Aiding autobiographical memory by using wearable devices

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Abstract

With the numerous studies in recalling individual's life, we intend to use two lifelog devices for supporting personal lifelogs retrieval: Autographer for capturing visual information and GPS, Polar A360 for recording daily heart rate. In this paper, we investigate the effectiveness of two distinct techniques (Special Moment Approach & Spatial Frequency Approach) for reviewing the lifelogs, which were collected by lifeloggers who were willing to use a wearable camera and a bracelet simultaneously for one day. Generally, Special moment approach is a technique for extracting episodic events and Spatial frequency approach is a technique for associating visual with temporal and location information, especially heat map is applied as the spatial data for expressing frequency awareness. Based on that, the participants were asked to fill in two post study questionnaires for evaluating the effectiveness of those two techniques and their combination. The preliminary result showed the positive potential of exploring individual lifelogs using our approaches.

Keywords: Autobiographical memory, Autographer, Polar A360, Lifelog images, GPS, Heart rate, Heat map, Temporal, Special moment, Spatial frequency, Effectiveness

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Chapter 1

Introduction

1.1 Introduction

1.1.1 Autobiographical Memory

When we speak of autobiographical memory we are referring to the memories a person has of his or her own life experiences. Like many other aspects of human behavior, the study of personal recollections predates the emergence of psychology as a discipline. From the beginning biographers and historians have used personal recollections to construe the individual and collective past. The archival function of memory has often been given primary emphasis in biographical and historical work. According to this view, life memories are time capsules, records of an unrepeatable past. As such they can be used both to recount the past and to teach lessons for the future. The intimate association between memory and narrative arises from this urge to use the past to instruct present and future generations. An awareness of the fallibility of memory, however, is as old as man's fascination with memory itself, and efforts to authenticate and verify recollections by various means (e.g., documents, corroborative reports from contemporaries) are among the factors that distinguish history and biography from legend and folklore. Historians and biographers were and remain c with the construction of judicious accounts of the past. They are not concerned with remembering per se, that has become the province of psychology [26].

Autobiographical memory [7] is a memory system consisting of episodes recollected from an individual's life, based on a combination of episodic and semantic memory, which is shown as the Fig.1.1. As for episodic memory, it mainly contains personal experiences, specific objects, people and events taken place at particular time and space. On the other hand, semantic memory includes general knowledge and facts about the world. It is acknowledged

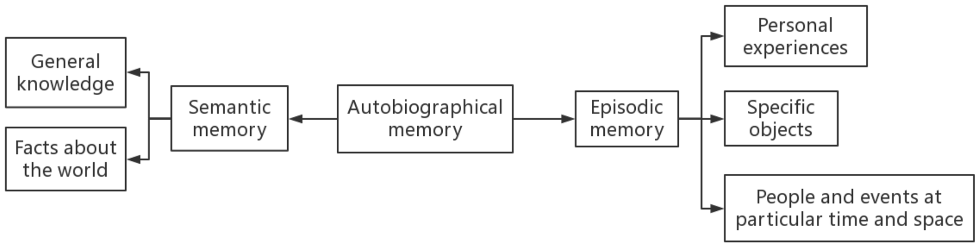


Figure 1.1: Brief composition of autobiographical memory.

that everyone can hardly remember all events taken place before. In such case, lifelogging, a visualization way of retrieval to memory, is providing us with solutions to supporting human autobiographical memory.

Episodic memory refers to the conscious recollection of specific events that took place at a particular point in time in the past, involving such information as what, where, and when. It supports the mental time travel of the self to relive previous experiences. Endel Tulving calls episodic memory “a true marvel of nature” [31]. Tulving views episodic memory as a major neurocognitive memory system distinct from semantic memory, which deals with context-free, general knowledge of the world. Not all episodic memories (e.g., where and what did you eat last Thursday) become part of one’s autobiographical history, however. Only those that are highly significant to the individual constitute autobiographical memories. Conway and Rubin [8] highlights the personal relevance in their definition of autobiographical memory. Nelson [19] discusses the functional importance of autobiographical memory from an evolutionary standpoint, emphasizing the unique role of such memory in defining the self and facilitating social integration.

1.1.2 Autographer and Polar A360

In recent year, due to the development of storage technology, the price of high-capacity storage devices getting cheaper, so people are increasingly easy to get lifelog device to record the daily life, but also can help people to review the past and enhance people’s memory, especially for the people who are suffering from memory impairment. Steve Mann was the first person to do lifelogging via a wearable camera in 1994. JenniCam (1996–2003) was followed by collegeboyslive.tv. That same year, the streaming of live video from the University of Toronto became a social networking phenomenon.

"We Live In Public" was a 24/7 Internet conceptual art experiment created by Josh Harris in December 1999. Gordon Bell's MyLifeBits (2004), an experiment in digital storage of a person's lifetime, including full-text search, text/audio annotations and hyperlinks. Social networking took a quantum leap in 2006 with live webcam feeds on Stickam. In 2007 Justin Kan arrived wearing a webcam attached to a cap, Kan began streaming continuous live video and audio, beginning at midnight March 19, 2007, and he named this procedure "lifecasting" [34]. Recent years with the advent of smartphones and other pervasive devices the paradigm of life logging extended to ubiquitous devices. For instance UbiqLog [24] and Experience Explorer [3] employ mobile sensing to perform life logging.

While other lifelogging devices, like the Autographer, use a combination of visual sensors and GPS tracking to simultaneously document where you are and what you see.Autographer [32] is one of the lifelog devices passively captured images in current research. Due to its nature of collecting various sensory data attached to images, it is applied to capture personal life. The Autographer is basically a small black box, about half the size of a shirt-pocket compact camera, that's designed to be worn on a neckstrap or clipped to your clothing. It has a custom-designed semi-fisheye lens with a 136 degrees ultra-wideangle view, a 5MP sensor, and has built-in GPS and Bluetooth. But what is really interesting (and unique) is that it uses five sensors to decide automatically when to take a picture - an accelerometer to determine whether it's moving, a colour sensor, a magnetometer (i.e. compass), a thermometer, and a PIR proximity sensor. No pressing of a shutter button is required. After capture the images can be used as single frames, or compiled into stop-motion movies [13, 29]. Fig.1.2 illustrates the Autographer that we employ in the research.

Another device involved in this paper is Polar A360 [23], with the photoelectric transmission measurement method, recording the heart rate once per second. Like so many other all-purpose fitness trackers, the A360 emphasizes serious training. Tapping the "My Day" icon on the display brings up your activity progress, which includes step count, distance traveled, and calories burned, as well as how much more you have to do before you've completed your daily activity goal. A cute animation shows different ways to reach your goal. When I was at 94 percent, the A360 told me I could finish up by jogging for three minutes or walking for six. I love this feature because it put my remaining activity into perspective, and what was left was often less than I expected. The A360 also divides activities into categories like "low," "medium," "high," "sitting," and "resting," which encompasses both sleeping and lying down. If you take a morning run before sitting in your office for the rest of the day, your activities will be divided mostly into the "sitting"

Figure 1.2: The overview of applying Autographer in the system.

and "high" categories. The "Training" icon lets you choose from a number of exercises and sports to track, including general options like "indoor sport" and "group exercise" for workouts that don't fit into tidy categories like "run" and "cycle." Starting the timer is as simple as tapping the exercise you want to track. The A360 automatically monitors your pulse changes and their corresponding heart rate zones. When your workout's finished, press and hold the side button to pause, then press and hold the stop button to end and save the routine. The "My Heart Rate" icon allows you to find out your heart rate at any time. The A360 only takes about ten seconds to read your pulse and yields results similar to putting your fingers to your wrist. A small on-screen bubble appears before you start a training session to let you know the heart rate monitor is warming up [2, 30]. Besides, Fig.1.3 displays the Polar A360 that we apply. And Fig.1.4 explains the whole lifelog devices utilized for research.

1.2 Organization of the Thesis

The rest of this thesis is organized as follows: Chapter 2 states the research goal. Chapter 3 describes the background, fundamental knowledge and related work. Chapter 4 gives the method that utilized in preprocessing the images that captured by participants. Chapter 5 introduces the system design our prototype. Chapter 6 presents the implementation of two distinct approaches that depict how to extract episodic events by the change of heart rate and how to combine the visual information with the temporal and spatial

Figure 1.3: The overview of employing Polar A360 in the system.

information. Chapter 7 shows the experiment settings, evaluation metrics, and results of two post-study questionnaires. Chapter 8 concludes the work and give the discussion on the future work.

Figure 1.4: Brief composition of autobiographical memory.

Chapter 2

Research Goal

Memory is an extremely significant thing to everyone, considering that all human beings can forget the little things occasionally on what happened today or in the past. It is likely to influence their daily life more or less. In order to provide the people with the comprehensive memory, which is accessible and available. It is necessary to find out an effective and intuitive way for better memory reviewing and reconstruction.

There are several web viewer systems for lifelog reviewing in current studies. The basis of the SenseCam Image Viewer is a window in which images are displayed and a simple VCR-type control which allows an image sequence to be played slowly (around two images/second), quickly (around twelve images/second), rewound and paused. Also, there are several viewer options. It is possible to display an analogue clock to indicate at what time of day the image displayed was originally taken and to load and display the raw sensor data associated with an image sequence [17]. Another popular viewer is Autographer, which is available for running onto the PC or smartphone. Essentially, autographer provides three modes for user reviewing: stream, cinema and calendar. And the user can tag to the images while browsing.

However, the conventional viewers are limited and have no characteristics. Although, most of the viewers are capable of massive information, there are no specialized or emphasized approaches for assisting a kind of user's memory. In such case, we intend to make the more well-directed and specific viewer for better effect on recalling one's certain daily life. We try to investigate the powerful and meaningful methods for assisting autobiographical memory. With the insight of prior work [5, 20], we propose two approaches utilizing the biophysical data (heart rate) and lifelogs (images & GPS) for generating the effective visual retrievable memory. Those, called Special Moment approach and Spatial Frequency approach, are applied in aiding user's daily life reviewing. Besides, we aim at evaluating the effectiveness from the combination of special events and space-time, to prove the feasibility of those approaches.

Chapter 3

Background and Related Work

This chapter will introduce the fundamental knowledge and related work about the previous studies on how to assist individual memory and the neuroscience field work about the correlation of heart rate and emotion and the relationship between emotion and memory.

3.1 General Related Work

In most of the studies using lifelog devices, lifelogs are often displayed in the form of events or other kind of visualization results [10–12, 15]. These events are meaningful logical units that are derived from the merged various sensor data. It explains how to identify travel behaviors from wearable image data. Doherty et al. [12] gave the solutions as events segmentation, events importance and events association to memory aid. They depict how to generate events in accordance with the various sensory data, normalizing the raw sensory data and setting up a threshold to extract events. Moreover, a web viewer, constructed with the purpose of exploiting the characteristics of personal memory, was reported for supporting the aims of memory rehabilitation [11].

