MyHealthAvatar: A Lifetime Visual Analytics Companion for Citizen Well-being

Zhikun Deng, Youbing Zhao, Farzad Parvinzamir, Xia Zhao, Hui Wei, Mu Liu, Xu Zhang, Feng Dong, Enjie Liu, and Gordon Clapworthy

University of Bedfordshire, Luton, UK, LU1 3JU
{zhikun.deng, youbing.zhao, farzad.parvinzamir, xia.zhao, hui.wei, mu.liu,xu.zhang, feng.dong, enjie.liu, gordon.clapworthy}@beds.ac.uk

Abstract MyHealthAvatar is a European Commission funded project aimed to design a lifetime companion for citizens to collect, track and store lifestyle and health data to promote citizen well-being. MyHealthAvatar collects and aggregates life-logging data from wearable devices and mobile apps by integrating a variety of life-logging resources, such as Fitbit, Moves, Withings, etc. As a lifelong companion, the data collected will be too large for citizens, patients and doctors to understand and utilise without proper visual presentation and user interaction. This paper presents the key interactive visual analytics components in MyHealthAvatar to facilitate health and lifestyle data presentation and analysis, including 3D avatar, dashboard, diary, timeline, clockview and map to achieve flexible spatio-temporal lifestyle visual analysis to promote citizen well-being.

Keywords: MyHealthAvatar, interactive visual analytics, wearable computing, lifestyle analysis

1 Introduction

The widespread use of wearable monitoring devices and mobile apps makes effective capture of life-logging personal health data come true. Effective collection of these long-term health-status data is valuable for clinical decisions and leads to strengthened interdisciplinary healthcare research and collaboration in supporting innovative medical care. However, the design of a mature and reliable healthcare platform for aggregating these heterogeneous life-logging data is extremely challenging due to heterogeneity of wearable devices connected, multi-dimensionality and high volume of the data set. To our knowledge, the literature survey suggests that no platform is reported to successfully aggregate heterogeneous data from different resources for effective data analysis in a proper and continuous manner. The MyHealthAvatar project [14,13] is a research project that aims to provide a unique interface that allows data access, collection, sharing and analysis by utilising modern ICT technology, overcoming the shortcomings of the existing resources which are highly fragmented. It is designed to be the citizen's lifelong companion, providing long-term and consistent health status information of the individual citizen along a timeline representing the citizen's life. Data sharing potentially provides an extensive collection of population data and offers extremely valuable support to clinical research. MyHealthAvatar believes that healthcare should not only care for patients but also look after the health and well-being of all citizens. It needs to be available to healthy people through maintenance of a healthy lifestyle and the notification of early symptoms. Hence, MyHealthAvatar targets both healthy citizens and patients. MyHealthAvatar offers significant assistance to users by:

- displaying related information in a body-centric view around the avatar.
- allowing simulation via access to the model repositories, supported by the computing resource that is provided by the architecture.
- performing visually assisted data analysis (i.e. visual analytics) to extract clinically meaningful information from the heterogeneous data of the individual and shared avatars, such as the patterns of symptoms, experience of treatments, medicines, self-care guidelines, risk factors etc.

In this paper, we investigate MyHealthAvatar as a life-logging data aggregator of wearable devices and mobile apps for general healthcare visual analysis. We give a comprehensive review of existing life-logging health data collection techniques. Then, the visual analytics components are introduced to effectively analyse health data collected from Fitbit [4], Moves [11] and Withings [17] by MyHealthAvatar. The experimental visual anlytics components demonstrates that MyHealthAvatar successfully records, stores and reuses the unified and structured personal health information in the long term, including activities, location, exercise etc. The data repository provided by MyHealthAvatar has also been successfully applied to several other other projects for effective disease diagnosis, such as in CARRE [2] and MyLifeHub [15].

2 Related Work

This section reviews existing life-logging health data collection tools and technologies, including wearable sensors and devices based health data collection tools, mobile apps based health data collection tools and health information sharing platform.

