RunMerge: Towards Enhanced Proprioception for Advanced Amateur Runners

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Abstract
While amateur running is one of the most popular recreational sport activities, it also produces many injuries, which are often caused by improper technique or shoe choice. In this paper, we present the design and initial evaluation of RunMerge — a mobile application that integrates data from location and motion sensors to give runners a better understanding of their running. With RunMerge, we investigate how technologically enhanced bodily awareness can help amateur runners achieve a better running experience. We present the design RunMerge, and the insights of its user study. Our work indicates that enhanced proprioception (i.e. the awareness of one's body parts and movement) can be beneficial for everyday running training. Finally, we reflect on future work on increased bodily awareness for endurance sports.

Author Keywords
Running; foot sensor; HCI for sports; reflection.

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Introduction
Running is becoming more and more popular, be it as a means to control weight, battle health issues, relieve stress

or simply as a passion. While running is accessible to many and practised without much prior preparation, it is also a common source of injuries. Advanced and novice runners alike develop ailments that are often caused by improper shoe choice or deficient running technique.

Previous research in Human-Computer Interaction (HCI) has addressed various aspects of the running experience. Mueller et al. [3] investigated how technology can mediate the social aspects of running. Knaving et al. [2] aimed to determine the factors involved in designing successful motivation technology for runners. However, a smaller number of researchers investigated running technique and in-run feedback. Notably, Woźniak et al. [5] designed a system that enabled runners to communicate with supporters during races. Runright [4] provided visual and audio feedback about the current running rhythm. Our work is interestingly different from these examples as it specifically aims at preventing injuries and focuses on increasing the runner's awareness of their own body (as opposed to the environment or other people as proposed in past research).

Runners can already collect extensive data about their training using commercial systems. Mobile applications like Nike+[1], Runkeeper[2] or Zombies, Run! [1] aim to support runners by, respectively, harvesting various metrics, proposing workout formats or adding a competitive factor. A remaining challenge for HCI that this work addresses is designing interfaces that help runners understand the gathered metrics.

We propose a design that provides runners with a tool to view data gathered during their running sessions and stimulates reflection on their performance. Our concept is built upon two popular products: Runkeeper, a software tool that logs routes and speed using the GPS of smartphones, and RunScribe[3], a hardware device that dynamically measures the movement and forces exerted on the feet during the run. We use RunMerge to conduct a preliminary inquiry on how runners can reflect on collected physiological data. In a broader context, we aim to understand how increased bodily awareness can enhance the running experience.

Running metrics

RunScribe is designed to collect metrics about running technique. It consists on a bottle-cap-sized sensor that can be mounted on the heel of a running shoe or attached to its laces. By means of three-axial accelerometers, the device generates 9 different metrics that describe the movement of the runner's foot while walking or running. The system uses two sensors, one attached to each foot, to measure their movements separately, allowing a comprehensive analysis of the runner's performance.

The metrics provided by RunScribe[4] consist of: *Contact Time* (duration of the contact between the foot and the ground), *Impact Gs* (which correlates with the ground impact force experienced when the foot strikes the ground, decomposed in vertical and horizontal components),*Step Rate*, *Stride Length*, *Footstrike Type* (part of the foot that strikes the ground first: heel, midfoot or forefoot), *Max Pronation Velocity* (maximum angular rate at which the foot pronates between footstrike and the point of maximum pronation), *Pronation Excursion* (total angular range the foot rolls inwards) and *Stance Excursion* (total range of pitch angular movement between footstrike and toe off, divided in two segments by the point of maximum pronation). All these parameters are

[1] https://nike.com/nikeplus
[2] https://runkeeper.com
[3] http://runscribe.com
[4] http://runscribe.com/metrics/ - Last retrieved in Jan. 2017

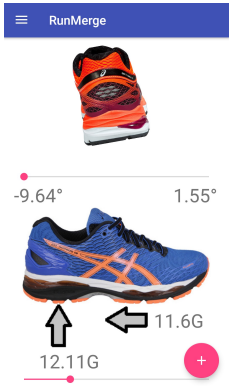

Figure 1: Back view (top) and side view (bottom) of the shoe. Pronation angles and Gs values are visible.

Figure 2: Side view (top) and bottom view (bottom) of the shoe. Pronation and stance angles are visible, as well as Gs values and footstrike colouration.

presented to the user in form of a table with numerical values.

While the metrics are very accurate, they are hard to interpret to users without extensive knowledge of running physiology. With proper interpretation, users could understand which shoes work best for their feet, which training formats cause the most strain and how their technique can be improved. RunMerge is the first attempt to communicate these metrics in a visual way and combine them with data from other sources. We extract the timing, speed and location of the runner from Runkeeper. The combination of both data sources provides a comprehensive description of the runner's performance during a given run.