There are several web viewer systems for lifelog reviewing in current studies. Ono [21] proposed the lifelog viewer based events estimation, which accuracy of events generation is still controversial. Memoria [16] is a viewer provided personalised memory augmentation service without events extraction. Autographer made a casual viewer comprising of calendar view, stream view and graphic view. Smeaton [28] introduced a viewer the images are all manually annotated for memory query.

3.2 Significant Related Work

Several researches have been turned out that emotion is crucial to memory construction and retrieval [25, 27]. However, changes in emotion are usually accompanied by changes in heart rate, which has been explained in the neuroscience field [1, 18]. In particular, Palomba et al. [22] mentioned the correlation of heart rate and memory. Therefore, Niforatos et al. [20] proposed a biophysical driven capture process to acquire events used for aiding user's recoverable memory, but it only reported the idea, prototype and planned study design without any detailed evaluation in that paper. They adopted an android phone and a lifelog camera.

Prior work reported by Chowdhury et al. [6] gave the hints of generating key frames for daily life review. A recent study of his team [5] investigated the effectiveness of four distinct techniques used for memory reminiscence. Four distinct techniques represent for (a) visual-temporal; (b) visual-spatial; (c) visual-temporal-spatial; (d) trending location. In his research, it proved that the combination of visual, temporal and spatial information had the best effect on visual lifelogs reviewing. Nevertheless, we introduced heat map as the spatial information, which is more intuitive for users‘ location awareness and frequency. The following figures illustrate the results on the different combination of acquired information. Technique (a) outlines the temporal and spatial information, which is so-called trails dairy. Technique (b) sketches the spatial and visual information, which indicates the visualization of each collected location spot. Technique (c) interprets the combination of visual, temporal and spatial information, which demonstrates the visualization of each location spot with its temporal information. Technique (d) exposes the trending location in accordance with the records obtained by the participant, which means the high-frequency visited places.

Chapter 4

Robust Motion Deblurring

However, due to the user's movement or camera swing, it is likely to cause the photo to be blurred. In order to be able to get more and more effective photos, we used the algorithm proposed by Li Xu and Jiaya Jia, called robust motion deblurring [36].

They discuss a few new motion deblurring problems that are significant to kernel estimation and non-blind deconvolution. They found that strong edges do not always profit kernel estimation, but instead under certain circumstance degrade it. This finding leads to a new metric to measure the usefulness of image edges in motion deblurring and a gradient selection process to mitigate their possible adverse effect. They also propose an efficient and high-quality kernel estimation method based on using the spatial prior and the iterative support detection (ISD) kernel refinement, which avoids hard threshold of the kernel elements to enforce sparsity. They employ the TV-l1 deconvolution model, solved with a new variable substitution scheme to robustly suppress noise. That's what they proposed employing two-kernel phase for robust motion deblurring.

Based on their Two-Phase Sparse Kernel Estimation for Robust Motion Deblurring, they have developed a software for images processing. Fig.A.27 is the screenshot of the entire Robust Motion Deblurring system. And then, Fig.A.28 explains the system has already loaded the processing image. Ultimately, Fig.A.29 demonstrateds the result of employing robust motion deblurring.

After completing the collection of pictures, all the pictures should be preprocessed with this method, get the next step in the need for images. The following Fig.A.30 explains how their algorithm works.

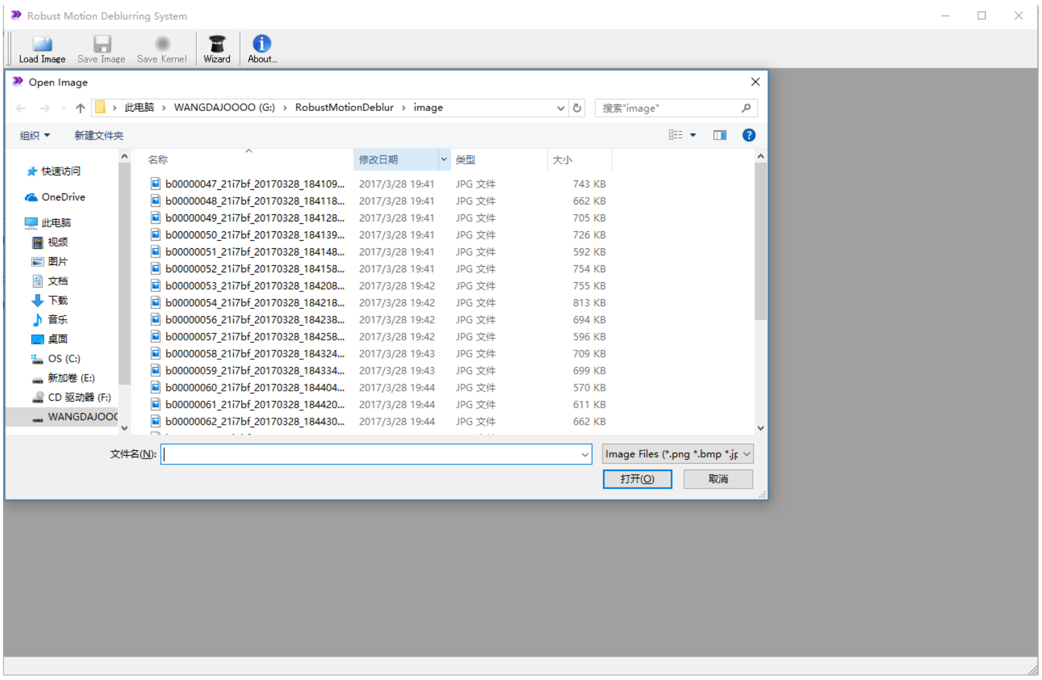


Figure 4.1: The overview of Robust Motion Deblurring system.

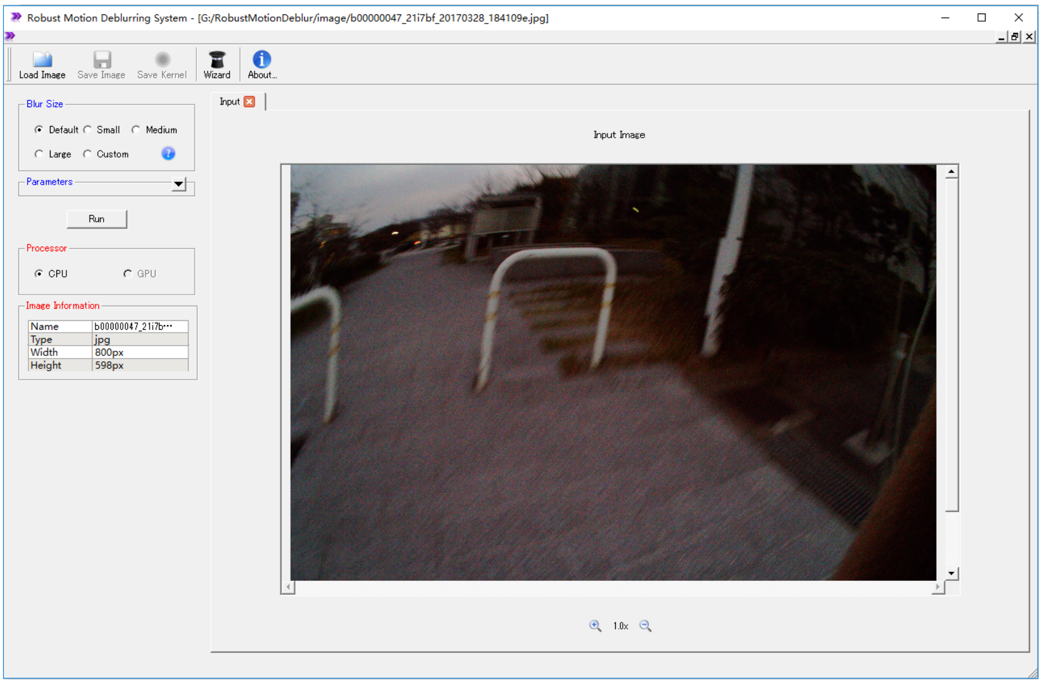


Figure 4.2: The screenshot of deblurring system after selecting the intended image.

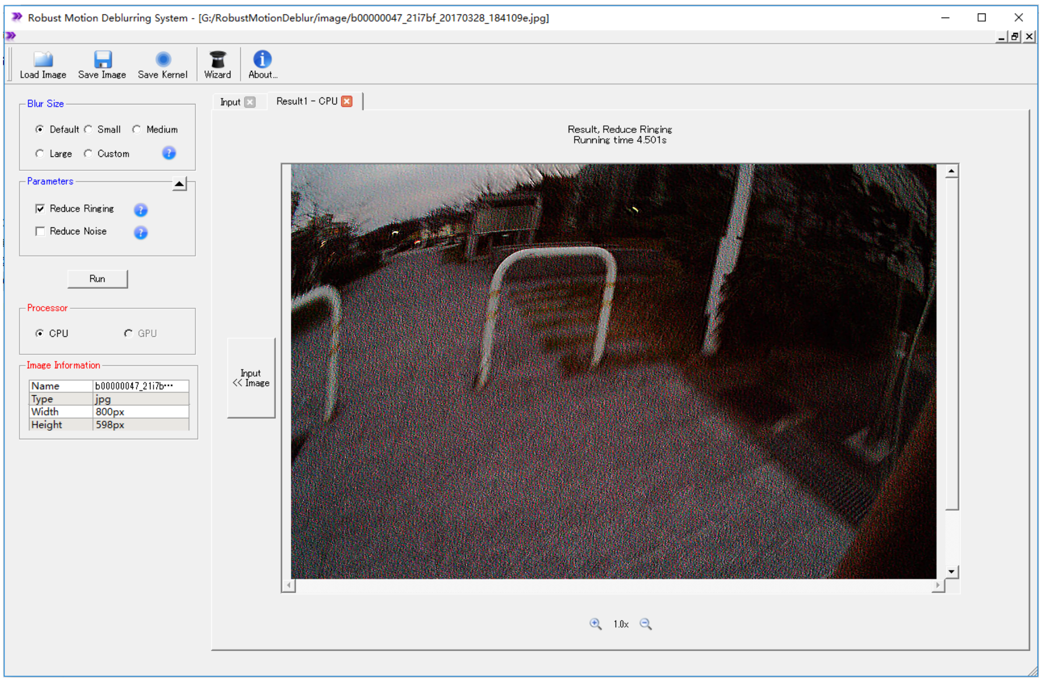


Figure 4.3: The screenshot of deblurring system after processing the intended image.