2.1 Wearable devices for health data collection

Wearable device based health data collection tools traditionally refers to use of medical devices to monitor medical data, such as heart rate, blood pressure, glucose, etc. Recently, the use of wearable devices in life-logging data collection mainly indicates the record of some personal physical activity data. In particular, prior work has shown that wearable sensors can benefit individual patient's health and individual personal fitness. The most popular products are listed below:

- Fitbit [4] provides wearable devices which record steps, distance, and calories, etc. These devices communicate with a host computer using Bluetooth that sends their data directly to a user's account on the Fitbit website.
- Withings[17] is also a high-profile consumer-level activity device providing steps, distance, calories, heart rate, etc. Devices include wristband, watch, scales, blood pressure monitor, etc.
- iHealth Labs [9] offers a range of connected health products : blood pressure monitors, scales, activity trackers, glucometers, body analysis scale. Devices include blood pressure monitor, scales and body analysers, fitness tracker, glucometer, etc.
- Nike+ Fuelband [7] is worn on the wrist and records calories, steps, distance, and Nike's own unit of activity, termed "Nike Fuel". The device connects via USB to a host machine which synchronises the health data to a user's account on the Nike+ website.
- Jawbone Up [10] is also a activity device providing steps, distance, calories. Currently, Jawbone up can only be used with a mobile device, not supporting laptop and desktop PCs.
- The Apple Watch [1] is a smartwatch developed by Apple Inc. It incorporates fitness tracking and health-oriented capabilities as well as integration with iOS and other Apple products and services. The three rings of the Activity app provide a simple visual snapshot of the individual's daily activity, and can help motivate them to sit less, move more, and get some exercise.
- Samsung Gear [16] is a line of wearable computing devices produced by Samsung. The line includes the Android smartwatch Samsung Gear S and the successor S2, and the Gear Fit wristband. They monitor fitness activities including heart rate, steps, activity mode and sleep quality.
- Huawei wearables include Huawei Watch and Huawei Talkband. They monitor fitness activities including heart rate, steps, activity mode and sleep quality. The Huawei Watch tracks movement, activities, heart rate, exercise pattern and visualises the health information. Huawei TalkBand also monitors sleep quality.

2.2 Mobile app-based health data collection

Mobile applications are recently turning out to be a great source of user empowerment in healthcare fields. The most well-known mobile apps are based on observing GPS signal information for tracking user movement activities outdoor, including location, speed and distance. Some mobile apps explore the further use of mobile phone sensors for improving accuracy of tracking physical activities and observing other types of health information. Currently, the type of health data collected by mobile applications includes location, distance, speed, calories, heart rate, emotion and other manually recorded health data.

- Moves [11] is a very popular app for fitness and activity recording. Moves automatically records the step number and location of the user and calculates calories burned and distance of movement. It automatically recognises the

activity type, such as walking, running, cycling, transport, etc. The user can either view the distance, duration, steps, and calories data on the mobile phone or export the data from the Moves server. The daily activities are visualised in a storyline in the app. The daily route can be visualised on the map.
- Google Maps Timeline [7] provides similar functionality to the Moves app. It is also based on the use of GPS to record users' path, speed, distance and elevation while they are walk, run, and bike or do any activities outside. The daily tracks can be shown on the map.
- Endomondo [3] is a GPS-based mobile application for tracking route, distance, duration, split times and calorie consumption. It can record a full history with previous workouts, statistics and a localized route map for each work out. Another important feature of Endomondo is to incorporate community and allow users to challenge friends and share results.

The main drawback of GPS-based mobile apps is a short battery longevity and only available for outdoor tracking. This might limit accuracy and continuities of life-logging captured personal activity data. Cardiio and Emotionsense are both research based mobile apps, which support only particular mobile system and have no API documentations for further development.

