is used to gain knowledge about the underlying data, discover, and identify certain patterns or properties (Chao, 2011.). The algorithm can be predictive (future outcomes), or descriptive (knowledge/patterns) or both at the same time and these different approaches need different learning algorithms and learning strategies. Researchers often use different algorithms for the same problem, because there is not always a golden standard algorithm for an explicit task (Shalev-Shwartz & Ben-David, 2014).

Cons and criticism

As mentioned above the dataset is one of the most important factors when using ML. If the quality or the quantity is not sufficient, the results might not be very meaningful. As well as the learning algorithm and learning strategy have to be the right choice for the underlying task or problem. Therefore, knowledge and a lot of work are necessary to get useful insight for the athletes or a whole team. In addition, it is just a mathematical prediction and should not be 100% trusted without hesitation and overthinking.

Other problems might be that sports organizations will not approve the use of ML in sports science because they would rather use traditional ways and therefore ban it.

Another big problem might be that richer/bigger organizations have access to more and better data and analysts then smaller ones and therefore have even more advantages (Schumaker et al., 2010).

Justification and estimation of course hours

ML has been one of the most important developments in the software industry and has found its way into scientific applications as well. In the field of sports science, it is still in its earlier developing years and far from fully utilized but will be more and more essential (Hurwitz, 2018). The data produced by athletes, teams, and games will rise every year, and therefore ML will get more attention and usage. Not only in the field of sports science but also in many other applications ML will be an important future technique (Schumaker et al., 2010).

Estimation

One to three hours. Quick overview (one hour) or more detailed (plus three hours) depends on how much information we want to give the participants about ML.

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3.3 Data analysis

a) Software

Introduction and application
Nowadays everyone can measure many things with different sensors. After measuring there are different possibilities to analyze the collected data with software tools. Today, the smartphone or smartwatch can calculate everything by itself. In this case there isn´t a specific request. However, there is more to read out of the data and tools like SPSS and Matlab will give more details. Capturing and processing them could probably improve the training of an athlete.

Functionality
If the users want more information they have to understand some fundamentals in programming. There are two types of coding. The first variant is very rudimentary and must be written from the ground up (low level). The next one is high level. This means that a lot of functions have to be mastered, which then do not have to be extra programmed. An example would be Matlab (Thyagarajan, 2011). If the user wants to plot a series of datasets he just has to write the command "plot" in front of the dataname. In a low-level program there is to write some lines of code for it. Of course it is to whatever the user wants. Some small applications like using filter for dataset and plotting data play a major role because athletes and trainers are visual. The possibilities are manifold and it is a great advantage to do own studies and process the private data according to own ideas.
In addition to software for data processing, there are also programs for statistical analysis. An example would be SPSS (Tobergte & Curtis, 2013). This can be various things like looking for normal distributions or output of variances (see chapter below, statistics).

Cons and criticism
Good programs like Matlab and SPSS are expensive and in the beginning it is very hard to understand the functionality.

Justification
With the right program it is possible to analyze data in any way and there is a lot of freedom. It is very important in today's world to understand and use software tools. Especially in the field of science, where always-new things are researched, and large datasets are generated, the programs must be mostly adjusted to the own needs. And that can only be achieved by writing the appropriate scripts by the user. The good thing is that several useful open source software is available. A Matlab pendant would be for example Scilab (Stephen, Campbell & Nikoukhah, 2010), and a pendant for SPSS can be PASW.

Estimation
Four hours of content: explain programming, show some basic stuff with an open source program (can extend to six hours).

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b) Statistics (basics)

Introduction and application

Scientific work is important to develop and analyze training protocols to further improve human performance. Therefore, it is necessary to observe daily situations, make concrete assumptions, and to formulate scientific questions and hypotheses. Then, data acquisition has to occur, either on the basis of a literature research or by empirical studies. Afterwards, statistical analysis has to be performed: descriptive and inductive statistics (Zinn, 2010).

Tests of hypotheses and regression models can be run by use of statistical models (idealized assumptions) (Domges, 2014).

Descriptive statistics or explorative statistics means the description of the sample, while with inferential statistics or inductive statistics generalizations from the sample to the population can be made. Using inferential statistics, parameters can be estimated and statistical hypotheses can be tested. Thus, inferential statistics has two subsections: in the first subsection no expectations are met by use of confidence intervals, while in the second subsection concrete expectations are examined using significance tests (Bühl, 2014, Engelhardt, 2016).

Functionality

In the content of the online content, we will focus on descriptive statistics.

With descriptive statistics it is possible to describe properties of the present data, such as central positions, spread, correlations, regressions, and graphical presentations like box-plots ([1]).