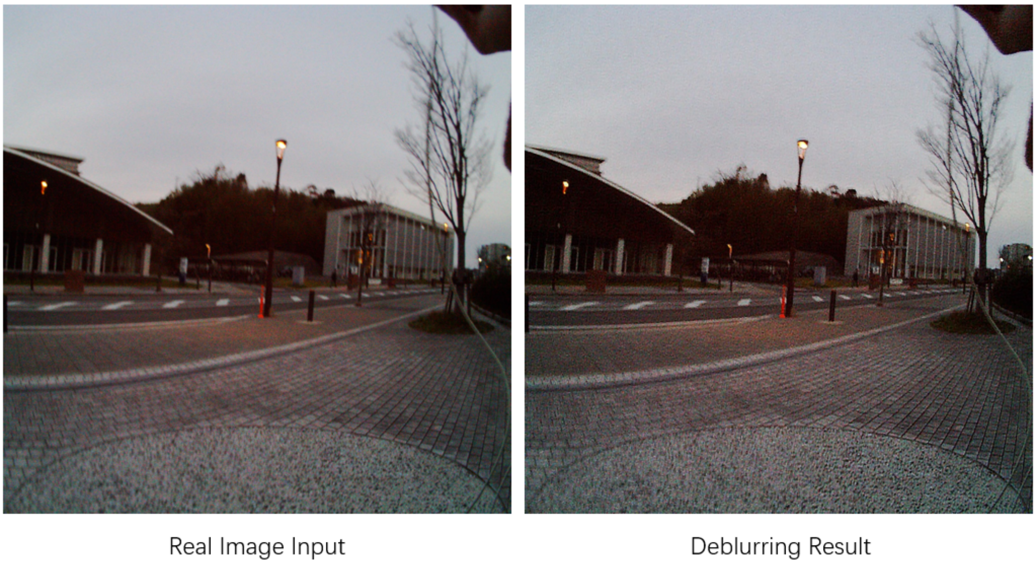


Figure 4.4: Lifelog image input (L) and processed image after deblurring (R), which is captured by the participant outside the campus.

Chapter 5

System Design

5.1 System Overview

We designed a lifelogging system that follows a three-step process of capture, process, and review to support recollection of autobiographical memories (Fig.5.1 & Fig.5.2). In Fig.5.1, we put the captured images and heart rate data together as an input data. The process is based on the sudden change of heart rate, extracting a series of images of specific periods which are called Episodic Memories. Finally, the participant will review the result of his daily Special Moment. However, in the Fig.5.2 which depicts the rough procedure of Spatial Frequency Approach. First, we associate images with GPS, both of which are collected by autographer. Meanwhile, time information is attached to images and GPS that is the key to those two data engage together later. Once we get the lifelog data, we match the location spot with each corresponding image according to the their temporal information. Only when the time of image and spot are the same, they could be a pair to be processed and displayed in the heatmap. Ultimately, the participant will interact with the heatmap for looking through their daily Spatial Frequency.

5.2 Captured Data for Lifelog Processing

In this part, the specific data for Life-log service are described. The images, physiological, location, and time information are signals for Life-log service. The information for life log can be obtained from two wearable devices: Autographer and Polar A360. The GPS built-in Autographer is used in order to obtain the exact time and the location information. We can measure the heart rate through the Polar A360. These signals give us the information including HR (Heart Rate) and time information, which is available when

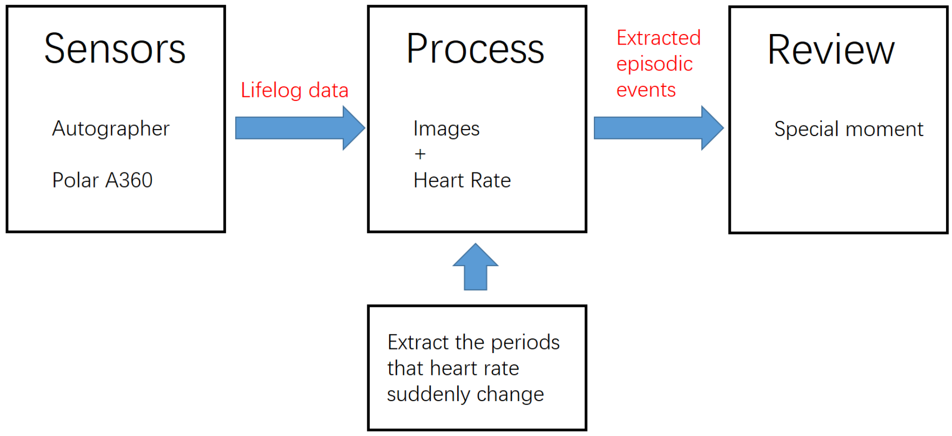


Figure 5.1: System overview of Special Moment: Capture, Process, Review .

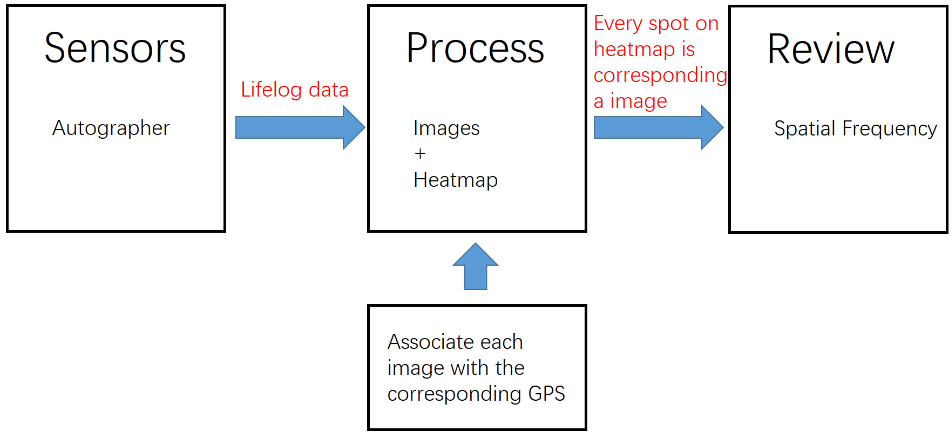


Figure 5.2: System overview of Spatial Frequency: Capture, Process, Review
.

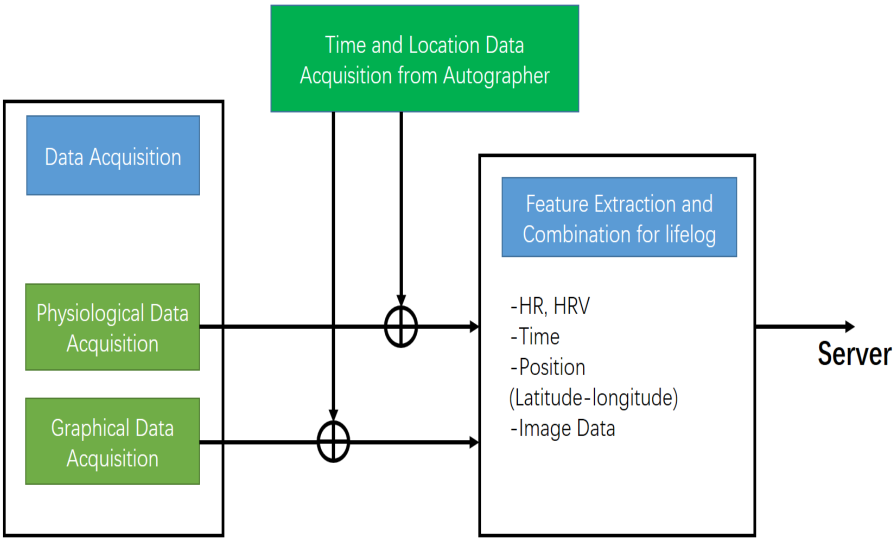


Figure 5.3: Block diagram of aiding autobiographical memory system.

connecting to the computer and synchronizing the data to the web automatically. Therefore the measured physiological signals and images in routine life can be merged with the obtained time. If this information are sent to the server and saved, this can provide the life-log service. Fig.5.3 shows the block diagram of wearable devices based on temporal and spatial data. And the still images can be obtained from the Autographer.

5.2.1 Images

The image information is the visual information of a user provided by Autographer. The still image is provided to the form like JPEG. Basically, the device takes a picture around every 30 seconds. When connecting to the computer, the collected data will update automatically, including all the sensory data and time information.

5.2.2 Physiological Information

The bio-signal of a user is the important information for the health condition and emtion. Optical sensor is the most important part in A360, which is Polar's first built-in optical heart rate meter products, structurally, this sensor uses dual green LED for heart rate measurement. Analysis of HR provides an effective way to investigate the different activities of daily life.

5.2.3 Time Information

The time information is the important information for the Life-log, both of which are obtained from Autographer and Polar A360 in their own mechanism, and it is easy to synchronize them.

5.2.4 Location Information

The location information is the important information for the Life-log. This information can be acquired from a satellite through GPS. GPS provides the latitude and longitude information. Generally these are provided the NMEA(National Marine Electronics Association)0813 standard form. The longitude and latitude can be collected from GGA(Global positioning system fixed data) of the GPS signal.

Table 5.1: Sensing Signals, Data Feature provided by wearable devices

Sensing Signals	Data/Feature	Communication
Image	Still image, JPEG	USB/Computer
HR	Heart rate, CSV	
GPS	Latitude, Longitude	

Chapter 6

Implementation Details

In this chapter, there would be the explanation of implementation details on two approaches named special moment approach and spatial frequency approach in details. Actually, these two approaches are inspired by the previous studies on how to aid people who are in trouble remembering the stuffs or events. The Fig.6.1 shown as below roughly reveals the original intention about combining episodic memory and visual-temporal-spatial memory for recalling.

Our research can be essentially divided into three steps: First, collect the original data, including images, GPS and heart rate. Autographer takes responsible for capturing images and GPS information while Polar A360 for obtaining raw heart rate data. After that, process the data utlizing the proposed approaches. As for special moment approach, episodic memory will be displayed for participant according to the combination of images and heart rate. As for spatial frequency approach, visual-spatial-temporal memory will be exposed for participant according to the fusion of images, GPS and time information. Finally, all the results will be exhibited on the web viewer for user reviewing, meanwhile, they have to fill out two post-study questionnaires in order to evaluate the effectiveness of those two specific approaches. Their feedbacks are involved in the later evaluation.