2.3 Health information sharing platforms

Lastly, health information sharing platforms have come with the emergence of web-enabled healthcare services. Due to the great evolution of Internet technology, this is emerging as a new healthcare delivery trend. These web-based healthcare platforms provide a multi-functional server for users to store, manage and and make basic visualisation of health data from various third party devices.

- Microsoft HealthVault [8] is intended to enable users to gather, store, and use and share personal health information through many medical devices. It enables a connected ecosystem with privacy and security-enhanced foundation including more than 300 applications and more than 80 connected health and fitness devices.
- Fluxtream [5] is an open-source non-profit personal data visualisation framework to help the users make sense of their life and compare hypotheses about what affects the well-being.
- MyFitnessCompanion [12] is another healthcare platform for users to manage their personal health data, including metrics like weight, heart rate heart rate variability (HRV), blood pressure, food intake, blood glucose, insulin, asthma, etc. The functionalities are highly similar to Microsoft HealthVault. It has a real-time visualisation mode, which keeps track of and visualise all user measurement with simple time graph and can share these graphs with others.

Most of the health data collection devices, apps and health data repository platforms only provide very basic visualisation of the data they collected or imported. They lack a visualisation and data analysis strategy on a systematic level, especially for analysis of wide time range data from heterogeneous sources. In addition, the employment of user interactions have not seen being widely studied in data visualisation and analysis in those applications. In contrast, MyHealthAvatar provides standalone components as well as integrated views for interactive visual analysis of personal health and lifestyle data from multiple heterogeneous data sources.

Healthcare has been an important research and application field of data analysis and visualisation for several decades [19]. Behind healthcare visual analytics, much of the focus is on the visualisation of electronic health records (EHRs). [18] gives a detailed review of the related work, categorising by individual patients or group of patients. [25] also presents a recent review of innovative visual analytics approaches that have been proposed to illustrate EHR data, including [22,24,27,21,26,20], etc. .

Personal health information has been increasingly collectible and accessible in the information era. With the trend of "predictive, preemptive, personalized and participative" healthcare [23], more personalised data is desired for predictive analysis of medical care. Valuable lifestyle patterns can be discovered by analysing the personal data collected by sensors and apps. Together with the clinical information that has long played the major role in health and medical decision making, this information can introduce more added value for health monitoring and medical decision making.

MyHealthAvatar can not only directly access personal health and lifestyle data from devices such as Fibit, Withings, but also analyse the data to extract high level lifestyle data. Together with appropriate models, MyHealthAvatar aims to provide personalised health monitoring, analysis and risk management based on multiple heterogeneous data sources, which is a key difference from the existing health data sharing platforms or healthcare visual analytics systems.

3 Interactive Visual Analytics Components

MyHealthAvatar provides several web-based components for interactive visualisation and analysis of personal health and lifestyle data, including 3D avatar, dashboard, timeline, diary, clock view and map. Lifestyle, health, fitness and medical data are inherently time dependent. To visualise time-varying data, linear and radial layouts can used and user interaction is highly desired. A timeline is a linear visualisation of data spanning a long period while the clock view uses the common clock metaphor to interactively visualise daily events. A calendar is another common layout to visualise human-related events. To visualise spatio-temporal data, MyHealthAvatar uses the map and integrates the clock view with the map. A calendar-like diary is also provided for activity data input, edit and planning.

3.1 Dashboard

There are many components and data that can be accessed by the user from the web-based MyHealthAvatar portal. However, as there is a variety of data sources and data types, it is very difficult for a user to grasp an overview with important notifications from the scattered health status information. To present the user a quick overview of their health status, MyHealthAvatar provides a dashboard as the front page. The dashboard provides a summary of the user's latest health status and may present important notifications. It may include several simple visualisation components to depict data for a relatively recent period. Figure 1 shows the example dashboard with data tiles, map and a timeline. The user can interact with the map and the timeline to obtain more detailed information.