Descriptive statistics describe, show and summarize data in a meaningful way so that patterns emerge. There are measures of central tendency, which describe central positions of a frequency distribution for a group of data. Three kinds of averages exist: mean, mode (value which exists most often) and median (value in the middle, 50th percentile). Furthermore, there are measures of spread: range (difference between lowest and highest value), quartiles (25th and 75th interquartile range), absolute deviation, variance (difference between every data point and the mean, summing them up and taking the average of those numbers), and standard deviation (square root of variance) ([2], Domges, 2014). Standard deviation would be best when the data set is unimodal (normal distribution). A low standard deviation means low spread, thus, data are close together (Bühl, 2014, Domges, 2014).

Cons and criticism

Often there is the problem with the adequate sample size. Samples are often not large due to necessary inclusion or exclusion criteria. Thus, there can be blurs in the sample and it will be difficult to draw generalizations from the sample to the population. With descriptive statistics only statements concerning the sample can be made, but no generalizations to other people or objects ([2]).

Statistics is a branch of mathematics dealing with collecting, organizing, and interpreting data and often difficult to understand (Domges, 2014).

Justification

With using descriptive statistics, data can be visualized to understand and interpret them better. Especially in sports, where big data can be generated, it makes sense to (i) process these data to give a fast and precise feedback to athletes and coaches to enhance their performance, and (ii) edit these data for economization of sports data to recognize connections in a fast way (Perin et al. (2018). In high-performance sports, it is important to give a fast and individual feedback to the athletes so that athletes are able to connect the feedback to the previous actions. Therefore, visual illustrations of the collected data make sense (Perin et al., 2018).

Tabulated descriptions (e.g. tables), graphical descriptions (e.g. graphs or charts) and statistical commentary in the discussion of the results can be made to explore the data and to make interrelations visible. Furthermore, large volumes of data can be clarified ([2]). Descriptive statistics are also an important part of machine learning (Domges, 2014).

Estimation

One hour of content to describe and analyze statistics and give some examples on datasets.

References

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c) Signal analysis

Introduction and application

The analysis of signals is the main point in smart sport technologies. It is everywhere. The signal processing comprises all processing steps, which have the goal of extracting information from a received or measured signal or preparing information for the transmission from an information source to an information consumer. The main goal is the acquisition of information about processes, the reduction of data or the processing of signals (Bachmann, 1992).

Functionality

It is distinguished between digital and analogue signal processing. Digital signal processing is becoming increasingly important because it is easier to work with. That means data can be saved directly on a computer and the user can work with the data by filtering and analyzing.

Analogue signals usually require conversion to a digital signal. This happens with an Analogue-Digital-Converter (ADC). After the signal has been processed most of the time, it will be reconverted back with a Digital-Analog-Converter (DAC). This time the digital signal would convert into an analogue signal again.

If a sound is picked up or a camera takes a picture/video, it always starts with an analog signal. The same thing will happen with the most sensors. In an accelerometer for example there is a mass that will be moved by an external influence. The mass is connected with some springs that change their length. As a result, the length and the resistance changes. The measurement tool reads the voltage and saves it into a binary code for processing. After this process, it will give the value of the external force.

Cons and criticism

The complexity of the topic can be a problem and the staff has to be trained specific before a study. In a scientific usage, it is necessary to identify the expected values and the resolution. For example, normal accelerometers have a bandwidth from 0-16 g (m/s^2). Thus, the user has a limit in the resolution. It is a decision between huge range and resolution. In a bigger range the value can start from 0 g and reach up to 16 g, but the resolution is low. If the resolution isn´t enough it is necessary to reduce the range from 0 g to 8 g. That will increase the resolution.

Justification

The benefits of signal analysis prevail the criticism.

It is a very difficult theme but it is important to understand the essential subjects because it is everywhere. That means it is used if a camera takes a picture or a sound is recorded.

Every smart sport technology processes signals to help to improve the daily live. This could be the smartwatch on the wrist that measures the pulse rate, GPS signals, steps and so on. These results can improve the performance of athletes.

Estimation
Four hours of content: There is a lot of basic content concerning filters, Fourier and Laplace transformation.

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4. Innovative Sports Equipment and Technologies

4.1 Smart materials

a) Nanotechnology in sports equipment

Introduction, application and functionality

The term nanotechnology stands for the manipulation of matter on an atomic, molecular or supramolecular scale. Intensive research and development activities in the past decades have led to a broad range of practical applications. In general, nanomaterials may be defined as structures with a single unit size (in at least one dimension) between 1 to 100 nanometers, also known as the so called "nanoscale" (Buzea, Pacheco, & Robbie, 2007). Such nanoparticles were also categorized into groups of allotropes (=different structural forms of the same element) that can result in 2- or 3-dimensional structures based on sheets, spheres or cylinders (figure 1).