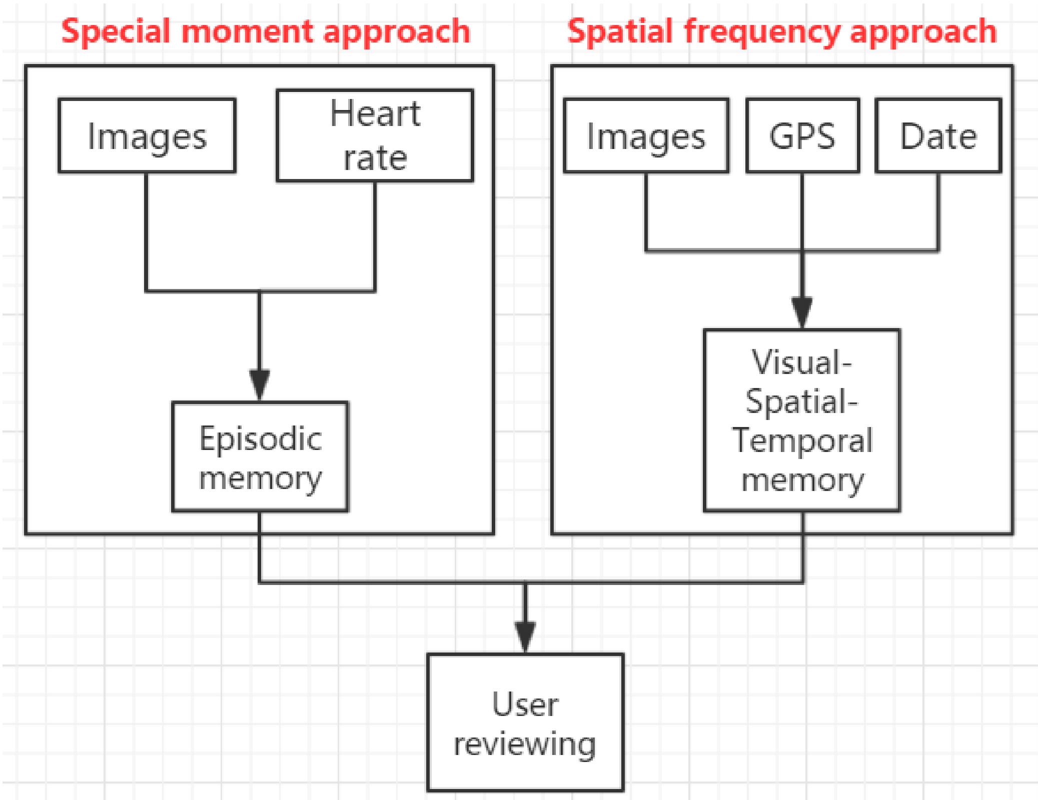


Figure 6.1: The structure of entire system including special moment approach and spatial frequency approach.

6.1 Special Moment Approach

Special Moment Approach, an idea comes from the correlation of emotion and memory construction, is focus on generating specific events that happen to the participant. Based on the prior studies, several researches have been turned out that emotion is crucial to memory construction and retrieval [25, 27]. However, changes in emotion are usually accompanied by changes in heart rate, which has been explained in the neuroscience field [1, 18]. In particular, Palomba et al. [22] mentioned the correlation of heart rate and memory. Thus, we intend to exploit the change of heart rate to define the specialized events in one's daily life. Generally, four steps are involved in this approach, composing of Obtain the Heart Rate, Normalize the Heart Rate, Combine the Heart Rate and Images and Extract Episodic Events.

6.1.1 Obtain the Heart Rate

With the photoelectric transmission measurement method, the sensor in contact with the skin will issue a beam of light hit the skin, measuring the reflected / transmitted light, resulting in heart rate value. Once the Polar A360 is connected to the computer and through the device comes with the synchronization tool Polar Flow, which will synchronize the data to the online database for the user to export or view. Exporting the heart rate into a CSV file is helpful for the later data processing. Figure.6.2 shows the raw heart rate generated by Excel. In this picture, we only extract part of the heart rate data, from 6:00 am to 12:26 pm, a total of 6 hours and 26 minutes.

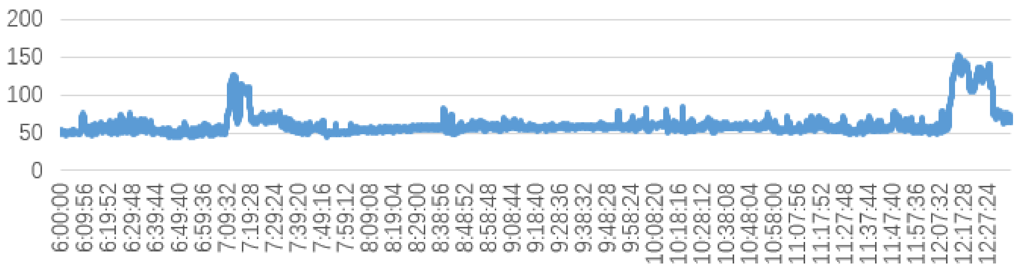


Figure 6.2: The part of raw heart rate data captured by the participant.

6.1.2 Normalize the Heart Rate

As it is known, Polar A360 records heart rate every second, but taking into account that the Autographer takes a photo every 30 seconds. So in order to link heart rate and pictures together, calculate the average of every 30 seconds of heart rate data as one value, corresponding to each picture. Figure.A.31 illustrates the result of heart rate normalization. It is apparent that the curve becomes more sparse compared to the foreahead one, which counts a lot in extracting part.

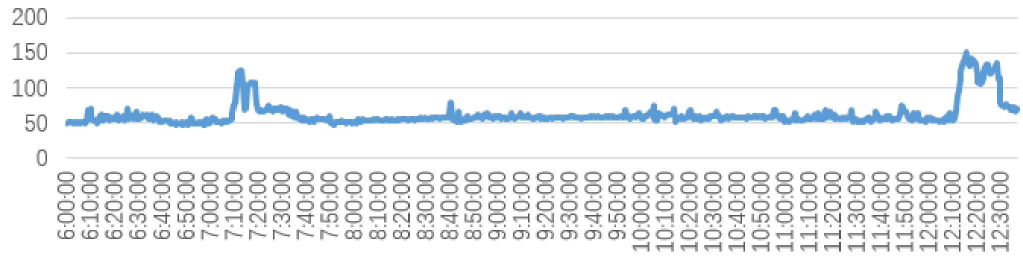


Figure 6.3: The part of normalized heart rate data corresponding to the previous data, which is captured by the participant.

6.1.3 Combine the Heart Rate and Images

According to the second step, we have converted the heart rate data into a 30-second data, for better match with each of the corresponding pictures. Before combining the heart raye and images, it is necessary to determine the start point of two data. Since each image and each set of heart rate data have the time information, we synchronize them with time information as the base point. Thus, each heart rate data is corresponding to a image, which is useful for extracting image flow in next section. Figure.A.32 depicts how the heart rate and image are combined and screened out of the extracting of the part. The top part shows the heart rate after normalization and synchronization, and the bottom part explains the image flow that user captured during the exact period. Once those two information are aligned, it is easy to know the correspondence between pictures and heart rate. In this figure, the highlight parts explain the prompt changes of heart rate, which also indicates the processing part.

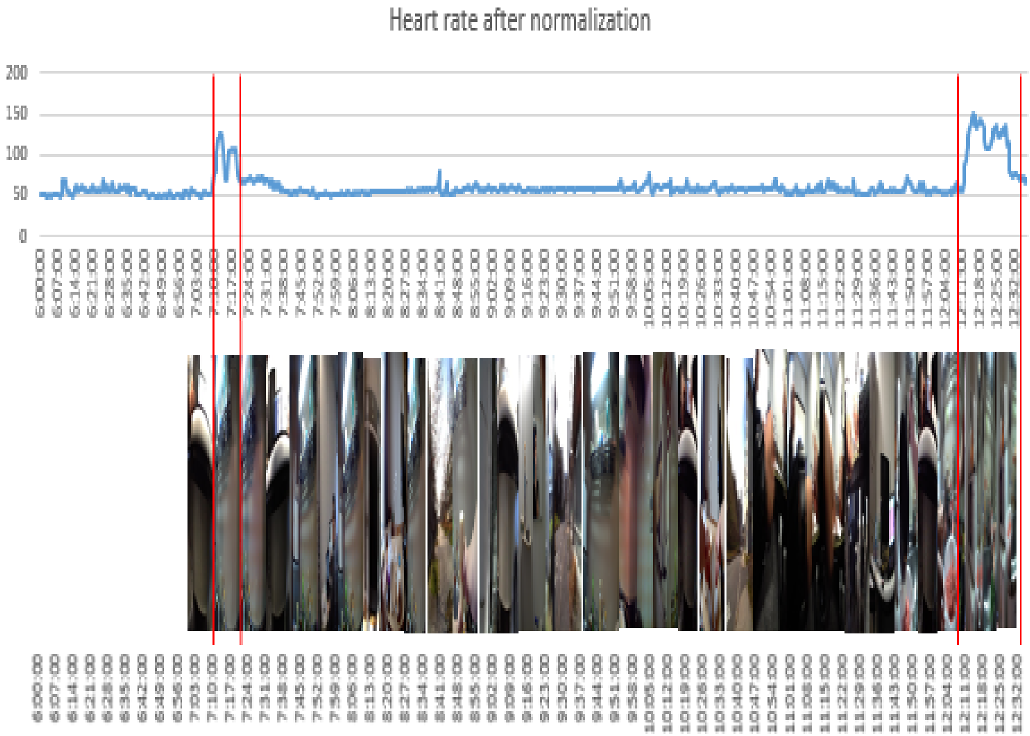


Figure 6.4: According to the temporal information, we synchronize heart rate data with the captured images.

6.1.4 Extract Episodic Events

After finishing the fusion of heart rate and images, it is obvious to extract the periods that user's heart rate changes suddenly. The following pictures are the partial of extracting periods and have been described by the user. In the figure.A.33, it is highlighted that only two parts are processed, the definition of the events given by user himself. However, those periods have been extracted manually so far.

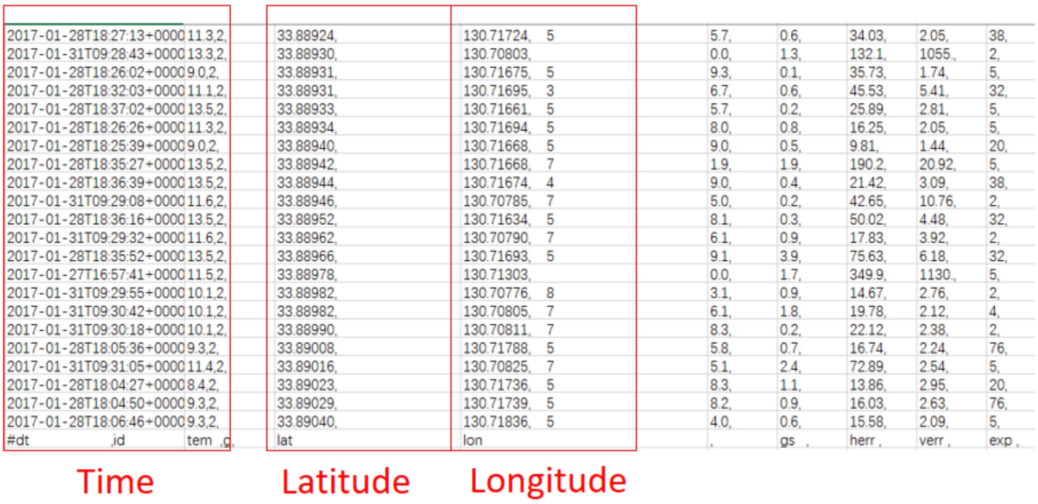
Figure 6.5: After unifying both heart rate data and images, extract episodic events based on the sudden change of heart rate obtained by participant.

6.2 Spatial Frequency Approach

Spatial Frequency Approach, inspired by the visual-temporal-spatial technique proposed by chowdhury's previous researches [5, 6], is a method based on heat map for individual browsing their lifelogs. It is acknowledged that heat map is more intuitive for users' location awareness and frequency, which can be regared as the enhancement of visual-temporal-spatial technique. In this approach, there are four steps for implementing including: Get GPS Information, Generate Heat Map, Match each spot with image and Review the Lifelog.