RunMerge

We began our inquiry by conducting semi-structured interviews about the runner's views on tracking applications like Runkeeper and RunScribe, and attitudes towards enhanced sensing while running. We recruited three runners aged 23, 28 and 29 (two females). One of them was an experienced marathoner, another one ran occasionally and the last one was a beginner when the study took place. Two of them used Runkeeper regularly, one used Nike Plus. A key insight from the interviews was that while runners appreciated the extra data provided by applications and sensors, they remarked that the interpretation and analysis that was often required was a discouraging factor. Consequently, in RunMerge, we aimed to use visualisations which were easy to interpret.

RunMerge models the average measured movements involved all through the foot-to-ground contact time. This allows visualising the typical step of the runner, from the moment the foot strikes the ground until the point it leaves it. The visual representation of this average values consists of a three-fold orthographic projection from the back, bottom and side points of view, and a slider that allows the user to select any given instant of the cycle (see Figure 1 and 2). The user can select which metric is displayed in the animations. The «Stance» option animates only the side view of the shoe, showing the rotation of the foot during contact time. Under the slider, the minimum and maximum angles of rotation are displayed. The «Pronation» option shows the pronation excursion. In this case, only the back perspective is animated, and under the slider the respective minimum and maximum are also displayed. The Footstrike option shows on which part of the foot the runner steps during the run by colouring on the bottom view either the heel, the mid-foot or the forefoot. Depending on the value of the Impact Gs and Braking Gs, the displayed colour goes from green for light stomps, to red for heavy stomps (in this case, the runner should consider altering running technique and/or acquiring special shoes). Additionaly, the G-values are displayed under the side view of the shoe.

User feedback

We gathered impressions of RunMerge from the users involved in our design process. Feedback was collected during semi-structured interviews, and using a questionnaire with five Likert items, quantifying intuitiveness, reaction time of the application, graphical layout, clearness of the data visualization and visibility. The questionnaire gave an overall positive impression, with all answers being at least neutral, but the most relevant feedback was obtained with the interviews.

Intuitiveness of use was the main concern of the participants, stating that some hints or a short tutorial would result on a faster understanding of the application from part of the users. Some particular tasks, like uploading and merging files, were mentioned by the participants as challenging

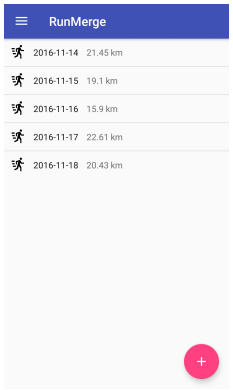

Figure 3: The application presenting an overview over past runs.

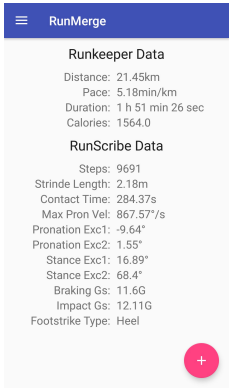

Figure 4: The application presenting a combined view over all runs.

without a previous explanation. Users commented on the responsiveness and clear visual representation of the metrics as a positive aspect of RunMerge. Most importantly, the users found the juxtaposition of the data types useful. Given the pace data provided by Runkeeper, they were able to verify if and when excessive forces were exerted on their feet.

Conclusion

We created an application capable of displaying complex measurements in a graphical way, allowing users to better understand the metrics provided by commercially available applications for runners. Its main advantage over existing mobile applications for athletes is the visual depiction of the metrics. This feature allows users to have a better understanding of their own performance and technique, increasing body awareness. Harmful movements and postures can potentially be detected preventively, long before symptoms or injuries would indicate their existence. The perfecting and optimization of movements and posture to achieve better performance can be aided by RunMerge to a large extent. Of course, the users must know beforehand the ideal or recommended parameters for their body measurements and running style by seeking professional advice.

Overall, RunMerge shows that runners are eager to incorporate new advanced metrics in their training and identify the benefits of extra information. However, the extra metrics need to provided in a form that can be related to the experience of a given run and in line with the data that existing running applications already provide. An emerging challenge is communicating the complex physiological metrics provided by current sensors in a way that is meaningful and actionable to amateur runners.

Future work

RunMerge is only a first approach to this kind of data visualization for sport applications and it leaves plenty of space for enhancement. It is the first step in our inquiry in enhanced proprioception for advanced amateur runners. As excessive forces exerted on the runners feet are a very common cause of injuries, minimising them can have a significant impact on the sport. RunMerge illustrates that complex impact metrics can be combined with other data sources and presented in a reasonable way. In our future research, we will aim to build tools that will empower the runner to reflect on the complex metrics and build a complex understanding of their equipment and technique.

Furthermore, we see an opportunity to further develop the system and enable real-time proprioception augmentation. As the runners welcomed additional foot strike information, it may be possible to provide real-time feedback and help improve running technique or simply prevent users from running in shoes that may cause injuries. In our next study, we will aim to determine which type of feedback could possibly be used without negatively affecting the running experience (cf. [2, 5]).

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