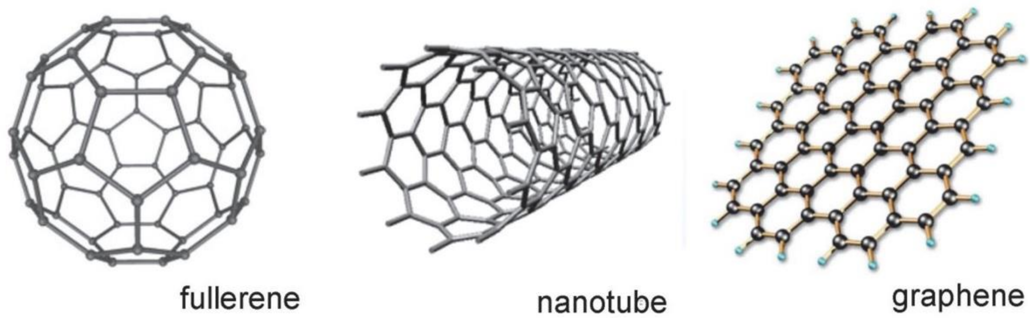

Figure 1: The most common representatives of nanomaterials used in modern sports equipment are fullerenes, carbon nanotubes (CNTs) and graphene (Flowers, 2018).

In the context of sports equipment development, the main focus is related on nanomaterials mostly based on carbon or silicon with unique physical and mechanical properties (Hübler & Osuagwu, 2010) in order to improve selected performance criteria of sport devices. The nanoscale particles were often used as an additive component on or between existing layers of material in composite constructions made of carbon fiber. Because of its enormous physical properties (especially regarding strength, stiffness but also elasticity), existing constructions may be optimized in many ways (figure 2).

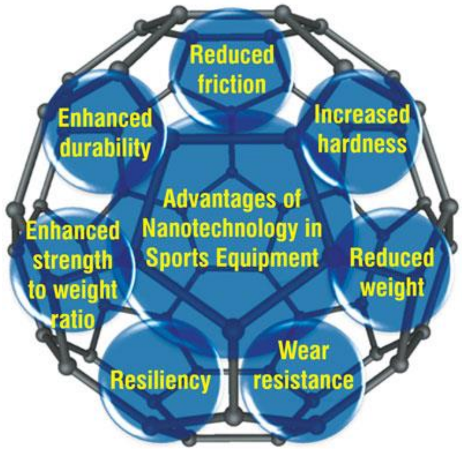

Figure 2: Examples for potential improvements of mechanical properties in new sports equipment constructions when using nanomaterials.

Tennis balls, for instance, can be enhanced by applying nanocomposite coatings inside the core to significantly decrease air diffusion through the hull and so avoid air loss during impacts (InMat Technology). Also, the repulsion properties of tennis rackets can be increased by adding fullerenes or CNTs to the composite constructions of the racket frame (Hyper-MG, Yonex). These additives increase the bonding between single carbon fibers and that allow a reduction of the filling material (usual epoxy resin) which results in light weight rackets while increasing the stiffness of the frame. Lots of comparable examples can also be found in bicycle components (frames, cranks, handle bars), golf clubs (shaft), ski poles, arrows (archery) or hockey sticks (Muir, Dudley, & Peterson, 2011). Other applications deal with the sealing of surfaces in order to make them harder, more durable or smoother (reduction of friction). Golf club heads with harder front surfaces (e.g. drivers) may benefit in the manner of energy transfer when hitting the ball. In winter sports, new developed ski wax (Syntec Race, Holmenkol) can be extended with silicon nanoparticles in the form of powder when ironing it into to the running surface of nordic skis (optimized gliding performance).

Cons and criticism

There are numerous studies where authors warn against having direct contact via the skin with nanomaterials such as CNTs, even more when there is the risk of inhalation. Experiments with animals have demonstrated the pulmonary and dermal hazards associated with CNT exposure. One possible explanation of these effect might be the structural similarity compared to asbestos fibers regarding scale and geometry. Latest findings reveal, that negative effects on human health can be reduced when CNTs are short enough in length.

Justification and estimation of course hours

Nanomaterials have been successfully applied in many sports devices and other sports goodies (e.g. sport textiles). Because of the fact, that potential applications for this new material are still growing, the market potential of nanomaterials is enormous. Several market analysts expect that the global market volume will double in the next 5 years.

This topic will fill estimated up to three to four hours of theoretical online content.