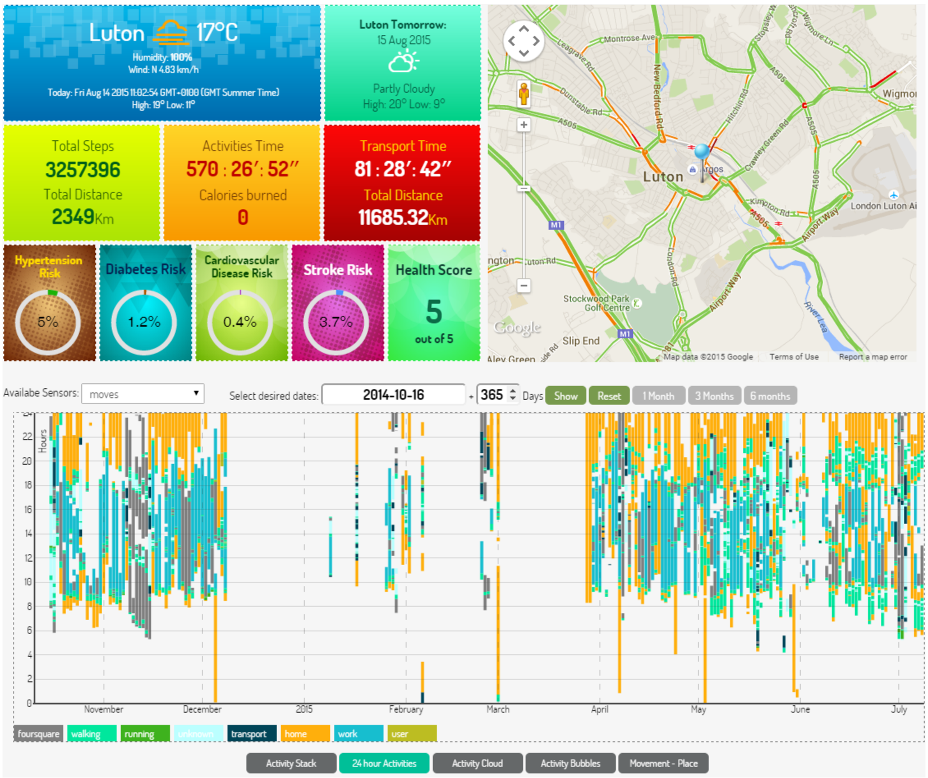

Figure 1. An example screenshot of MyHealthAvatar dashboard

3.2 Diary

MyHealthAvatar provides health data collection, storage and access to end users. The data can either be automatically collected or manually input. For lifestyle and health tracking, the data are often time-dependant, especially date-dependant. A natural form of date-based data organisation, display and editing is a calendar, which is a traditional way to visualise daily events. In MyHealthAvatar, a calendar-based diary is used for daily data display as well as daily event input, editing and planning.Figure 2 shows an example view of the calendar with the event editor. The calendar displays a brief summary of the fitness data such as daily steps, walking and transportation distance, as well as calories burned. With the event editor the user can add events, providing the start and end time, location, and detailed descriptions. The user can add tags for events to facilitate event categorisation. The user can plan by adding events. The events and planning will be shown in the calendar.

3.3 Timeline

A timeline is a traditional method to visualise time-varying data and events in a linear layout. Compared to a calendar, a timeline is more suitable for visualising continuous variables which cover a relatively long period, such as health indicators and medical measurements. Activity events which are time dependent can also be shown in a timeline if a longer time scale is desired to view daily activity events and activities. In the current implementation, the timeline supports interactive visualisation of Fitbit/Withings sensor data as well as Moves data. There are five different visualisation styles including activity stack, 24-hour activity, activity cloud, activity bubbles and movement-place. Activity stack shows activities directly on the timeline in a form similar to stack bar charts. A 24-hour activity organises the activities on a daily basis for easier comparison of daily activity changes. The activity cloud uses concentric disks of different radius to represent the activities; activity bubbles use bubbles of different colour and radius. Movement-place shows the movement and place in the user's Moves data.

