SixFeet: An Interactive, Corona-Safe, Multiplayer Sports Platform

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Abstract
The global COVID-19 pandemic left few facets of our lives unchanged, including the possibility to play organised sports. Many gyms and sports clubs had to shut down due to social distancing measures, which resulted in reduced physical activity. Co-located group sports that promote social interaction and fun became almost impossible. This lack of physical interaction combined with social isolation and confinement have shown negative impacts on physical and mental well-being of people (for example, lack of motivation, anxiety, low immunity, low academic performance, negative mood and feelings) especially in children and young adults. Recent research therefore recommends exploring more creative approaches that allow physical activities during a pandemic, especially the ones that increase social interaction and engagement and allow users to share the same physical space. Towards this, we developed SixFeet, a novel digital-physical sports platform that allows its participants to play rigorous, collaborative sports—at a six feet distance. SixFeet ensures that the players are 1.5m away from each other at all times without them noticing it or without them having to worry about the social distancing measures. We developed a prototypical implementation of SixFeet and conducted a pilot study to evaluate its technical feasibility and practicality as well as obtain a first insight into user experience with the platform. Results show that participants never came within 1.5 meters of one another, felt connected nevertheless and were physically exerted. This paper presents the design and architecture of SixFeet, results of the preliminary user study, and a discussion on the versatility of SixFeet in accommodating training for different sports in times of a pandemic.

CCS Concepts
• Human-centered computing → Ubiquitous and mobile computing systems and tools; Human computer interaction (HCI); Systems and tools for interaction design.

Keywords
Sports Interaction Technology, SportsHCI, COVID-19 pandemic, Exertion Games, mental and physical well being, social isolation

1 Introduction
Sports is more than just physical activity. People play sports, for example, to feel socially related, physically fit or skilful [5, 29, 43, 44, 54, 59]. Indeed, there are as many motives to playing sports as there are individual athletes, each having their own unique motivational profile [5, 59]. As such, most people struggled when it was no longer possible to play their favourite sport under the rules and regulations that came with the corona-pandemic.

Although individual physical activities and exercises can still be carried out during a pandemic and when the social distancing measures are in effect, it lacks the social dimension, feeling of togetherness and the positive experiences and feelings one gets during co-located sports activities with peers. Close physical interaction, a key characteristic in many sports, is not allowed with social distancing in play. This renders it difficult to meaningfully engage in many fielding sports, invasion sports, and net and courts sports. Consequently, (adolescent) athletes practised these sports less during the COVID-19 pandemic [45], leaving them less empowered to fulfil their social and physical needs. Indeed, physical inactivity increased during the COVID-19 pandemic [4].

Research shows that physical inactivity and social isolation, due to social distancing and confinement during the pandemic, have shown negative impacts on physical and mental well being of people; causing inter alia lack of motivation, anxiety, low immunity, negative mood, and lowered academic performance [1, 49, 63] especially among children, young adults (aged between 18 and 29) and men [9]. Furthermore, social isolation and lack of physical activity can have long term negative effects on the mental well being and development of social skills among children as they are in a crucial stage of development [51]. Physical activity has been identified as an important clinical target to sustain and improve mental health during the pandemic [7, 21, 42] and research suggests that public health interventions that encourage physical activity especially
among the vulnerable age groups are needed [9]. It is generally recommended that children and adolescents should be active with moderate to vigorous-intensity physical activity or active play for 60 minutes per day, for children of 2 to 5 years, this is 180 minutes per day [49]. However, during a pandemic and with social distancing this becomes a challenge, thus it is required to develop more creative approaches to facilitate these types of physical activities, especially the ones that increase social interaction and engagement and that allows users to use a shared physical space [49].

To promote physical activity and boost social relatedness among (team) athletes and other sports enthusiasts, including children, we developed SixFeet, an interactive, corona-safe, multiplayer sports platform that takes the debilitating ‘six-feet measure’ and turns it into a feature for an interactive exercise platform.

The basic setup of the interactive SixFeet installation consists of 5 LED-stations that are positioned at least 1.5 meters from each other in a circular orientation (Figure 1a). This setup, combined with a ‘smart player allocation algorithm’, enables 2 players to dynamically share a physical space without ever getting within six feet of each other. The system can be easily expanded to accommodate more players. With SixFeet, we strive to ease the transition to normalcy by enriching the possibilities that (team) athletes and sports enthusiasts have to practice facets of their sport (in a social setting) again. In addition, SixFeet could be an effective method for making more vulnerable groups, such as children, participate actively in a collaborative, physically challenging play activity with their peers, thus reducing the social and mental health effects of stay-at-home orders.