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b) Active fiber composites

Introduction, application and functionality

Sports equipment in general has been refined over many decades including among others new materials, enhanced functionality or improved constructions. In some sports (e.g. tennis, alpine skiing), the devices also need to manage disturbing vibrations occurring during their application in order to enable proper use. One common strategy for damping such oscillations is to use specific materials with improved viscous properties combined with an adequate application (position, orientation) inside the construction.

Ongoing developments of active fiber composites (AFC) materials provide access to new components like piezoelectric fibers for use in modern constructions of sports equipment. One company from Austria (HEAD Sport GmbH, Kennelbach) first introduces in 2000 the use of this technology in tennis rackets (Yoshida, 2002) by developing an active damping system (intellifiber™ technology). About two years later, a similar development has been embedded into alpine skis in order to achieve better stability and user control during skiing on the slope (intelligence™ technology).

Figure 10: AFCs & electronics may be integrated into tennis rackets (left) and also embedded in sandwich construction of alpine skis (right).

Piezoelectric fibers may be used in two opposite directions, first as a sensor delivering actual displacement and secondly as an electrically driven actuator. The principle of action inside the sports equipment is to temporarily store the generated energy caused by bending of the fibers and deliver it immediately back again to the fibers to increase their stiffness. For transferring the mechanical energy (e.g. vibrations after ball impact) into electrical energy (electric charge), an additional electronic (chip) is needed in order to convert the piezoelectric charge into electrical voltage and also to control the timing of activation (optimum: 180° phase shift). Focusing on tennis rackets, this technology might also lead to an increase of power and sweet spot area because of a more effective damping of the racket frame (Kawazoe, Takeda, & Nakagawa, 2010). One of the latest developments using AFCs originates again from the above mentioned company and concerns a further development of the intelligence™ technology (KERS™, Kinetic Energy Recovery System). The main improvement that has been implemented consist of a capacitor which stores the generated energy during ski-flexion (e.g. mid-time of a carved swing). A new version of the electronics then returns the stored energy at the right moment back to the piezoelectric fibers (in the form of electrical voltage) in order to straighten them and support thus the rebound effect of the ski.

Cons and criticism

Literature research reveals a lack of studies dealing with the validation of the concrete implementation of AFCs in sports equipment. Unfortunately, there is no study that investigates the difference of two identical models of tennis rackets or alpine skis with and without the technology equipped. Theoretically, one precarious situation might occur when returning the energy back to the piezoelectric fibers at the wrong timing (improper phase angle ϕ). Rather than being out of phase (ϕ around 180° -> signal canceling), it might happen that the resulted oscillation will increase in its amplitude (ϕ from 0 to 90°, see figure 11).

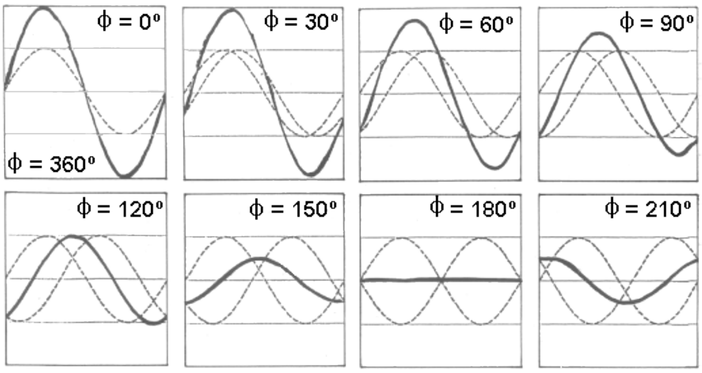

Figure 2: Effect of the addition of two identical sinus waves (one cycle) for different phase angles between the signals.

Justification and estimation of course hours

AFCs have been successfully applied in racket sports and alpine skiing in order to improve damping behavior and stability of the such devices. There is a serious market potential for being implemented also in other sports equipment where either disturbing oscillation is unwanted (e.g. bicycle frames, golf clubs) or increased rebound would be appreciated (e.g. rowing oars, ice hockey sticks).

This topic will fill estimated up to one hour of theoretical online content.

References

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4.2 Sports equipment

a) Shoe laces

Introduction, application and functionality

Shoelaces are used for tying in everyday and sports shoes. With the choice of lacing tightness, number of laced eyelets and special lacing techniques a runner is able to adjust the shoe to his/her individual foot morphology and to optimize shoe fit (Hagen et al., 2010). Research revealed that seven-eyelet lacings showed a significant enhancement of perceived stability, which improves foot-shoe coupling without increasing peak dorsal pressures on the tarsus and therefore no differences in comfort. Higher lacing tightness led to reduced loading rates and pronation velocities (Hagen & Hennig, 2009). Lace loosening might lead to loss of stability and injury proneness. Shoelaces must hence be considered an important factor in comfort and performance in sports shoes.