In addition to interactive time period selections and zooming, the timeline supports interactive filtering and automatic clustering of events as the number of events may be too large for web-based applications. Figure 3 shows an example of daily activity events visualised in a timeline.

3.4 Clock View

For daily activities, timeline provides visualisation over a relatively long period. Interactive timelines can provide zooming to smaller scales. However, the linear layout may make it difficult for the user to understand and compare daily events. A fine-grained view of activities within one day is better visualised in a radial layout. A natural, real-life way of radial daily time representation is the clock. MyHealthAvatar uses a similar radial layout called ClockView to visualise daily events. Movements and places from Moves data are visualised in the radial layout. Activity types are marked by icons and colours. When the user hovers the mouse over the icons more detailed information will be displayed, as shown in Figure 4.

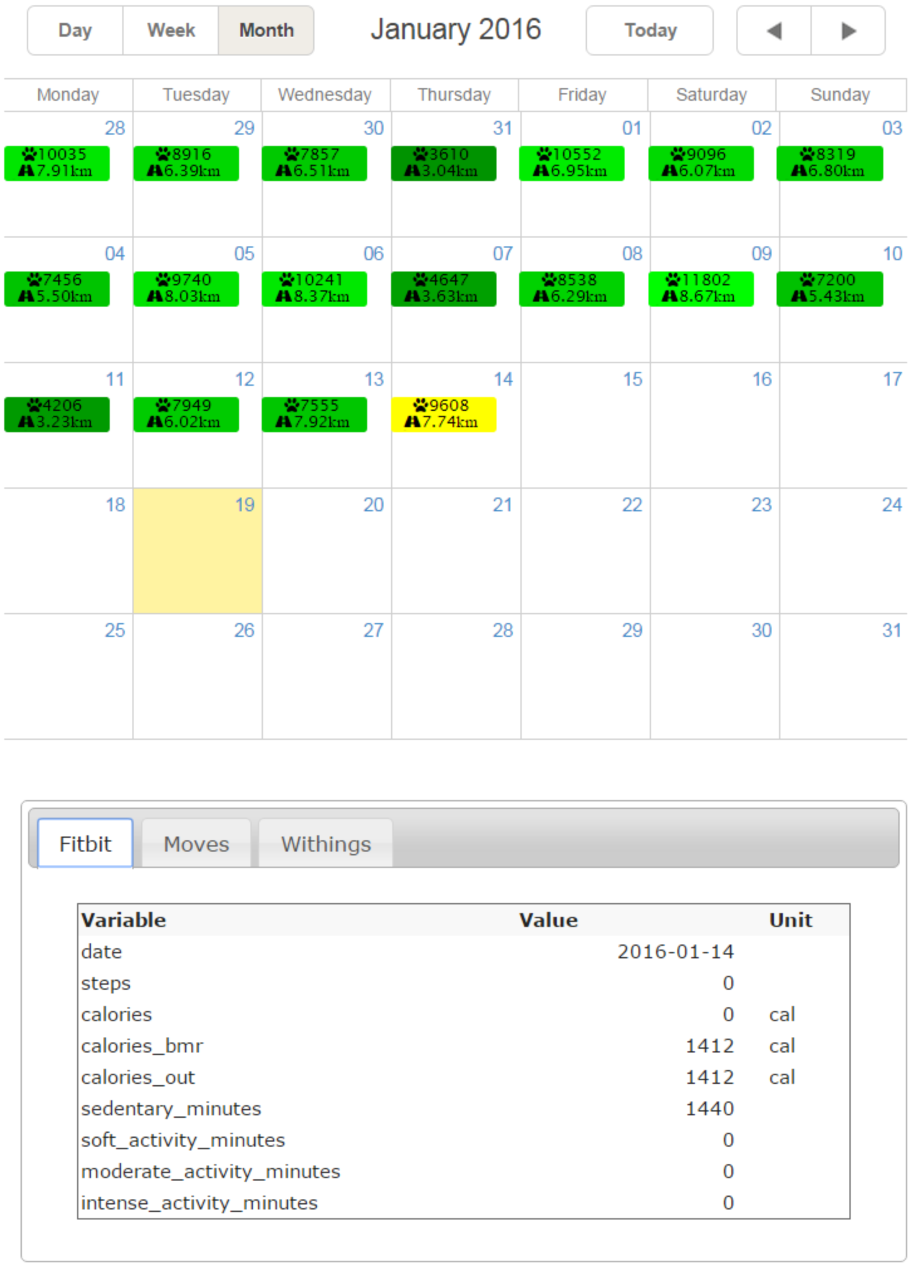

Figure 2. An example view of the diary and information panel

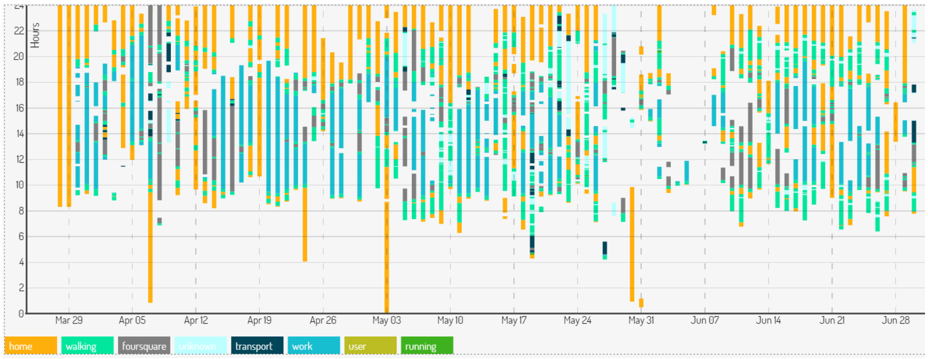

Figure 3. A timeline view of daily events in a 24-hour style

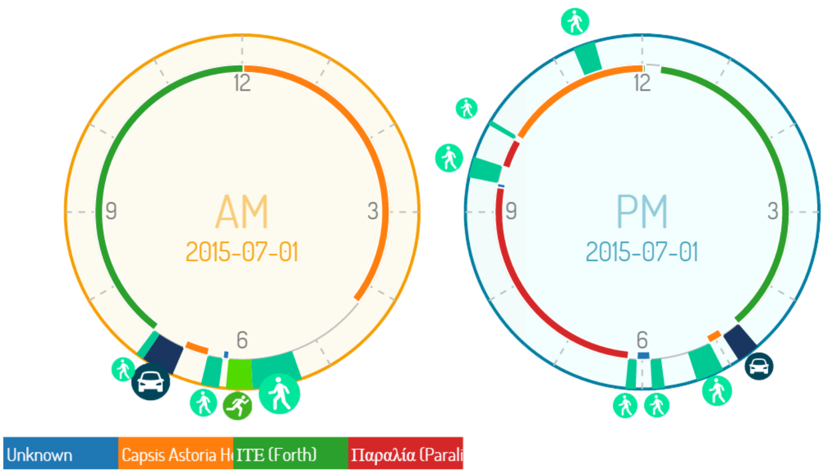

Figure 4. A ClockView example

3.5 Map

While dairy, timeline and clock view are largely designed for visual analysis of temporal data, they can hardly be used to visualise spatial locations. A map is a natural choice to provide intuitive spatio-temporal visualisation and analysis of the user's locations and routes for better understanding and knowledge discovery of the lifestyle. The map implementation is based on Google Maps [6]. Currently, in MyHealthAvatar the map is used for visualisation and analysis of the Moves data only but it is capable of supporting other location-sensor-based apps.