6.2.1 Get GPS Information

Basically, the GPS information are provided by Autographer. Due to its mechanism, the spatial information is likely to be not acquired in some conditions, especially in the buildings. Thus, the data is not covered all the trails of one's whole recorded day. Despite of that, we intend to apply all available GPS information into the next procedure. In the Figure.A.34, it contains several information recorded by various embedded sensors. From the left to right, the first one represents for temporal data, and the rest are latitude and longitude.



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2017-01-31T09:28:43+0000	13.3,2,	33.88930,	130.70803,		0.0,	1.3,	132.1,	1055.,	2,
2017-01-28T18:26:02+0000	9.0,2,	33.88931,	130.71675,	5	9.3,	0.1,	35.73,	1.74,	5,
2017-01-28T18:32:03+0000	11.1,2,	33.88931,	130.71695,	3	6.7,	0.6,	45.53,	5.41,	32,
2017-01-28T18:37:02+0000	13.5,2,	33.88933,	130.71661,	5	5.7,	0.2,	25.89,	2.81,	5,
2017-01-28T18:26:26+0000	11.3,2,	33.88934,	130.71694,	5	8.0,	0.8,	16.25,	2.05,	5,
2017-01-28T18:25:39+0000	9.0,2,	33.88940,	130.71668,	5	9.0,	0.5,	9.81,	1.44,	20,
2017-01-28T18:35:27+0000	13.5,2,	33.88942,	130.71668,	7	1.9,	1.9,	190.2,	20.92,	5,
2017-01-28T18:36:39+0000	13.5,2,	33.88944,	130.71674,	4	9.0,	0.4,	21.42,	3.09,	38,
2017-01-31T09:29:08+0000	11.6,2,	33.88946,	130.70785,	7	5.0,	0.2,	42.65,	10.76,	2,
2017-01-28T18:36:16+0000	13.5,2,	33.88952,	130.71634,	5	8.1,	0.3,	50.02,	4.48,	32,
2017-01-31T09:29:32+0000	11.6,2,	33.88962,	130.70790,	7	6.1,	0.9,	17.83,	3.92,	2,
2017-01-28T18:35:52+0000	13.5,2,	33.88966,	130.71693,	5	9.1,	3.9,	75.63,	6.18,	32,
2017-01-27T16:57:41+0000	11.5,2,	33.88978,	130.71303,		0.0,	1.7,	349.9,	1130.,	5,
2017-01-31T09:29:55+0000	10.1,2,	33.88982,	130.70776,	8	3.1,	0.9,	14.67,	2.76,	2,
2017-01-31T09:30:42+0000	10.1,2,	33.88982,	130.70805,	7	6.1,	1.8,	19.78,	2.12,	4,
2017-01-31T09:30:18+0000	10.1,2,	33.88990,	130.70811,	7	8.3,	0.2,	22.12,	2.38,	2,
2017-01-28T18:05:36+0000	9.3,2,	33.89008,	130.71788,	5	5.8,	0.7,	16.74,	2.24,	76,
2017-01-31T09:31:05+0000	11.4,2,	33.89016,	130.70825,	7	5.1,	2.4,	72.89,	2.54,	5,
2017-01-28T18:04:27+0000	8.4,2,	33.89023,	130.71736,	5	8.3,	1.1,	13.86,	2.95,	20,
2017-01-28T18:04:50+0000	9.3,2,	33.89029,	130.71739,	5	8.2,	0.9,	16.03,	2.63,	76,
2017-01-28T18:06:46+0000	9.3,2,	33.89040,	130.71836,	5	4.0,	0.6,	15.58,	2.09,	5,
#dt ,id	tem ,g,	lat	lon		,	gs ,	herr ,	verr ,	exp ,

Figure 6.6: The screenshot of excel file of GPS information provided by Autographer.

6.2.2 Generate Heat Map

Once the GPS data has been obtained, it should be imported to generate heat map by calling the Google Map API [14]. The principle of its generation is simply summarized as four steps:

(a) Set a radius for discrete points to create a buffer;
(b) For each discrete point of the buffer, the use of progressive grayscale (the complete gray scale is 0 255) from the inside out, from shallow to deep fill;
(c) As the gray value can be superimposed (the larger the value is, the lighter the color is in the grayscale.) In practice, you can select any channel in the ARGB model as a superimposed gray value, so that for a buffer Area, you can stack the gray value. In such case, the more the buffer cross, the greater the gray value is, meanwhile, this area will be more "hot";
(d) The color is mapped from a 256-color ribbon (such as a rainbow) with the grayscale value after the overlay, and the image is re-colored to achieve the heat map [33].

It can be simple to aggregate large amounts of data through the heat map, which use a progressive ribbon ensures the elegant performance. Ultimately, it can be very intuitive to show the density of spatial data or frequency level. Figure.A.35 explains the flow chart of generating heat map and shows how heat map looks like respectively.

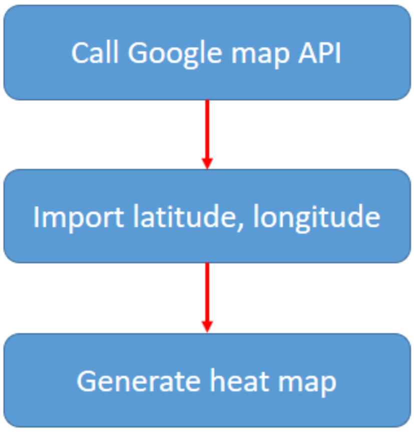


Figure 6.7: The procedure of generating heatmap calling Google API (L) and the result of heatmap processing Google API (R).

6.2.3 Match each spot with image

As aforementioned, heat map is comprised of massive discrete spots. Additionally, each spot is generated with its temporal information, and each image is recorded with its temporal information as well. In such case, it is apparent that each spot corresponds to one image respectively if that image gets GPS information at first. As a matter of fact, only the temporal information of spot and image is the same, they are associated with each other literally.

6.2.4 Review the Lifelog

Basically, the GPS information are provided by Autographer. Due to its mechanism, the spatial information is likely to be not acquired in some conditions, especially in the buildings. Thus, the data is not covered all the trails of one's whole recorded day. Despite of that, we intend to apply all available GPS information into the next procedure. In the Figure.A.36, it contains several information recorded by various embedded sensors. From the left to right, the first one represents for temporal data, and the rest are latitude and longitude.

Figure 6.8: The prototype of reviewing system: The entire heatmap including all the location spots and the highlight spot indicates the spot that the user is browsing (L) and the corresponding image to the specific spot (R).

Chapter 7

Experiments and Evaluation

7.1 Experiment

The objective of our experiment is to investigate the effectiveness of special moment approach and spatial frequency approach for supporting autobiographical memory. Of course we have also compared to the regular review of utilizing the viewer comes with Autographer. Essentially, autographer provides a viewer for exploring individual lifelogs without filtering some useless images. According to the studies, massive information has a decreased impact on the memory reviewing.

As Table 7.1 shown, there are 8 participants involved in our research so far, but the number of participants will be increased in the future. And all the participants are students with computer sicience background, living in this city for more than one year. All of them are taken the pre-description of how to use the devices, how to capture the data, and some hint messages that may be involved their privacy.

Table 7.1: Subject Demographic Information

Participants	7 males, 1 female
Age	21-24; Mean:22.5
Professional	Students
Time spent in the city	More than 1 year

In the experiment, four steps are made up of the procedure of our experiment as it shown below:
(1) Each participant was asked for using the devices simultaneously for 1 days around 8 hours per day. There is no requirement on when the users have to open the devices for recording. It all depends on the personal intention and

the recommendation periods is from the morning to the afternoon, considering the influence of environmental light condition on capturing pictures.
(2) And then submit the data for processing. All the data are imported to the processing computer and divided into three parts: images, heart rate data and GPS.
(3) After that, all the participants were involved in the personal interview one by one with lifelogs which are processed, and it takes place in a quiet place in order to decrease the effect of the possible unnecessary factors (eg. environmental noise, interruption and etc). Meanwhile, 8 people were required to fill in two questionnaires while looking through their lifelogs. Actually, the two questionnaires were filled in simultaneously whereas the duplicate reviews on the same set of lifelogs will affect those two evaluation.
(4) The regular review is applied for the Autographer viewer, the participants were required to use Cinema mode for scanning all the images. They browsed each image for 5 seconds and fill in the questionnaire1 for about 10 seconds. If the participant recalled one event, he ought to make the record of the rough description of that event, which is convenient and apparent when comparing to other two approaches.
(5) As for Special Moment Review, we provided the participants with processed images, which were separately distinct event flows. If the participant recalled one event, he ought to make the record of the rough description of that event whether it's the same as foregoing one.
(6) As for Spatial Moment Review, we provided the participants with a web viewer including two panels: one is heat map, another is viewer part. The participants were asked to look through the heat map practically at the first glance. And then browsed all the spots involved in the heat map on their own sequence. If the participant recalled one event, he ought to make the record of the rough description of that event whether it's the same as foregoing one.
(7) Once the participants were browsing their processed recorded, they were asked to answer two questionnaires (Q1 & Q2) capturing information regarding:

We have taken three aspects into consideration to investigate the effectiveness of each approach. (Q1.1) Whether the presented information is meaningful?
(Q1.2) Whether the information presented clearly and can be easily interpreted?
(Q1.3) whether the approach provides an intuitive and effective way for visual review?

Table 7.2: Post-Study Questionnaire1 based on a participant's answer

Question	Regular Review					Special Moment					Spatial Frequency				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
How meaningful is the presented information?			3					3						4	
Is the information presented clearly and can be easily interpreted?		2							4					4	
Does the visualization help the lifeloggers in calling up the past in an intuitive way?		2							4				3		

The questionnaire2 is three questions as well. And each question is progressive. (Q2.1) The basic level of recalling the events, because of using the autographer application?
(Q2.2) Are there any changes after using Special Moment Approach for reviewing?
(Q2.3) Are there any changes after using Spatial Frequency Approach for reviewing?

Eventually, the evaluation is given out by analysising the feedback of contributors.

Table 7.3: Post-Study Questionnaire2 based on a participant's answer

Question,Answer	
How many events that you can reminisce without any help?	5
After using Special Moment approach, how many new events that come to your mind?	1
After using Spatial Frequency approach, how many are new events that come to your mind?	0

7.2 Evaluation

After collecting the results given by the participants, the evaluation of two approaches for aiding autobiographical memory can be carried out. They were asked to rate on a Likert Scale ranging from 1 to 5. Therefore, results of the assessment are based on the user's questionnaire, calculating the average of each answers and illustrating the following fig.7.1.

