On the Implications of Sense of Control over Bicycling: Design of a Physical Stamina-Aware Bike

Chao-Lung Lee[1], Da Lee[2], Yun-Maw Cheng[3], Li-Chieh Chen[5]*,Wei-Chia Chen[6]
{Dept. of Computer Science and Engineering,
Dept. of Media Design*}
Tatung University
Taipei, Taiwan
{d9806006[1], d9806003[2]} @ms.ttu.edu.tw,
{kevin[3], lcchen[5]}@ttu.edu.tw,
ann770402[6]@gmail.com

Frode Eika Sandnes[4]
Dept. of Computer Science,
Oslo University College
Oslo, Norway
frodes@hio.no

ABSTRACT
Bicycling has become a mainstream activity among the environmental aware generation. Bicycling communities have gradually shown interests in quantitative data of the bicycling experiences such as road roughness, inclination, pollution, etc. Bikers utilize these data to infer the possible stamina cost and quality of surroundings. This supports them to make a better decision. This study assumes that fitness level indexed by stamina cost could enhance a biker's sense of control. The prototype in this paper was developed to provide stamina cost information, which is inferred from the terrain patterns of a biking route. In the system evaluation, participants took a positive attitude toward this prototype and approved the importance of stamina cost feedback. This paper also concluded several key issues about designing the stamina cost feedback system for bikers.

Author Keywords
Sense of control, stamina-aware, bicycling, mobile sensing system, machine intelligence and smart services

ACM Classification Keywords
H.5.m Information Interfaces and Presentation: Miscellaneous

INTRODUCTION
Bicycling is a common form of enjoyment and helps people staying healthy and fit. It is inexpensive and environmentally friendly. Recently, the increased focus on global warming has helped promote the popularity of bicycling. Primarily driven by sport cycling, a range of cycle-based computing technologies and applications have emerged. The variables recorded by such systems include pedal power, road inclination, heart rate, etc. Increasing numbers of recreational bicycling communities have substantial interests in collecting data to quantify various aspects of the bicycling experience in order to reflect fitness metrics among exercise enthusiasts and health sensible individuals (Reddy et al., 2010).

OZCHI 2010, November 22-26, 2010, Brisbane, Australia.

OZCHI 2010 Proceedings ISBN: 978-1-4503-0502-0

A general task performed by bikers is to seek “just good enough” routes, where the quality of the route stems from safety, efficiency, and enjoyment. The route information based on trial and error is then shared between members of a bicycling community. Rogers claims that people act quickly and make “just good enough” decisions by using fast and frugal heuristics (Rogers, 2009). Rather presenting exuberant information, researchers should focus on better strategies for designing technological interventions that support just enough information for making sensible decisions. In addition, different bikers have distinct bicycling proficiency based on their previous bicycling experience. Bikers may be concerned whether they can accomplish a particular route given their individual levels of proficiency and fitness (Rowland et al., 2009). The unknown physical stamina cost through bicycling is the threshold for common bikers. Recently, several projects provide environmental information to complement the human senses and share empirical knowledge of important factors within the bicycling community (Eisenman et al., 2009; Reddy et al., 2010).

In this paper, we assume fitness level to be the key information and indexed according to stamina cost. We attempt to infer the stamina cost of a biking route from terrain patterns, so as to provide a stamina feedback system to enable bikers have the situation well in hand while bicycling a route. Finally, we obtained user suggestions from an evaluation and distilled it into several key issues for designing this application.

RELATED WORKS
Of all common reasons for bicycling, a very high percentage is exercising, followed by recreation, and running errands (Reddy et al., 2010). Bikers perceive bicycling as a mean of participation in physical activity involving fitness and health considerations. Bicycle use also depends on the personal features and experience. Age is an important factor as well as people’s physical fitness. Quality of infrastructure and physical conditions, such as weather and flatness of road, affects comfort (Rietveld & Daniel, 2004).