This paper presents the details of SixFeet and the preliminary user study conducted to evaluate its practicality: Section 2 positions SixFeet within the state of the art and describes its usefulness in times of a Corona (like) pandemic. Section 3 presents the architecture of SixFeet and describes its ‘smart allocation algorithm’. Details of the pilot study and preliminary results on the system’s ability to maintain appropriate social distancing (together with some initial user experiences) are presented in Section 4. Finally, in Section 6, we discuss how our system can be tailored to fit a range of sports contexts. In doing so, we touch upon player interaction patterns [15]; opponent formats [23, 40, 52, 60] and training physiology [48].

2 Related work

The COVID-19 pandemic pushed our lives further into the digital domain than ever before. Sports was no exception to this. More than ever before, people turned to online / networked forms of exercise to fulfill their sporting needs [45]. The corona pandemic inspired online yoga classes and gyms digitised their classes to accommodate the needs of their clientele. The COVID-19 pandemic also spurred more elaborate and interactive forms of SportsHCI. People turned to exergame platforms (e.g. Wii and Kinect) to fulfill their need for physical activity and e-biking became the vogue [32].

E-biking takes a networked approach to connecting cyclist from all over the world to race against each other from the comfort of their own homes [64].

Playing “sports over a distance” has received interest from athletes and researchers alike (most notably Mueller, who coined the term [36]). Mueller explored many forms of playing sports over a distance and the unique user interactions that it allowed for [e.g. 35–37, 39, 41]. Jogging over a distance is one such an example [41]. With jogging over a distance, two geographically distributed users are connected by audio while running. The audio-feed for both runners is spatialised, meaning the runners can hear the audio coming from ‘in front’ or from ‘behind’ them. Audio is spatialised on the basis of the runners’ relative heart rates. When the heart rate of both runners is similar, it will sound as if they are running right beside each other. When, however, heart rates are dissimilar, the sound will be modulated such that the other runner appears to be running either in front of (higher relative heart rate) or behind (lower relative heart rate) the user. Mueller reported that jogging over a distance sparked a sense of ‘togetherness’ and that the system reduced feelings of discomfort and pain that might be associated with running (alone). Another example of distributed sports is ‘Remote Impact’, a digital physical installation that allows users that are physically distanced to engage in a kickboxing experience [35]. The extremely physical, yet mediated, nature of this installation makes Remote Impact unique. Other interactive technologies that enable distributed players to play sports together include tangible-interface technologies for Tug-of-War [2, 62]; augmented running [17] and mixed reality cycling [64].

All previously mentioned systems enable athletes to exercise together in a corona-safe manner by taking a networked approach. However, for many sports and sport specific scenarios, such a networked approach might not suffice for creating relevant training experiences. Especially in team sports, the interactions between athletes are often rich, fast-paced, subtle and intricate. Space and player-proxemics play a key role in facilitating these interactions. Indeed, “the collective interaction space is emphasised as a forum where decisions made by one participant continually depend on the actions of others.” [13]. Also, the sense of interpersonal ‘closeness’ is co-determined by physical interaction proximity [28]. As such, athletes might still prefer being physically co-located while playing sports. There are a number of systems that, although not expressly designed to maintain a six feet distance, potentially allow for a corona-proof sporting experience. Kajastila et. al. [25, 27] have designed an interactive climbing wall that allows for playing Pong: with each player staying on their side of the climbing wall. Similarly, Graf and colleagues developed iGym, an interactive floor projection system that allows people with motor disabilities to play a motion-based pong-like game with able-bodied peers [18]. In both scenarios however, players share their physical space in a static way. That is to say, players remain on their side of the playing area (just as in, e.g., tennis). Yet, in many sports, especially invasion sports (e.g. basketball, soccer, field hockey and rugby), the physical playing space is contested. Players ‘share’ the space dynamically [31].

While some interactive sports systems exist that allow their users to share the playing field in a dynamical manner (e.g. FitLight [11] and Yalp Memo [61]), these systems do not feature the express ability to keep their users at a safe social distance. More in general, the same goes for interactive playgrounds [34]; interactive sports courts [47, 50]; and other such technologies. With SixFeet, we aimed

The system can be easily adjusted to account for different social distancing norms (e.g. 1 meter, 1.5 meter, ‘six feet’, 2 meters, etc). Throughout this paper, we will use ‘six feet’ to refer to social distancing in general. If we are referring to a specific norm (e.g. 1.5 meters) we will refer to that norm as such.
to create a platform that allows athletes to play sports together in a co-located and dynamical, yet corona-safe, manner.