Numerous no tie shoelaces with different approaches are on the market, promising easy use and prevention from loosening. They are fashionable, colorful, easy to clean and prevent pressure concentration underneath the knot. Silicone laces (e.g. Easy Lace® by Charles Birch, 2018; Hickies, n.a.) have a defined length. They are fixed with clips either to the eyelet (pull & lock design) or like wristbands around two horizontal eyelets. Elastic rubber bands keep constant, adjustable tension over the instep by lock devices (e.g. Lock Laces®, 2018; U-Lace No-Tie Sneaker Laces, 2018; Xpand, 2018) (see figure 1, left) or bumps (e.g. Caterpylaces, 2018; XTENEX®, 2018) (see figure 1, middle). Zubits (2018) are magnetic arrays in different sizes with 7 or 16 lbs holding force to be fixed onto any existing shoelaces (see figure 1, right).

Figure 11: Left: Xpand. Middle: Caterpylaces. Right: Zubits.

Self-tying or self-lacing shoes go one or more technological steps further. The first self-closing shoe without laces was the Reebok Instapump, released in 1989 and still available, selling more than $1 billion worth of units and opening up a new market for novel fastenings (Haworth, 2016). The Powerlace (2018) self-lacing mechanism is activated by the body weight of the wearer (see figure 2, left). The Nike HyperAdapt is equipped with E.A.R.L. (Electric Adaptable Reaction Lacing) technology that electronically adjusts the lacing, pressure and fit to the contours of the foot (Nike, 2018). The most known self-lacing shoe is the Nike Air Mag (Nudd, 2016).

Figure 2: Left: Powerlace. Right: Digisole Smartshoe.

The Digitsole Smartshoe combines several smart technologies in one product: auto-tightening, shoe warming, activity and cushioning sensors, and the integrated smartphone app shows several activity features (Kickstarter, 2018).

Cons and criticism

Research on shoelaces has taken place in the late 2000s, and no recent data on self-tying laces or self-closing shoes could be found. The increased weight of technology has to be taken into account, as well as the price. While no tie shoelaces are very cheap, a pair of self-tying shoes can cost about 250 to 700 €, and the customer cannot be sure if that price justifies the (yet unknown) benefits. The Nike Air Mag was not available through any classical way to increase the hype.

Justification and estimation of course hours

Self-lacing shoes could be a technological breakthrough, because the replacement of traditional shoelaces has long been an obsession of sports shoe industry. In the last few years, this trend has reached unprecedented levels, and hardly a week goes by without a sports shoe being released with some sort of new type of shoelace built into it (Haworth, 2016).

This topic will fill estimated one to two hours of theoretical online content.

References

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b) Compression garments

Introduction, application and functionality

Nowadays, compression garments (CG) are widely used by athletes. First they were mostly used for medical purpose, but their use has become more and more popular in athletes (Duffield & Portus, 2007).

The types of garments available on the market vary widely. It includes those that cover the upper body, specifically the torso and arms in full or part, the lower body beneath the waist, and those that cover specific body parts (e.g. socks, sleeves and stockings) (Figure 1).

Figure 12: Different types of compression garments

This special clothing contains elastomeric fibres and yarns to apply substantial mechanical pressure at the body surface, thereby compressing the underlying tissue. The pressure on the skin and the musculature depends on the mechanical properties of the garment defined by the manufacturer (MacRae et al., 2011).

As a result of different research studies, it was reported that CG enhancing performance (Bringard et al., 2006; Doan et al., 2003), increase power (Wallace et al., 2006) and are beneficial for recovery (Gill et al., 2006; Kraemer et al., 2010). The positive effects are initiated by an improve of peripheral blood circulation and venous return (Agu et al., 2004; Davies et al., 2009; Lawrence & Kakkar, 1980; O´Donnell et al., 1979; Ramelet, 2002; Sigel et al., 1975), an increase of arterial perfusion (Bochmann, et al., 2005) and a reduce of the space available for swelling (Davies et al., 2009). Other purported benefits of compression sportswear are keeping the muscle warm, wicking sweat away from the body to prevent chafing and rashes and stabilizing joints.

The compression sportswear is often made from spandex-type or elastane material. These form fitting garments are used during exercise or during recovery phase. Additionally, it is also commonly worn while traveling.