In addition, MyHealthAvatar uses an integrated view which is called Life-Tracker to visualise and analyse events and activities, including diary, map and clock view, as shown in Figure 5. The advantage of this compound view is that it provides integrated spatio-temporal visualisation and analysis. The page itself provides the user an extensive view of data collected from different sources and the user does not need to refer to multiple pages to view and analyse related spatio-temporal data collected and stored on the MyHealthAvatar platform.

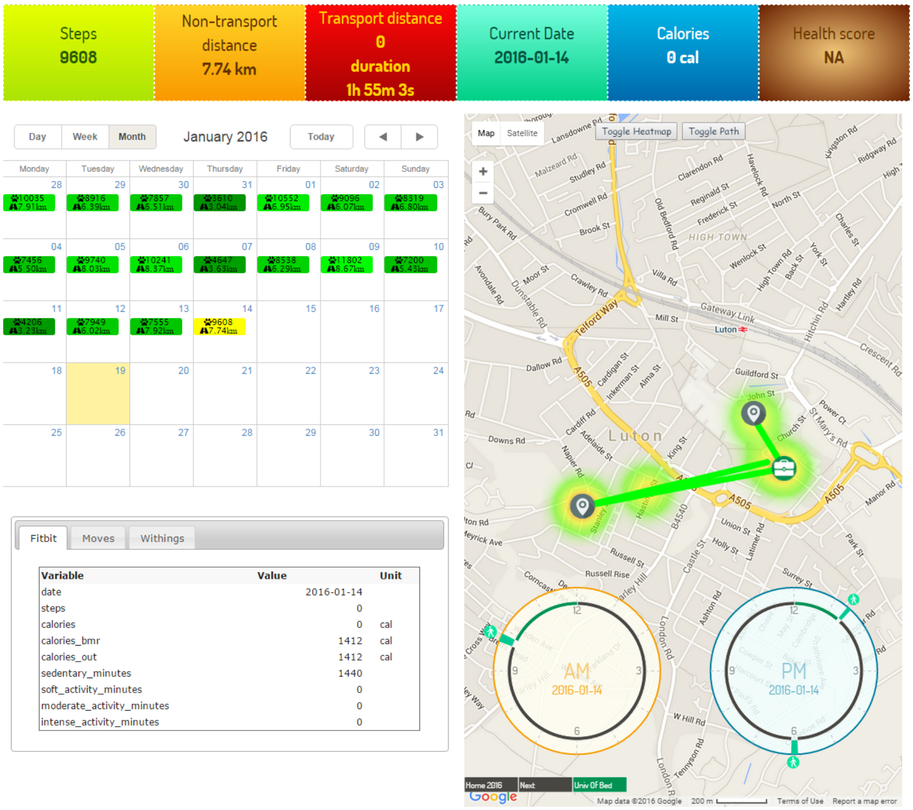

Figure 5. An integrated view of diary, map and clockview

4 Conclusion and Future Work

MyHealthAvatar aggregates lifestyle and health data from a variety of heterogeneous data sources to promote a citizen's lifetime well-being. It is extremely challenging for citizens, patients and doctors to view, utilise and understand these data without proper visual presentation and user interaction. To meet this challenge, MyHealthAvatar provides interactive visual analytics components to facilitate health and lifestyle data presentation and analysis, including 3D avatar, dashboard, diary, timeline, clock view and map. These components can be integrated to achieve flexible visual analysis of spatio-temporal lifestyle data. The current visual analytics work in MyHealthAvatar is only designed for a single user. In the next stage, MyHealthAvatar will focus more on data sharing among multiple users. How to effectively visualise data sharing and shared data will be more of interest. Consequently, interactive shared data visualisation and analysis will be the next-step work.

Acknowledgments MyHealthAvatar project is funded by 7th Framework Programme of European Commission - ICT under agreement of FP7-ICT-2011-9. MyLifeHub project is funded by EPSRC under grant EP/L023830/1. CARRE project is funded by 7th Framework Programme of European Commission - ICT under agreement of FP7-ICT-611140. We would like to thank the European Commission and EPSRC for the funding and thank the project officers and reviewers for their indispensable support for both of the projects.