Before that, it is necessary to introduce the Likert Scale, which is employed in the experiment and the evaluation of questionnaire1 is based on that. A Likert scale is the sum of responses on several Likert items. Because many Likert scales pair each constituent Likert item with its own instance of a visual analogue scale (e.g., a horizontal line, on which a subject indicates his or her response by circling or checking tick-marks), an individual item is itself sometimes erroneously referred to as a scale, with this error creating pervasive confusion in the literature and parlance of the field. A Likert item is simply a statement that the respondent is asked to evaluate by giving it a quantitative value on any kind of subjective or objective dimension, with level of agreement/disagreement being the dimension most commonly used. Well-designed Likert items exhibit both "symmetry" and "balance". Symmetry means that they contain equal numbers of positive and negative positions whose respective distances apart are bilaterally symmetric about the "neutral"/zero value (whether or not that value is presented as a candidate). Balance means that to the distance between each candidate value is the same, allowing for quantitative comparisons such as averaging to be valid across items containing more than two candidate values[4]. Often five ordered response levels are used, although many psychometricians advocate using seven or nine levels; an empirical study[9] found that items with five or seven levels may produce slightly higher mean scores relative to the highest possible attainable score, compared to those produced from the use of 10 levels, and this difference was statistically significant. In terms of the other data characteristics, there was very little difference among the scale formats in terms of variation about the mean, skewness or kurtosis[35].

It can be seen from the fig.7.1 that significant changes have taken place in all questions, compared to the Regular Review. Here, Regular Review stands for the participants review their lifelogs by using Autographer application. The blue bars for three questions are about 2.94, 3.25, 3.16. However, owing to Special Moment Review and Spatial Frequency Review have different impacts on the user's memory recalling in different circumstances, so in the histogram to the three questions corresponding, there are some slight difference between those two methods. The orange bars for three are around 3.75, 4.22, 4.22. Besides, the gray bars for three questions are approximate 3.86, 4.09, 4.28. In general, the estimation indicates that the approaches enhance the effectiveness of assisting autobiographical memory but respectively.

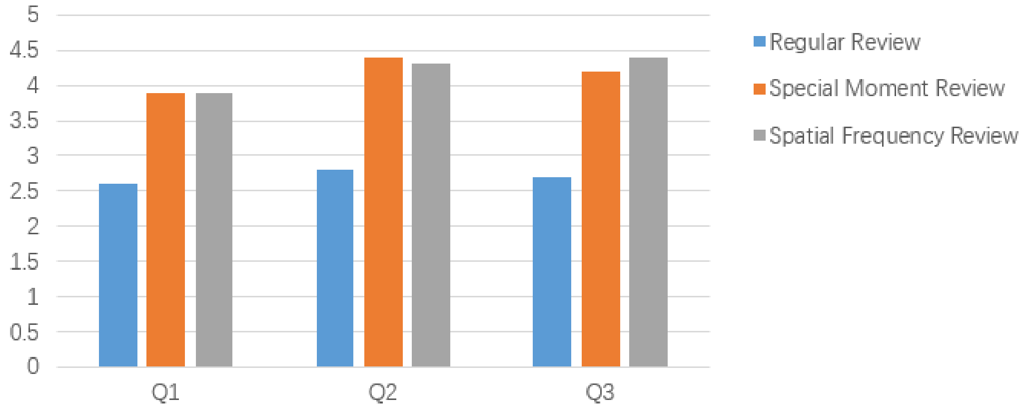


Figure 7.1: The evaluation based on questionnaire1 given by participant.

In fig.7.2, Regular Review explains the basic level of exploring lifelogs as well. The data corresponding to three bars are 5.51, 6.72, 7.75. As it shown in the second bar, the increase number of new events after using Special Moment approach. The same situation to the last one, which not only reflects the growth of new events after exploiting Spatial Frequency approach, but also the total increase of new events after utilizing two methods literally.

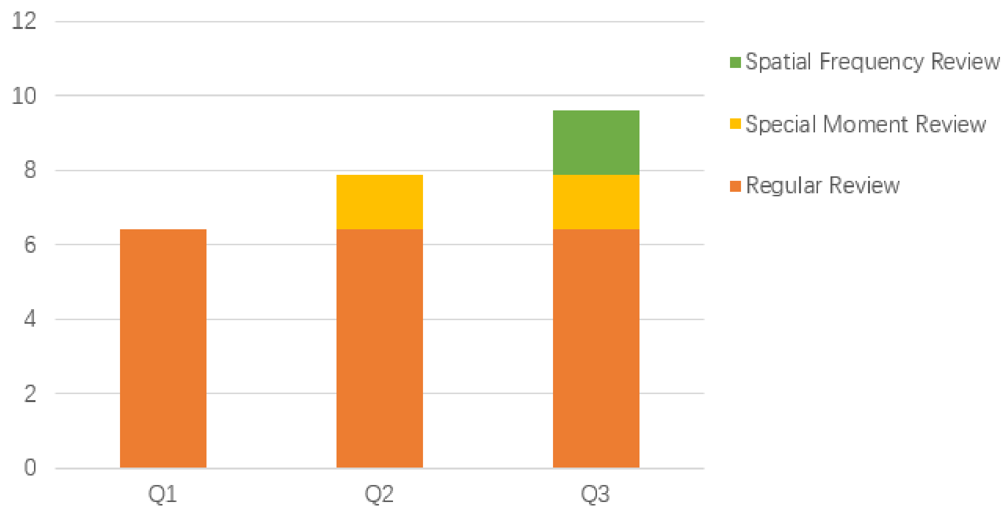


Figure 7.2: The evaluation based on questionnaire2 given by participant.

Chapter 8

Conclusion and Future Directions

8.1 Conclusion

In summary, this paper explains the combination of two distinct visualization techniques supporting explore personal lifelogs and recall the past, which make the reviewing engaging and informative using Autographer and Polar A360 simultaneously per day. All captured images are engaged with heart rate and Spatial-Temporal information, making the visualization of memory recalling more informatively. Moreover, the results with respect to the effectiveness of assisting autobiographical memory has been discussed, suggesting the meaningful and easily interpreted summarization of the lifelogs using Special Moment Approach and Spatial Frequency Approach. The techniques reported in this paper explicitly set forth the visualization fusion of biophysical data and GPS brought out the feasibility of making more available memory retrieval. The results also indicate the positive potential compared to the prior work. We are completely convinced that it will show the much better results and significant changes when the quantities of participants increase.

8.2 Future Directions

Up to now, there are several possibilities for the future research on this topic. Investigate the possibility of combining additional body signals to improve effectiveness, such as Galvanic skin, which is a vital signal for personal emotion detection. With the combination of heart rate and galvanic skin, the result may turn out in a different way. As we propose in the Spatial frequency approach, there are three kinds of information involved in. Thus, taking other information in to consideration is also a new idea.

References

[1] Bradley M Appelhans and Linda J Luecken. Heart rate variability as an index of regulated emotional responding. *Review of general psychology*, 10(3):229, 2006.

[2] arstechnica. *Polar1*, March 2016. `https://arstechnica.com/gadgets/2016/03/polar-a360-reviewed-another-fitness-tracker-with-smartwatch-envy/`.

[3] Petros Belimpasakis, Kimmo Roimela, and Yu You. Experience explorer: a life-logging platform based on mobile context collection. In *Next Generation Mobile Applications, Services and Technologies, 2009. NGMAST'09. Third International Conference on*, pages 77–82. IEEE, 2009.

[4] A.C. Burns and R.F. Bush. *Basic Marketing Research: Using Microsoft Excel Data Analysis*. Pearson education. Pearson Prentice Hall, 2008.

[5] Soumyadeb Chowdhury, Md Sadek Ferdous, and Joemon M Jose. A user-study examining visualization of lifelogs. In *Content-Based Multimedia Indexing (CBMI), 2016 14th International Workshop on*, pages 1–6. IEEE, 2016.

[6] Soumyadeb Chowdhury, Philip J McParlane, Md Sadek Ferdous, and Joemon Jose. My day in review: Visually summarising noisy lifelog data. In *Proceedings of the 5th ACM on International Conference on Multimedia Retrieval*, pages 607–610. ACM, 2015.

[7] Martin A Conway. *Autobiographical memory: An introduction*. Open University Press, 1990.

[8] Martin A. Conway and David C. Rubin. The structure of autobiographical memory. In A. Collins, S. Gathercole, Martin A. Conway, and P. E. Morris, editors, *Theories of Memory*, pages 103–137. Lawrence Erlbaum, 1993.

[9] John G Dawes. Do data characteristics change according to the number of scale points used? an experiment using 5 point, 7 point and 10 point scales. *International Journal of Market Research*, 2012.

[10] Aiden Doherty, Paul Kelly, and Charlie Foster. Wearable cameras: Identifying healthy transportation choices. *IEEE Pervasive Computing*, 12(1):44–47, 2013.

[11] Aiden R Doherty, Chris JA Moulin, and Alan F Smeaton. Automatically assisting human memory: A sensecam browser. *Memory*, 19(7):785–795, 2011.

[12] Aiden R Doherty, Katalin Pauly-Takacs, Niamh Caprani, Cathal Gurrin, Chris JA Moulin, Noel E O'Connor, and Alan F Smeaton. Experiences of aiding autobiographical memory using the sensecam. *Human–Computer Interaction*, 27(1-2):151–174, 2012.

[13] DPReview. *Autographer1*, August 2013. `https://www.dpreview.com/reviews/omglife-autographer`.

[14] Google Developers. *Heatmaps*, April 2017. `https://developers.google.com/maps/documentation/javascript/examples/geocoding-region-us`.

[15] Cathal Gurrin, Alan F Smeaton, Aiden R Doherty, et al. Lifelogging: Personal big data. *Foundations and Trends® in Information Retrieval*, 8(1):1–125, 2014.

[16] Hyeju Jang, Jongho Won, and Changseok Bae. Memoria: personal memento service using intelligent gadgets. In *International Conference on Human-Computer Interaction*, pages 331–339. Springer, 2007.

[17] Microsoft. *sensecam*. `https://www.microsoft.com/en-us/research/wp-content/uploads/2011/01/Memory.pdf`.

[18] Hidehiro Nakahara, Shinichi Furuya, Satoshi Obata, Tsutomu Masuko, and Hiroshi Kinoshita. Emotion-related changes in heart rate and its variability during performance and perception of music. *Annals of the New York Academy of Sciences*, 1169(1):359–362, 2009.

[19] Katherine Nelson. The psychological and social origins of autobiographical memory. *Psychological science*, 4(1):7–14, 1993.

[20] Evangelos Niforatos, Veranika Lim, Christian Vuerich, Marc Langheinrich, and Agon Bexheti. Pulsecam: Biophysically driven life logging. In *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct*, pages 1002–1009. ACM, 2015.

[21] Masayuki Ono, Kunihiro Nishimura, Tomohiro Tanikawa, and Michitaka Hirose. Neural network based event estimation on lifelog from various sensors. In *Virtual Systems and Multimedia (VSMM), 2010 16th International Conference on*, pages 84–87. IEEE, 2010.

[22] Daniela Palomba, Alessandro Angrilli, and Alessio Mini. Visual evoked potentials, heart rate responses and memory to emotional pictorial stimuli. *International journal of psychophysiology*, 27(1):55–67, 1997.

[23] Polar Electro. *Polar*, 2017. `https://www.polar.com/us-en/products/sport/A360`.