Cons and criticism

So far little is known about the adequacy of the compression garments regarding pressure variability within and among individuals, maintenance of the applied pressure during an exercise or over the life of the garment and whether any of these points actually influence potential benefits. Moreover, the pressure of different garments varies widely (10 to 25 mmHg), although pressure measurement has become more popular in studies on compression garments in sports (Ali et al., 2010; Trenell et al., 2006).
The beneficial effects of CG still remain a matter of debate in literature. The current body of research is riddled with large inconsistency, especially the beneficial effects on the athletes' performance should be regarded with caution.

Justification and estimation of course hours
Although the beneficial effects should be regarded critical, no negative effects on performance or recovery has been reported. Therefore, compression garments remain a recommended tool for recovery and performance enhancement.

The topic will fill estimated three hours of online content.

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c) Outdoor wear

Introduction, application and functionality

Functional outdoor clothing has several goals: protection against UV radiation, resistance to washing and wear, antibacterial and anti-odor function, optimal fit under changing body shape due to movement and aesthetic demands (Choudhury & Majumdar, 2011). It has to fulfil seemingly contradictory requirements to provide comfort under different conditions: water vapor regulation – breathability and waterproofness, thermoregulation – cooling and warming. In addition, environmental concerns increasingly gain attention among clothing manufacturers and customers (McCann, 2015).

All these goals can only be met by layering, where every layer has its own function and properties: the inner layer next to the skin for tactile comfort and moisture transport, a middle layer for insulation, and an outer shell layer for wind and moisture protection (McCann, 2015) (see figure 1). These layers can be realized by wearing several pieces of clothing, or they are combined into one piece. The inner layer is made from wool or polyester, weft or warp knitted, skin-tight, often containing antibacterial agents such as silver (Sun, 2011). The middle layer is made up of fleece fabrics that seamlessly vary density, loft and breathability in a single garment. It should be lightweight, a little more loosely cut and a compromise of zones which trap still air to insulate and move moisture away from the skin (McCann, 2015). Finally, the outer layer merges windproofness, water repellency, breathability, stretch for comfort and ease of movement. Soft shell constructions may be tailored more closely than fleece, and they allow for novel garment joining and finishing techniques (impregnation) (McCann, 2015). The first and most known Gore-Tex® membrane (Woodford, 2018) is only one of the available technologies (Patrouille des Glaciers, n.a.).

Figure 13: Outdoor clothing layering system.

Comfort is extremely subjective, objective measurements (Kilinc-Balci, 2011) do not always correlate with one's personal impression. Although the human thermoneutral zone for naked people is between 28.5°C and 32°C, this range strongly depends on sex, age, race, body composition and metabolic rate as well as acclimation (Kingma, Frijns & van Marken Lichtenbelt, 2012). Nevertheless, international standards are crucial to make outdoor clothing comparable among manufacturers. For example, water repellency (hydrophobicity) is given in units of mm water column or classified by IP codes (Hypergear, 2018). Special attention is given to the seams, which have great influence on waterproof performance (Ashour, Gabr & Abdel Megeid, 2017). Heat transfer is tested in human wear trials under defined laboratory (climate chambers) or outdoor conditions (Jussila, 2016). According to ASTM E96, cup method is used to test water vapor permeability, where a certain pressure difference is maintained on two sides of the specimen under specified temperature and relative humidity. The result is given in $g/m^2/day$ (Mocon, 2017).

Cons and criticism

The discussion on sustainability and environmental compatibility of functional textiles includes a broad range of topics. Manufacturing processes often entail the use of chemical substances that are harmful to the environment and workers. In addition to ethical considerations, CO_2 footprint of non-renewable sources and long transport routes are discussed (McCann, 2015). Silver nanoparticles (AgNPs) (Reed et al., 2016) and microfibers (Hartline et al., 2016) from outdoor clothing can be found in high alpine areas or in the sea due to washing release. This environmental hazard is a growing yet unsolved problem.

Justification and estimation of course hours

Outdoor clothing is an enormous worldwide market with large economic impact. Figures on sales are needless to mention in order to describe the importance of this segment to manufacturers. The contribution of outdoor wear to the prevention of undercooling and frostbites is undoubted. Technological improvements have led to an increase in comfort and performance in both leisure and professional outdoor sports.

This topic will fill estimated three hours of theoretical online content.

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4.3 Sports facilities

a) Artificial Surfaces

Introduction, application and functionality

Modern sports are often practiced on artificial or synthetic surfaces (such as artificial turf, artificial snow, running tracks, gymnastics floor) rather than on natural ones (e.g. natural lawn, natural snow). The advantages for the athletes are controlled and relatively constant conditions in different places worldwide, throughout the whole court, under any weather conditions (Watterson, 2017), both for indoor and outdoor sports.