References

1. Apple Watch. http://www.apple.com/watch/, accessed: 2016-01-19
2. CARRE Project. http://www.carre-project.eu/, accessed: 2016-01-06
3. Endomondo. https://www.endomondo.com/, accessed: 2016-01-20
4. Fitbit. http://www.fitbit.com/, accessed: 2016-01-06
5. Fluxtream. https://fluxtream.org/, accessed: 2016-01-06
6. Google Maps. https://zygotebody.com/, accessed: 2016-01-06
7. Google Maps Timeline. https://www.google.com/maps/timeline, accessed: 2016-03-10
8. HealthVault. https://www.healthvault.com/, accessed: 2016-01-06
9. iHealth. http://www.ihealthlabs.com/, accessed: 2016-01-06
10. JawboneUp. https://jawbone.com/up/, accessed: 2016-01-20
11. Moves. https://www.moves-app.com/, accessed: 2016-01-06
12. myFitnessCompanion. http://myfitnesscompanion.com/, accessed: 2016-01-20
13. MyHealthAvartar Platform. http://www.myhealthavatar.org/, accessed: 2016-01-06
14. MyHealthAvartar Project. http://www.myhealthavatar.eu/, accessed: 2016-01-06
15. MyLifeHub project introduction. http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/L023830/1/, accessed: 2016-01-18
16. Samsung wearables. http://www.samsung.com/us/mobile/wearable-tech, accessed: 2016-01-19

17. Withings. http://www.withings.com/, accessed: 2016-01-06
18. A. Rind, T. D. Wang, W.A.S.M.K.W.C.P., Shneiderman., B.: Interactive information visualization to explore and query electronic health records. Foundations and Trends in HCI 5(3), 207âĂŞ298 (2011)
19. Chandan K. Reddy, C.C.A.: Healthcare Data Analytics. Chapman & Hall/CRC (2015)
20. Gotz, D., Stavropoulos, H.: Decisionflow: Visual analytics for high-dimensional temporal event sequence data. IEEE Transactions on Visualization and Computer Graphics 20(12) (2014)
21. Monroe, M., Lan, R., Lee, H., Plaisant, C., Shneiderman, B.: Temporal event sequence simplification. No. 2 (2013)
22. Plaisant, C., Mushlin, R., Snyder, A., Li, J., Heller, D., Shneiderman, B., Colorado, K.P.: Lifelines: Using visualization to enhance navigation and analysis of patient records. In: In Proceedings of the 1998 American Medical Informatic Association Annual Fall Symposium. pp. 76–80 (1998)
23. Shneiderman, B., Plaisant, C., Hesse, B.W.: Improving health and healthcare with interactive visualization methods. IEEE Computer 46(1), 58–66 (2013)
24. Wang, T.D., Plaisant, C., Shneiderman, B., Spring, N., Roseman, D., Marchand, G., Mukherjee, V., Smith, M.: Temporal summaries: Supporting temporal categorical searching, aggregation and comparison. IEEE Transactions on Visualization and Computer Graphics 15(6), 1049–1056 (Nov 2009)
25. West VL, Borland D, H.W.: Innovative information visualization of electronic health record data: a systematic review. Journal of the American Medical Informatics Association 22(2) (Mar 2015)
26. Wongsuphasawat, K., Gotz, D.: Exploring flow, factors, and outcomes of temporal event sequences with the outflow visualization. IEEE Transactions on Visualization and Computer Graphics 18(12), 2659–2668 (Dec 2012), http://dx.doi.org/10.1109/TVCG.2012.225
27. Wongsuphasawat, K., Guerra Gómez, J.A., Plaisant, C., Wang, T.D., Taieb-Maimon, M., Shneiderman, B.: Lifeflow: Visualizing an overview of event sequences. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. pp. 1747–1756. CHI '11, ACM, New York, NY, USA (2011)