There are a number of factors hypothesized to directly influence bicycling behavior. Individual factors make for the motivation to ride while social and physical environment factors determine the quality of riding. Land

Terrain	Mean	SD	Stamina Cost	Terrain	Mean	SD	Stamina Cost
Flat blacktop	2.0	0.7	Low	Flat gravel road	3.4	0.7	Medium
Gentle uphill blacktop	3.1	0.9	Medium	Gentle uphill gravel road	4.4	0.9	High
Gentle downhill blacktop	1.2	0.4	Low	Gentle downhill gravel road	2.9	0.4	Low
Steep uphill blacktop	4.6	0.9	High	Steep uphill gravel road	4.9	0.9	High
Steep downhill blacktop	1.7	1.1	Low	Steep downhill gravel road	2.8	1.1	Low
Flat cement road	1.8	0.7	Low	Flat grass road	3.0	0.7	Medium
Gentle uphill cement road	3.3	0.8	Medium	Gentle uphill grass road	4.2	0.8	High
Gentle downhill cement road	1.3	0.5	Low	Gentle downhill grass road	2.4	0.5	Medium
Steep uphill cement road	4.5	0.8	High	Steep uphill grass road	4.9	0.8	High
Steep downhill cement road	1.6	0.9	Low	Steep downhill grass road	2.7	0.9	Medium

Table 1. The results of participants' opinion about stamina cost of a biking route over different terrain patterns via five-point Likert scale, and the level of stamina cost.

use patterns affect travel time, safety, and quality of bicycling experience that may be important to an individual when deciding whether or not to ride (Handy et al., 2008). Pikora et al. proposed a framework to assess the environmental determinants of bicycling. They found that people focus on the elements of route surface, regardless of whether the purpose is recreation or transport. Type of route, continuity, and gradient are critical factors within this framework (Pikora et al., 2003). Stinson and Bhat explored quite intuitive views in their study. Bikers generally prefer flat ground, moderate hills, and smooth pavements instead of steep hills and coarse sand covered surfaces (Stinson & Bhat, 2003).

A few projects use sensors to record bicycling behavior and environmental conditions for the purpose of emerging the information that people desire most. Bikenet fused multiple sensors on a bike that map to the biker experience in the form of bicycling performance, health scale or level of joy. This sensor-enabled bike processed the accelerometer data to measure the angle of inclination, and lateral tilt of the bicycle as the cardinality of the biker's own metrics. HillAngle's enjoyment metric was adopted to infer the degree of difficulty. That also implies physical cost while riding (Eisenman et al., 2009). Biketastic was designed to enrich biking experiences and the route sharing process based on an accelerometer embedded mobile phone. This project tries to refine basic route information and make it more comprehensive and effective to visualize road roughness (Reddy et al., 2010).

Both of the projects mentioned above demonstrate that calibration is a key issue when developing a sensible bicycle system. Different allocation positions will influence sensor data. For example an accelerometer may be tied to the stem or the crossbar, and furthermore, the phone located inside a bag or a pocket, etc.

OBSERVATION AND INITIAL FINDINGS

Several factors influence the motivation of bicycling as mentioned above. Bikers are both concerned with the information about the physical environment and factors that may influence their bicycling experience. The terrains of a bicycling route may be the key information that bikers need. They can estimate if a bicycling experience will be good or not based upon the information. On the other hand, a biker's residual stamina may be an index to assess whether the biker is comfortable. Thus, we suppose that the stamina cost of a bicycling route on terrain is the essential information for bikers.

We present a study about general bikers' perception of stamina cost for bicycling route on different terrain. A survey was conducted by asking twenty participants' opinions (all were male, aged 21 to 27, bike frequency at least once every two months) about the stamina cost of a biking route over different terrains. They presented their opinions based on their bicycling experience. Road surface and gradient are the determinants of terrain patterns which affect biker's opinion (Sener et al., 2009; Stinson & Bhat, 2003). In our initial study, we examined the relationship between twenty terrain patterns and stamina cost. We also used a set of Likert scales to quantify participants' opinion (five-point Likert scale; 1 = very low stamina cost; 5 = very high stamina cost). The results are shown in Table 1 and demonstrate that the stamina cost of smoother road surface (such as blacktop and cement road) is lower than a ride on rougher one (such as gravel road and grass road). Also, a ride on flat ground requires less stamina than gentle hills and steep hills. Although most participants view rides down steep downhill slope as requiring little stamina cost, some participants responded that it may cause psychological stress due to safety concern especially steep grass-covered slope and steep downhill gravel road. Finally we defined different levels of stamina cost for different terrain patterns and mapped it to Likert scale points for participants' opinion.