Artificial turf first appeared on a major professional sporting pitch as an "innovative" substitute for natural grass in the USA in 1966 and in Europe in the 1980s (Watterson, 2017). Currently used 3rd generation artificial "grass" is made from polyethylene monofilament yarn (Wang, Fleming & Forrester, 2014) on different layers for levelling and drainage (see figure 1, left). Artificial turf pitches can be used throughout the year and as opposed to natural grass surfaces, require relatively little care. On the basis of a useful life of around fifteen years, the costs of the two systems are roughly similar (Schweiger, n.a.). For soccer, FIFA allows only approved pitches produced by licensed manufacturers and tested by accredited test institutes (FIFA, 2015a). These tests are quite extensive, comprising e.g. yarn thickness and density, ball rebound and roll (see figure 1, right), shock absorption and energy restitution (FIFA, 2015b).

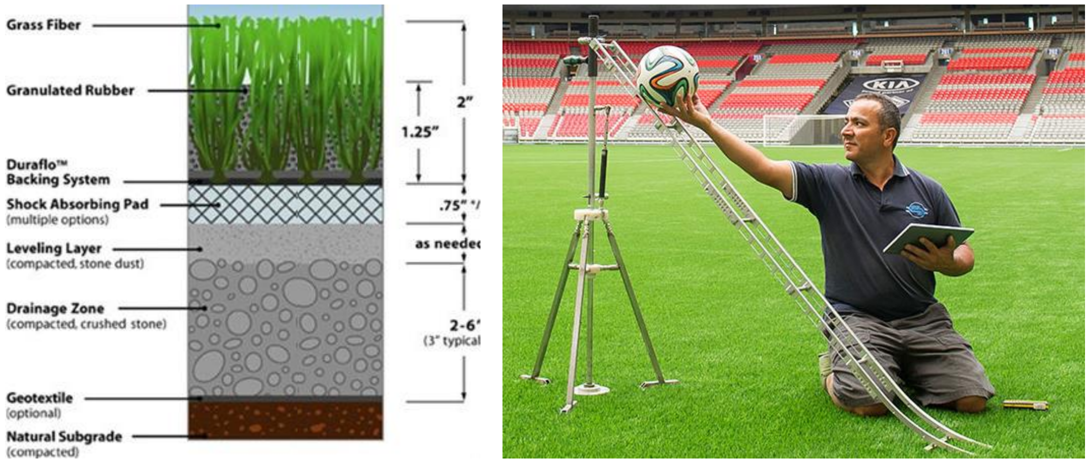

Figure 14: Left: Layers of artificial turf. Right: Ball roll testing.

Players wear turf shoes with hard outsoles and special cleats or spikes for effective traction on artificial turf (Hutchison, 2017). Research on epidemiology describe and compare characteristic types of trauma and overuse injuries by type of field surface (natural and artificial turf). Due to the increased friction between the ground and the players' spikes, players experience more powerful impacts when they collide. In addition, artificial turf deteriorates over time, leading to a significant increase in upper extremity traumata (Fujitaka et al., 2017).

With increasing temperatures and lower snowfall, a steadily rising number of alpine and nordic skiing resorts worldwide relies and depends on artificial snow

(Rixen, Haeberli & Stoeckli, 2004). The water is sprayed into the air through nozzles. At the same time, a mixture of compressed air and water is sprayed through smaller nozzles (see figure 2). These microscopic droplets immediately freeze to form tiny grains of ice, which serve as freezing nuclei, allowing snow to be produced at a temperature just below 0° C (SLF, n.a.).