3 SixFeet - System architecture

3.1 System setup

The SixFeet platform consists of minimally 5 LED-stations that are to be placed on the ground, 1.5 meters away from one another in a circular orientation (see: Figure 1a). The LED-stations are comprised of LED-rings and foot switches that register when a player is standing at one of the stations. With the 5-station setup, SixFeet can accommodate two players. Adding more stations will accommodate more players. When two players have registered at two different stations, the platform becomes active. This is indicated to the players by means of the LED-rings. Each player gets assigned their own colour (e.g. blue and green). Once players have registered, two novel stations light up either blue or green. Players have to get to the station of their colour as fast as possible. A smart allocation algorithm (Section 3.2) makes sure that players will never get within 1.5 meters of one another. Also, the algorithm ensures that player-paths will never cross.

3.2 Allocation algorithm

To clarify how the smart allocation algorithm works, consider the scenario that is illustrated in Figure 1b. Suppose that player 1 (blue) arrives from station 6 at station 8 and that player 2 (green) arrives from station 1 at station 5. The player who arrives first gets assigned a new node first. Player 1 arrives first and gets assigned a new node - e.g. node 7. As the paths of both players are not to cross, the options for the blue player are calculated using the current position of the blue player and the path of the green player. The green path shields off nodes [2,3,4] also, node 8 gets eliminated from the list as that is the node where the blue player is currently positioned. This leaves nodes [6,7]. The algorithm randomly selects one of these two options and updates the list of possibilities for both players accordingly. This way, the algorithm ensures that the players never cross paths or be within six feet from one another. This is affirmed by analysing players’ positions over time during testing, see Section 4.

3.3 Interaction

Users interact with the system by pressing the foot-switch. The LED-rings can take on any (mixed) colour and can be turned on and off. This quality can be used to program for all sorts of interactions. Specific colouring might for instance indicate to a player that they have to perform a specific action at that node; while a specific blink-frequency might tell the player how many times they have to perform that action. Basketball players that use the system might for instance be prompted to perform a cross-over three times in a row when they arrive at a certain station. From the minimal setup with five base stations, the system can easily be expanded to include more nodes. The more nodes, the more varied the distances are that people need to run between nodes. The system can also be played by more than two people. A three-person, corona-safe, setup is already possible with a minimum of 7 base-stations.

Finally, it should be noted that the SixFeet system can be tailored to expressly fit sport specific interactions. Figure 1c shows a SixFeet configuration specifically designed with basketball in mind. All the nodes are positioned at relevant basketball positions (i.e. guard, forward and centre positions). With the constellation depicted in Figure 1c, players can run basketball specific lines, upping the relevance for training. Each player might even be given a basketball so they can dribble from node to node, further promoting representative training design [3]. Similar designs can easily be made for
other sports as well, such as soccer, (field) hockey and rugby. With soccer and field hockey, the games could also include ball passing actions (with feet or stick) while the players are running from node to node.

4 Pilot study: SixFeet and social distancing

To investigate the ability of the SixFeet system in keeping athletes at a safe social distance, we designed a pilot in which we recorded athletes using the system under two versions (‘random’ vs ‘smart allocation’). In the random version, the LED-stations turned on randomly, that is without taking into account the running paths of the individual players. In the smart allocation version, the LED-stations turned on such that player paths would never intersect. We recorded the pilot with a drone camera and analysed the relative distances between the athletes for both the random and the smart allocation version. Specifics of this pilot, along with the results are given below.

4.1 Participants

For the pilot study, four participants were recruited. All participants were aged between 20-25 years and reported to be in good physical condition. The study was reviewed by the ethical committee of the faculty of Electrical Engineering Mathematics and Computer Science of the University of Twente. All participants signed an informed consent form.

4.2 Session design

Participants were divided in two dyads. Any two participants that formed a dyad were required to stem from the same household to comply with the corona rules and regulations. One dyad performed the ‘random’ version, in which subsequent LED-stations turned on randomly; the other dyad performed the ‘smart allocation’ version, in which subsequent LED-stations turned on such that the players’ paths would never cross. Both dyads performed three active sessions of 1 minute (allowing for a total of approximately 70 runs per player between nodes). Between sessions, participants were given half a minute rest, resulting in a work-to-rest ratio of 2:1, typical for High Intensity Training (HIT).