DESIGN AND IMPLEMENTATION

We developed an iPhone application to collect and analyze three-axis accelerometer data when biking. The iPhone is placed on the bike stem, and the application interprets amplitude of accelerometer data as the road surface texture. Accelerometer data is also processed for measuring the angle of inclination. This system then estimates stamina cost of the bicycling route from derived terrain patterns.

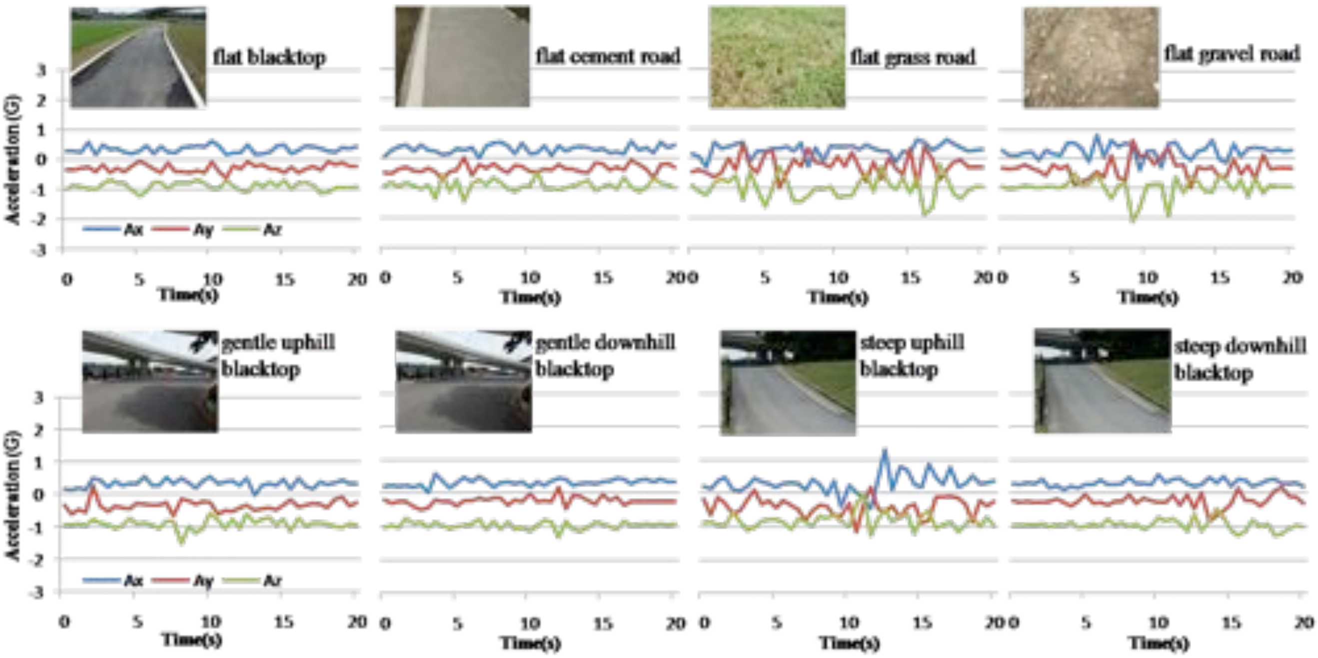

Figure 1. The raw data is generated from the tri-axis accelerometer embedded in a mobile phone that tied on the bike stem. The tri-axis acceleration (Ax, Ay, Az) is measured in time series when bicycling over different terrains.