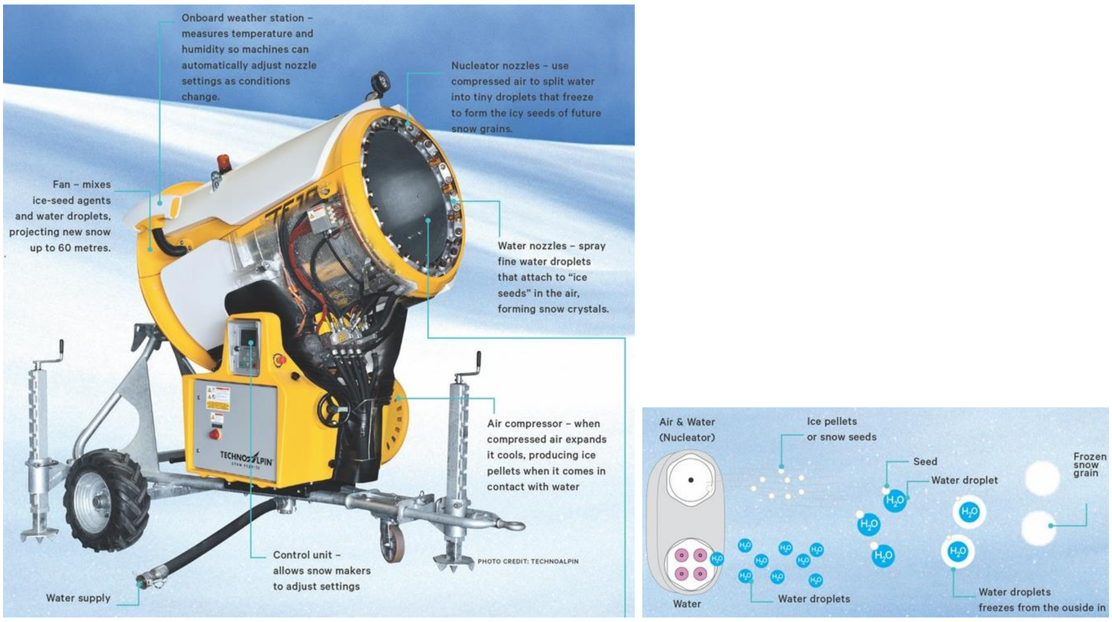

Figure 2: Operating principle of artificial snow production.

Most studies focus on environmental consequences (consumption of water and energy, vegetation) (Rixen, Haeberli & Stoeckli, 2004) rather than on performance or epidemiology issues. Artificial snow with its small snow grain size, high snow density and strong bonding between neighboring snow grains can be associated with aggressive snow conditions (Spörri et al., 2017). While Hasler et al. (2009) found a significantly different number of injuries between old snow and artificial snow, Stenroos and Handolin (2014) state that artificial snow evens out the differences in conditions between the warmer and colder months, which make the slopes safer for the skiers. Therefore, grooming seems to have greater effect than the type of snow.
In gymnastics, floor exercise is performed on spring floors (Sands et al., 2014) designed to reduce bounce. A further development of tumbling tracks are inflatable devices of different sizes, referred to as airtrack. Airtracks are air-filled, double wall airtight fabrics with spacer threads to keep them at a constant distance. In training sessions and schools, they are used more often than the official spring floors due to better impulsion and damping (Jemni, 2018). Even though only one scientific research on motion analysis could be found confirming reduced stress and strain in the lower extremity (Sands et al., 2013), airtracks are supposed to be an excellent resource for acrobatics teaching and learning, mainly due to the easy transport and storage of the equipment (Almeida & Bortoleto, 2016).

Cons and criticism

Initially, injury was the major concern about artificial turf, until research has started looking at possible risks of exposure and uptake of hazardous chemicals. Bases of artificial turf may are made up of crumb rubber from recycled tires – basically environmentally friendly – containing chemicals that might be swallowed by children or inhaled by workers, players or spectators (Watterson, 2017). Rixen, Haeberli & Stoeckli (2004) revealed that on pistes with artificial snow, soil frost occurred less frequently and the beginning of the snow-free season was delayed by more than two weeks. The water for artificial snow which is kept in reservoirs is not available to nature, and it is enriched with additives. The economic costs of snow cannons amortize within 15 to 20 years, yet the future of many ski resorts is strongly limited by global warming (Snajdr, n.a.).

Justification and estimation of course hours

In this chapter, the properties of artificial surfaces for several sports and their testing procedures will be described. The comparison between different artificial surfaces and with natural surfaces as well as physiological consequences will be addressed. Athletes don't always need to newly adopt to the conditions of the respective surface as they are standardized and checked by referees before and injury risks can be reduced in some cases.

This topic will fill estimated three hours of theoretical online content.

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Time estimation of the planned content

Module 1 – Smart devices	
1.1 smart devices	ca. 18 h
1.2 smart textiles	ca. 5 h
1.3 non-wearable technologies	ca. 10 h
1.4 feedback and motivation	ca.10 h
→in total	ca.35-45 h
Module 2 – Motion tracking and analysis	
2.1 single person	ca. 19 h
2.2 team	ca. 13 h
→ in total	ca.30-35 h
Module 3 – Data analysis tools	
3.1 life logging	ca. 10 h
3.2 machine learning	ca.1-3 h
3.3 data analysis	ca. 9-10 h
→ in total	ca.18-22 h
Module 4 – Innovative Sports Equipment and Technologies	
4.1 smart materials	ca. 4-5 h
4.2 sports equipments	ca. 7-8 h
4.3 sport facilities	ca. 3 h
→ in total	ca.14-16 h