4.3 Setup

Participants interacted with a 6-node circular setup of the SixFeet system. Sessions were recorded using a drone (DJI Mavic 2 Zoom) with integrated lens correction. The drone hovered at a stationary location right above the centre of the installation at an altitude of approximately 13 meters. The camera recorded at a 90 degree angle (i.e., perpendicular to the ground plane). High resolution video was recorded (3840x2160) at 29.98fps. Finally, for later data analysis, a measuring stick was placed on the ground, clearly visible to the camera of the drone.

4.4 Procedure

Before the start of the pilot, participants were informed about the objective of the game. Participants were told to visit as many nodes as possible within the active sessions. After an active 1-minute session, participants were allowed 30 seconds rest. After the pilot, participants were asked about their experiences with the system (see also Section 5.2).

4.5 Data analysis

The video-data from the drone were imported to MATLAB, R2019 (The MathWorks). Using a custom-made script, participants’ xy-positions were manually digitised. For digitisation, every third frame was sampled. The digital coordinates were subsequently transformed to world coordinates by using the measuring tape as reference. To account for slight variations in the recording altitude of the drone, the reference values of the measuring tape were sampled once every second and incorporated in the transformation from digital coordinates to world coordinates. Finally, all the data was smoothed and interpolated using a smoothing spline (smoothing parameter = 0.995). Digitised data was interpolated to match the original frame rate of the drone.

For final analysis we calculated the relative distances between the members of each dyad and counted the number of occurrences that participants got closer than 1.5 meter from each other. Furthermore, we calculated the mean relative distance between the members of each dyad and calculated the probability density function of the relative distances. In doing so, we expressly distinguished between the random version and the smart allocation version.

5 Results

5.1 Social distancing

The xy-coordinates of the participants could be reliably digitised in all of the analysed frames, resulting in the analysis of a total of 14,946 frames. The measuring tape could also be reliably retrieved in all of the frames. We analysed the relative distances between the members of a dyad for the random and the smart allocation version and found that the dyad in the random version came within 1.5 meters of one another 21 times while the dyad in the smart allocation version never came within 1.5 meters of one another (Figure 2a). Furthermore, it was found that on average, the players of the smart allocation version were kept further apart from each other at 4.31 meters than the players of the random version at 3.69 meters amounting to an average difference of 0.62 meters (Figure 2b). Finally, when looking at the distribution of the relative distancing between members of a dyad for both versions, it can be seen that the shape of the curve is similar, but that the position is shifted.

5.2 User experience

After the pilot, participants were informally asked about their experience with SixFeet. Both dyads were positive about the exertion experience, they felt that SixFeet invoked a sense of competitiveness and immersiveness. SixFeet was experienced as physically intense, participants reported to really need the 30 second break in between the active sessions to regain their breath. When informed about the two versions of the system, participants from the random and the smart allocation version all indicated they were unaware that their behaviour was steered by an algorithm. In fact, when...
while the members of the 'random' dyad do so 21 times. Fig-
while respecting social distancing norms. The SixFeet-platform
were surprised and mentioned that the interaction felt rather close.
within six feet of one another over the course of the session, they
we informed the ‘smart allocation’ dyad that they had never been
of the ‘smart allocation’ dyad never come within 1.5 meters of one another,
Dashed lines represent the average relative distance
Figure 2a shows the relative distance in meters between members of a dyad over time
for the random version (blue) and the smart allocation version (green). It can be seen that the members of the ‘smart allocation’ dyad do so 21 times. Figure 2b shows the probability density plot for relative distance for the random (blue) and the smart allocation version (green). Dashed lines represent the average relative distance between the members of a dyad. It can be seen that members of the ‘random’ dyad are on average closer to one another than the members of the ‘smart allocation algorithm’ dyad.

Figure 2: Direct comparison between the random algorithm and the smart allocation algorithm in terms of relative distance between members of a dyad. Figure 2a shows the relative distance in meters between members of a dyad over time for the random version (blue) and the smart allocation version (green). It can be seen that the members of the ‘smart allocation’ dyad never come within 1.5 meters of one another, while the members of the ‘random’ dyad do so 21 times. Figure 2b shows the probability density plot for relative distance for the random (blue) and the smart allocation version (green). Dashed lines represent the average relative distance between the members of a dyad. It can be seen that members of the ‘random’ dyad are on average closer to one another than the members of the ‘smart allocation algorithm’ dyad.