Data Capture and processing

Figure 1 shows the raw data of bicycling over different terrain. The allocated position of the sensing device is shown in Figure 2. The raw data, by tracing the signature of the ride, with higher variations are rougher road surface and uphill terrain types, and lower variations are smoother road surface and downhill terrain. In comparison with the results between participants' perception and raw data measurements, the raw data value is proportional to the point of participants' perceptions in the aspect of different road surfaces with flat gradients. The higher variation of the acceleration data is accompanied by higher stamina cost in a bike route. In the aspect of different gradients with the same road surface (such as blacktop), this phenomenon is only significant in steep uphill terrain. The system needs to identify bicycling terrain via other features first and then infer the stamina cost.

Terrain classification can help compare stamina cost level with a bike route. In our system, we use various statistics features (such as mean, standard deviation, range, skewness, and kurtosis) and the variations of the tri-axis acceleration as the low level features to estimate terrain patterns. The RSS (root sum of squares (Bourke et al., 2006)) measurements were calculated using the tri-axis accelerometer data for each bike route, and it mapped the variations of tri-axis accelerometer data in a bike route. We experimented with using those low level features process acceleration data that system captured in the real time, and then infer terrain patterns and stamina costs.

Stamina feedback system

We propose two main visualizations of the application, a stamina map and a user state, as shown in Figure 3. Users can browse stamina cost level of each route on the map and their remained level of stamina. They can also setup their initial stamina reservation as the calibration pivots before riding. For example, full strength contains 100% stamina, normal state brings 80%, and fatigue just remains 20%. During biking, this system can determine the biker's location via GPS tracking, and decrease the user's stamina percentage based on the immediate terrain pattern. We also adopted Bikenet's concept that tagging stamina cost level in various colors. Bikers can easily distinguish which routes suit their bicycling proficiency and status. Current resource of stamina information on this map is collected data from pilot experiment and general routes in the urban city. In the future, we will allow the users to upload their sensing data to the database over the Internet.

EVALUATIONS

We invited ten bikers to engage with the evaluation of the system for a short route including several terrain patterns (blacktop, grass, uphill and downhill). Most of the participants have more than eight years of bicycling experience and would ride a bicycle several times per month. A few bikers had used cyclocomputer or GPS

Figure 2. The mobile is placed at bike stem; it senses acceleration data when bicycling, and infers terrain and stamina cost.

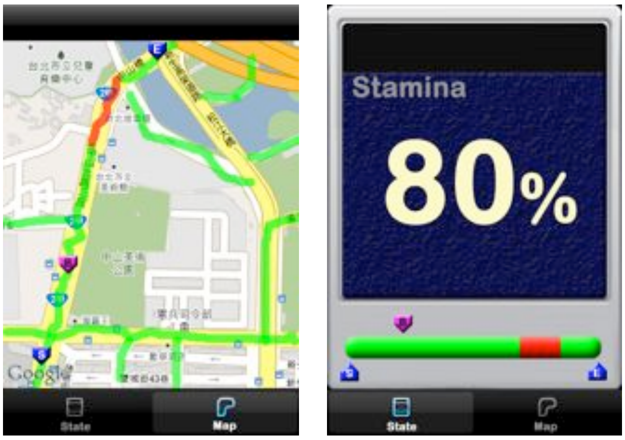

Figure 3. System prototype: stamina map and user state visualizations.

navigation. After a field evaluation, we conducted interviews to evaluate whether the stamina information feedback supports bikers to detect usability issues and acquire general critiques and suggestions.