[24] Reza Rawassizadeh, Martin Tomitsch, Katarzyna Wac, and A Min Tjoa. Ubiqlog: a generic mobile phone-based life-log framework. *Personal and ubiquitous computing*, 17(4):621–637, 2013.

[25] Daniel Reisberg and Paula Hertel. *Memory and emotion.* Oxford University Press, 2003.

[26] John A Robinson and DC Rubin. Autobiographical memory: A historical prologue. *Autobiographical memory*, pages 19–24, 1986.

[27] Jefferson A Singer and Peter Salovey. *Remembered self: emotion and memory in personality.* Simon and Schuster, 2010.

[28] Alan F. Smeaton, Kevin McGuinness, Cathal Gurrin, Jiang Zhou, Noel E. O'Connor, Peng Wang, Brian Davis, Lucas Azevedo, Andre Freitas, Louise Signal, Moira Smith, James Stanley, Michelle Barr, Tim Chambers, and Cliona Ní Mhurchu. Semantic indexing of wearable camera images: Kids'cam concepts. In *Proceedings of the 2016 ACM Workshop on Vision and Language Integration Meets Multimedia Fusion*, iV&L-MM '16, pages 27–34, New York, NY, USA, 2016. ACM.

[29] Techradar. *Autographer2*, July 2013. `http://www.techradar.com/reviews/cameras-and-camcorders/cameras/compact-cameras/omg-life-autographer-1169330/review`.

[30] Tom's guide. *Polar2*, March 2016. http://www.tomsguide.com/us/polar-a360,review-3450.html.

[31] Endel Tulving. Episodic memory: from mind to brain. *Annual review of psychology*, 53(1):1–25, 2002.

[32] Wikipedia. *Autographer*, March 2017. https://en.wikipedia.org/wiki/Autographer.

[33] Wikipedia. *Heat map*, April 2017. https://en.wikipedia.org/wiki/Heat_map.

[34] Wikipedia. *lifelog*, June 2017. https://en.wikipedia.org/wiki/Lifelog.

[35] Wikipedia. *LikertScale*, April 2017. https://en.wikipedia.org/wiki/Likert_scale.

[36] Li Xu and Jiaya Jia. Two-phase kernel estimation for robust motion deblurring. In *European Conference on Computer Vision*, pages 157–170. Springer, 2010.

Appendix A

How to use the system

A.1 Collect data

As we know, there are two devices involved into our research: Autographer and Polar A360. In the following parts, we will introduce how to use these devices to obtain information and update to the local sever.

A.1.1 Autographer

Once the autographer is already charged, we just push the button 'action' for seconds that depicts in Fig. A.1, after that we can see the front side of autographer screen is displayed: Electricity, Total images and Used images as Fig. A.2 shown. Then, we can change the options of autographer by pushing the button 'menu', if we would like to modify the status of each option, pressing the button 'action' and then the status will change. Fig. A.3 demostrates the option of capturing rate. There are three modes of capturing rate: fast, medium and low. Fig. A.4 stands for the GPS function, it is optional whether let it on or off. Fig. A.5 presents the status of autographer when taking photos, if the status is hide, that means there is no signal when taking photos; if the status is blink, that means there is a signal blinking when taking photos. Fig. A.6 illustrates the bluetooth function. Autographer provides two methods for data transmission: use a cable connect to the computer or use bluetooth to deliver the information.

When entire status of autographer have already settled, the participant is allowed to wear on via a neck band. And the device will collect the data automatically. When the user wants some privacy, he can press the 'action' button for seconds, and it will shut down soon.

Figure A.1: The open button of Autographer. Press that button for seconds and the device is on. we can shift the menu of autographer by forcing the button 'menu', if we would like to adjust the status of each option, press the button 'action' and then the status will change.

Figure A.2: The normal screen of Autographer when it is on, which illustrates three kinds of information: Electricity, Total images and Used images.

Figure A.3: The screen of Autographer's capturing rate. which demostrates the option of capturing rate, there are three modes of capturing rate: fast, medium and low.

Figure A.4: The screen of Autographer's GPS switch, which stands for the GPS function, it is optional whether let it on or off.

Figure A.5: The screen of Autographer's status of taking photos, which presents the status of autographer when taking photos, if the status is hide, that means there is no signal when taking photos; if the status is blink, that means there is a signal blinking when taking photos.

Figure A.6: The screen of Autographer's bluetooth switch, which illustrates the bluetooth function. Autographer provides two methods for data transmission: use a cable connect to the computer or use bluetooth to deliver the information.

A.1.2 Polar A360

Once the Polar A 360 is already charged, it will switch on automatically. Fig. A.7 explains the only button of Polar A360 for exiting or waking the screen, that means when you need to wake up the device, you should press that button; when you already load in one option, if you want to back to previous page, you should press that button as well. Fig. A.8 shows the basic screen of Polar A360. It displays the exact time along with the color change. When it is in the morning, the color is blue. And in the afternoon or evening, the color turns to yellow and orange. Fig. A.9 depicts the option of today and Fig. A.10 illustrates the details of today's record. The user can check the details of today's record, such as how many steps he has walked, how much time he has been training, the distance of today's walking or running and how many calories are consumed. Fig. A.11 presents the option of training and there are seven options as follow figure shown: Fig. A.12 walking, Fig. A.13 running, Fig. A.14 lifting, Fig. A.15 cycling, Fig. A.16 indoor, Fig. A.17 outdoor, and Fig. A.18 groupexercise. If the user wants to acquire the precise data of heart rate, he ought to select the appropriate options of training. After choosing one option, the screen will shift to the corresponding one and then the backside LEDs start to work,showing the real-time heart rate on the screen. Fig. A.19 portrays the option of heart rate, if the user touch the screen the device will start to detect the current heart rate. Besides, the user can switch the options by sliding the screen. There is one important thing that the heart rate can only be recorded when the device is on the training mode. If the user select the heart rate option, it can only detect the current heart rate and display on the screen without recording.

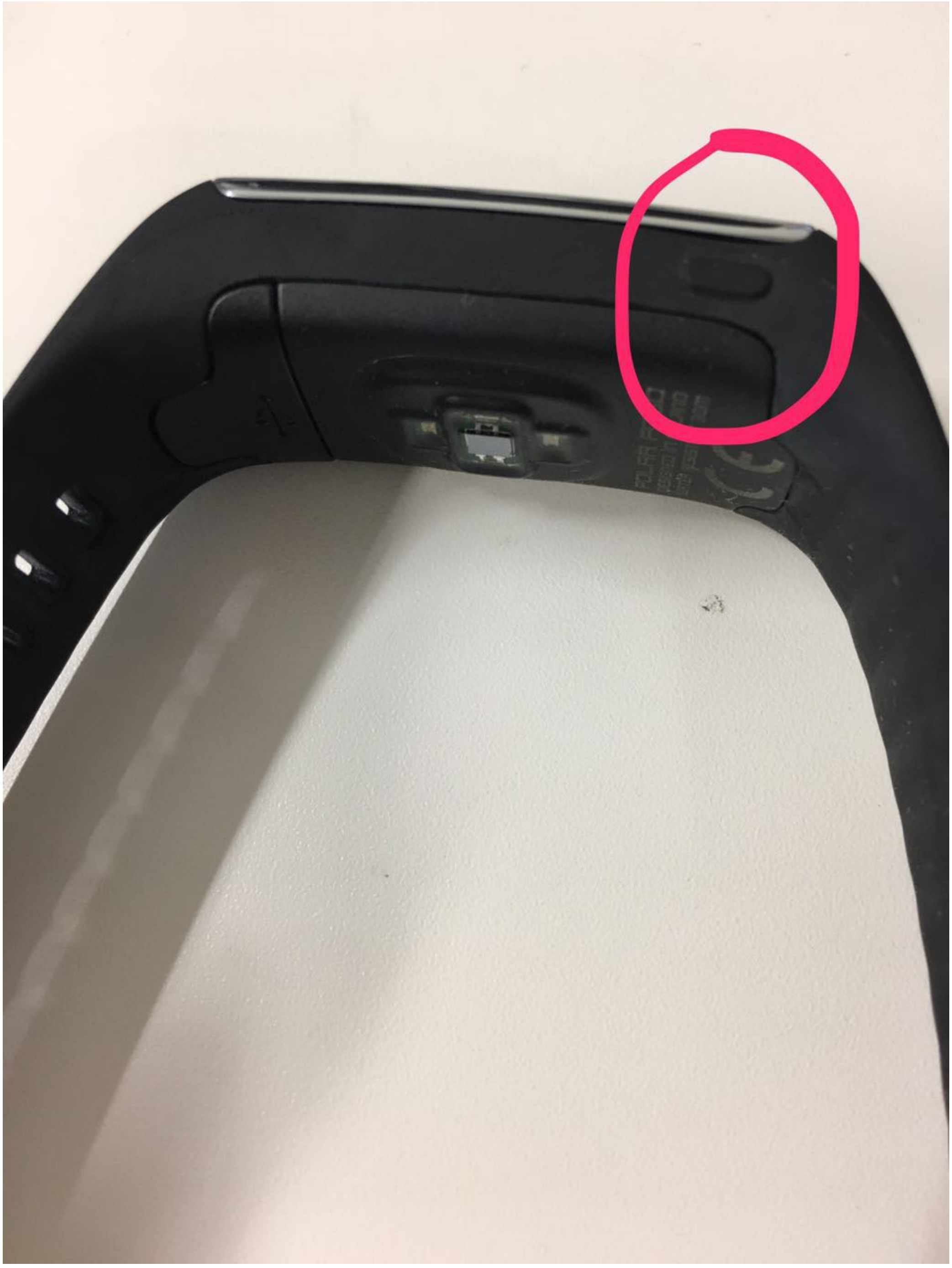


Figure A.7: The button of Polar A360 for exiting or waking the screen, that means when you need to wake up the device, you should press that button; when you already load in one option, if you want to back to previous page, you should press that button as well.

Figure A.8: The time screen of Polar A360 which displays the exact time along with the color change. When it is in the morning, the color is blue. And in the afternoon or evening, the color turns to yellow and orange.