6 Discussion
SixFeet is a simple interactive sports installation that enables ath-
letes to play sports together at a corona-safe distance. It is unique
in the way it allows athletes to dynamically share a physical space
while respecting social distancing norms. The SixFeet-platform
is built on the premise that people can safely interact, in times
of COVID-19 (or any other future pandemic that demands social
distancing), when keeping a six feet distance from one another.
Naturally, the six-feet adage is neither a scientific fact nor an insur-
ance against contracting the corona-virus. While the six-feet rule
is grounded in scientific literature, numerous factors are at play
that influence its effectiveness, e.g. air circulation, time spent in
interaction, virulence of the virus. Even wind and relative humidity
might play a role [10]. Crucial to the present case, the type of ac-
tivity that is performed while keeping a safe social distance might
also be of influence. As such, it is important to note that the SixFeet
platform should not be considered a safeguard against contracting
the coronavirus. Users should always consult the corona rules and
regulations of their government and sports clubs before implement-
ing the system in practice. That being said, the SixFeet platform
might be leveraged to ease the transition to normalcy, from training
under strict corona rules and regulations to training under little or
no corona rules and regulations.

Interestingly, the SixFeet system will not be rendered useless once the corona pandemic is over. In designing the system, we ident-
ified many opportunities for the design of ‘smart sports exercises’
for the SixFeet system. Due to its flexibility, the system can easily
be tailored to fit many sports contexts in a relevant manner. For
example, in Section 3.3, we illustrated how SixFeet might be im-
plemented in a basketball context by adjusting the physical layout
and the number of nodes (see Figure 1c). Many other interesting
adaptations are possible: SixFeet allows for various player interaction
patterns [15], opposition formats [23, 40, 52, 60], physiological
training regimens [46, 48], and the training of different skill do-
mains [8, 12, 16, 20]. Some of which have already been explored in
early play-testing.

In the present contribution, we have explored only the surface
of the system’s versatility. In future research, we aim to investigate
how SixFeet, and other such systems (e.g. SmartGoals [53], Yalp
Memo [61] and FitLight [11]), might be expressly designed to fit
specific training contexts. Along this line, we are interested in
charting the design space that fits such systems [cf. 22, 30, 38] and
systematically sample the design space to arrive at a “suite of games”
[cf. 56] (see [14] and [33] for excellent examples).

To arrive at meaningful suite of games for SixFeet and analo-
gous systems, it is of critical importance that the system and its
applications are appreciative of the task ecology of the target sport
[3]. That is to say, the training context that results from the use of
the system should be representative of the performance context of
the target sport [e.g. 6, 55, 58]. Otherwise, inexpedient behaviour
(as discussed in: [19, 24, 26]) might arise that is detrimental to
match-performance. Representative training design applies to all
levels of training, from bio-energetics to physiology and from motor
coordination to perception. As such, applications for SixFeet and
analogous systems have to be deliberately designed with the target
sport in mind.

The scope of the present findings goes beyond the SixFeet system.
Lessons learned can also be applied to systems such as the FitLight
training system and the interactive Yalp Memo playground. It is
therefore not the LED-stations that this paper is about, rather this
paper is about how a simple and representative training system
can be built from ubiquitous (electronic) components and some
simple programming. With this work, we showed how different
sport specific aspects can be identified and targeted through simple
SportsHCI design.
SixFeet provides a flexible system architecture that can be easily adapted to suit many sports contexts. For future work, we aim to investigate how we can make effective use of this flexibility to design for sport specific interactions and user experiences. The small sample size of our present study did not allow us to make precise statements about user experience, nor did it provide us with enough information to fully explore what different user groups would mean for the design of the system. In future research, we aim to do a full-scale user study in which we aim to more systematically explore different user groups; sports domains [31]; skill domains [8, 12, 16, 20]; opposition formats [23, 40, 52, 60]; and interaction patterns [15], not only for sports but also for play [57].

7 Conclusion

With the SixFeet system, we set out to facilitate the playing of (team) sports in times of corona. We designed a digital–physical training installation and showed its effectiveness in terms of maintaining sports in times of corona. We designed a digital-physical training to do a full-scale user study in which we aim to more systematically precise statements about user experience, nor did it provide us with small sample size of our present study did not allow us to make