We found several interesting suggestions in the evaluation process. Users suggested that the system may be more suitable for long rides. This system could be exerted a lot in recreation and sport rather than transport. *"I can't pay attention to the screen, I wish it could support voice reminder."* Users thought that the visual display would be cumbersome while bicycling. They preferred audio interface that does not require visual attention. Furthermore, one of the users asked for a combination of two visualizations, namely a map and user status. *"I need to review the past bicycling situation."* Users wish to have a ride logging mechanism so that they can know the stamina cost history, and the system can give a route recommendation based on these logs. *"I need to know if any stores on this route, as well as weather forecasts so that I can purchase supplies and avoid bad weather."* Some of the users suggested that the supply as the point of stamina relationship, and the weather condition are linked to their own comfort level and safety. They wanted this information to be presented on our system. *"What an interesting application, it's just like a game."* One user suggested this application be sculpted into a game that will promote bicycling activities. Stamina feedback information is in favor with most users. They can take more control of their own physical condition via this system, and obtain a better route section for self.

CONCLUSION AND DISCUSSION

This study was designed to determine the importance of physical stamina cost feedback for general bicycling. We proposed complementary information that gives bikers a better sense of control when bicycling. We intend to augment the human senses and reduce the cognitive effort to achieve better decisions. That is to use the stamina feedback system supports bikers to make a better decision. With this field trial, we explored the relevance of stamina information and sense of control. We also uncovered some issues from the process of the study. ***Sensor positioning can change sensing behavior:*** Accelerometer gets different values based on device orientation and position (e.g. positive or negative value of the axis). It not only makes variance of sensor data, but alters stamina cost. The system should adopt the sensing policy according to these elements. ***Unfavorable environmental conditions may increase stamina cost:*** Heavy rain, strong wind and sunshine, and air pollution produces additional physical burden. ***The visual display is not the only option for the bicycling system interface:*** Substantially, bicycling needs visual attention. General screen interaction may cause user aversion while riding. More and more researches make effort on shifting attention from vision to other senses when interacting with devices. The same concept can be applied to a bicycling system. This study primarily verifies the users' core information needs. Future work includes an in-depth study of these open research questions.

ACKNOWLEDGMENTS

This work was funded by Tatung University, Taiwan (B98-I08-071).

REFERENCES

Bourke, A., O'Brien, J., Lyons, G.M. (2006). Evaluation of a threshold based tri-axial accelerometer fall detection algorithm. In Gait & Posture 2006;26(2), 194-199.

Eisenman, S.B., Miluzzo, E., Lane, N.D., Peterson, R.A., Ahn, G. and Campbell, A.T. (2009). BikeNet: A mobile sensing system for cyclist experience mapping. In ACM Trans, Sensor Netw, 1-39.

Handy, S.L., Xing, Y. and Buehler, T.J. (2008). Factors Associated with Bicycle Ownership and Use: A Study of 6 Small US Cities. In TRB 87th Annual Meeting.

Pikora, T., Giles-Corti, B., Bull, F., Jamrozik, K. and Donovan, R.J. (2003). Developing a framework for assessment of the environmental determinants of walking and cycling. In Soc Sci Med;56, 1693–1703.

Rogers, Y. The Changing Face of Human-Computer Interaction in the Age of Ubiquitous Computing. (2009). In HCI and Usability for e-Inclusion, LNCS 5889, Springer Press, 1-19.

Rowland, D., Flintham, M., Oppermann, L., Marshall, J., Chamberlain, A., Koleva, B., Benford, S. and Perez, C. (2009). Ubikequitous computing: designing interactive experiences for cyclists. In Proc. MobileHCI 2009, ACM Press, 1-11.

Rietveld, P. and Daniel, V. (2004). Determinants of bicycle use: Do municipal policies matter? In Transportation Research Part A 28: 531-550.

Reddy, S., Shilton, K., Denisov, G., Cenizal, C., Estrin, D., and Srivastava, M. (2010). Biketastic: sensing and mapping for better biking. In Proc. CHI 2010, ACM Press, 1817-1820.

Sener, I.N., Eluru, N. and Bhat, C.R. (2009). An analysis of bicyclists and bicycling characteristics: Who, why, and how much are they bicycling? In TRB 88th Annual Meeting.

Stinson, M. and Bhat, C. (2003). Commuter bicyclist route choice: Analysis using a stated preference survey. In Transp. Res. Rec.;1828, 107–115.