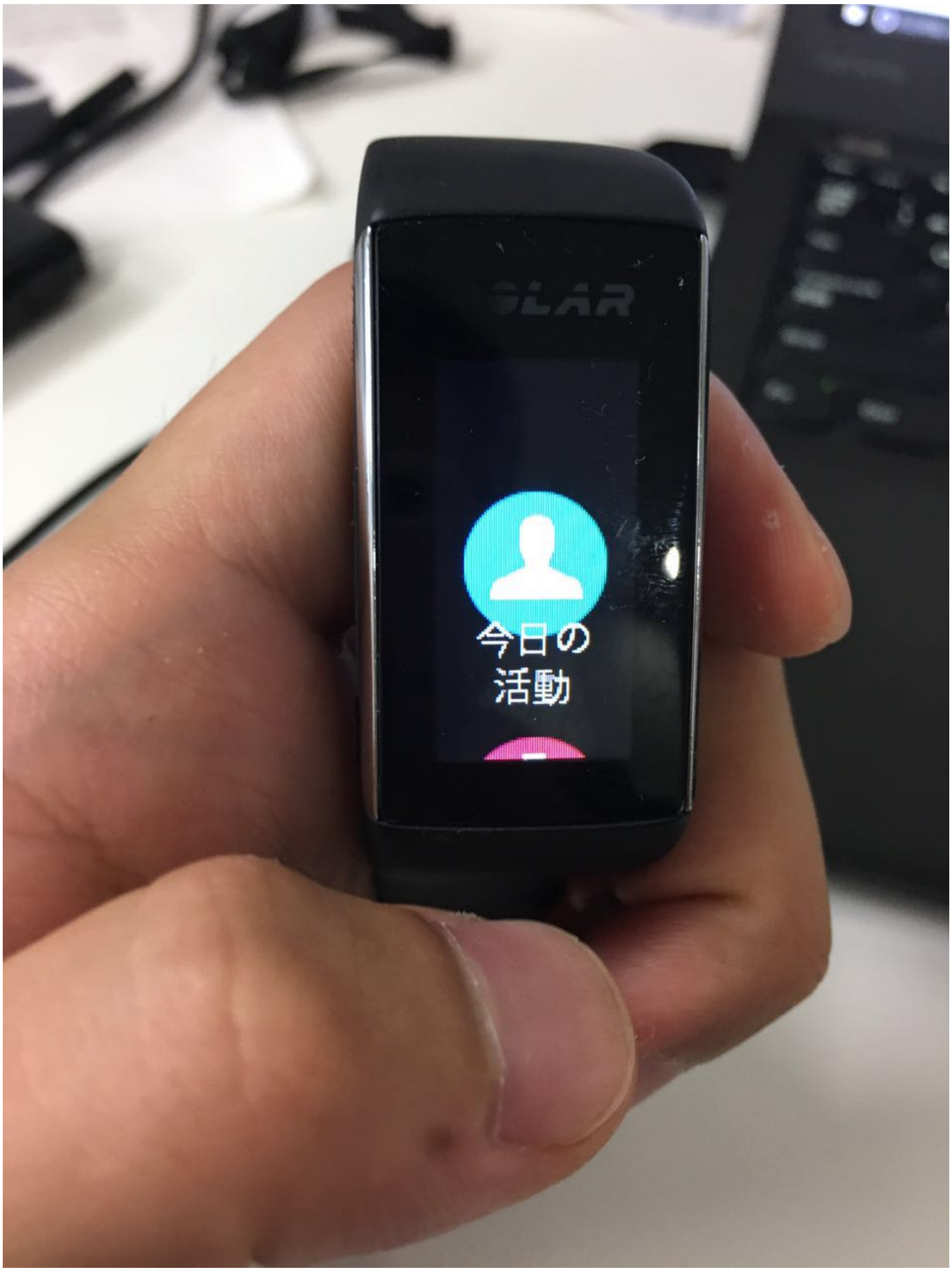


Figure A.9: The screen of today's option.

Figure A.10: The screen of details of today's option, which illustrates the details of today's record. The user can check the details of today's record, such as how many steps he has walked, how much time he has been training, the distance of today's walking or running and how many calories are consumed.

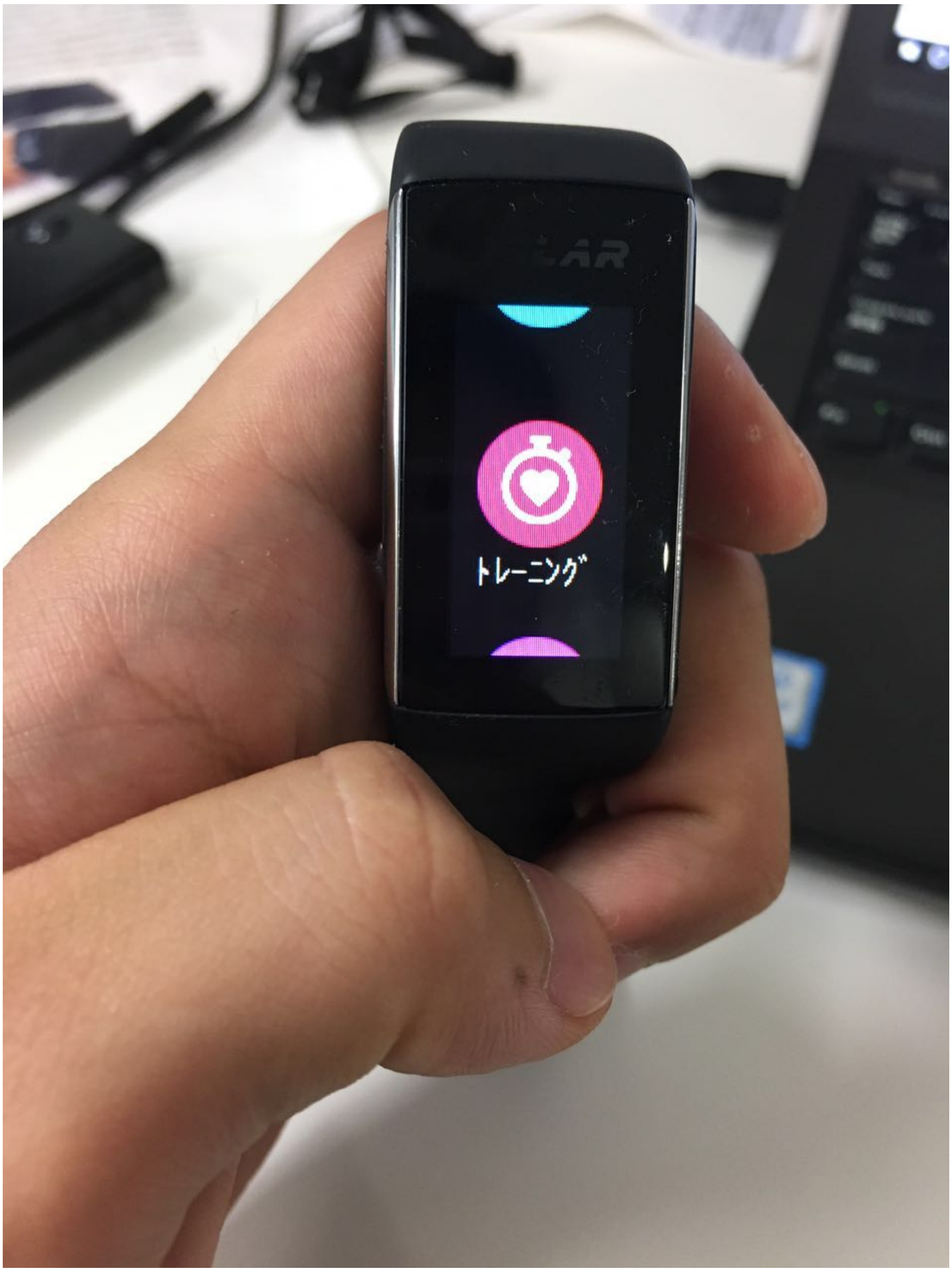


Figure A.11: The screen of training's option. Once you move into this option, there will be seven explicit selections of training activities.

Figure A.12: The option of walking, that means detect your real-time heart rate while you are walking

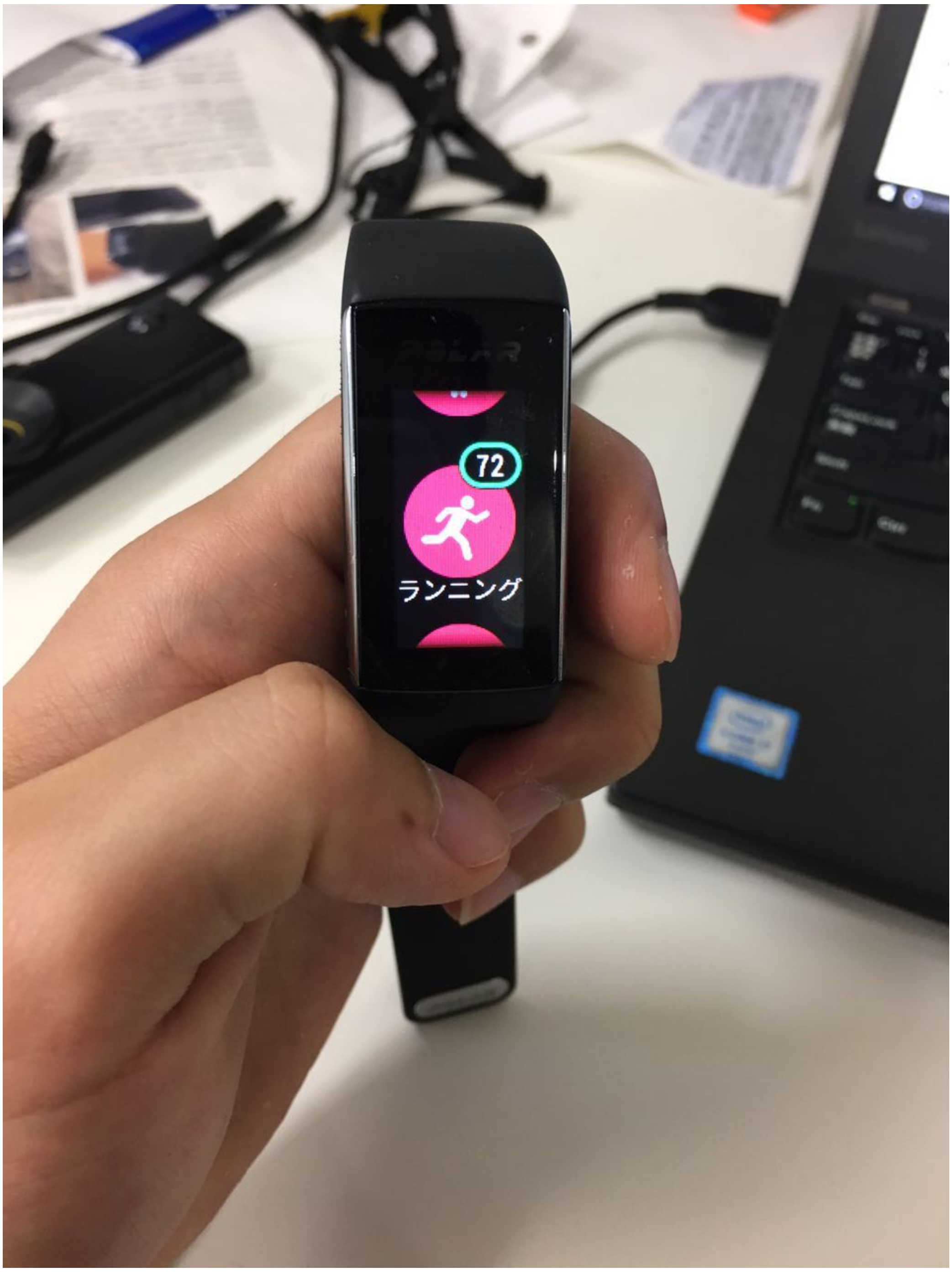


Figure A.13: The option of running, that means detect your real-time heart rate while you are running

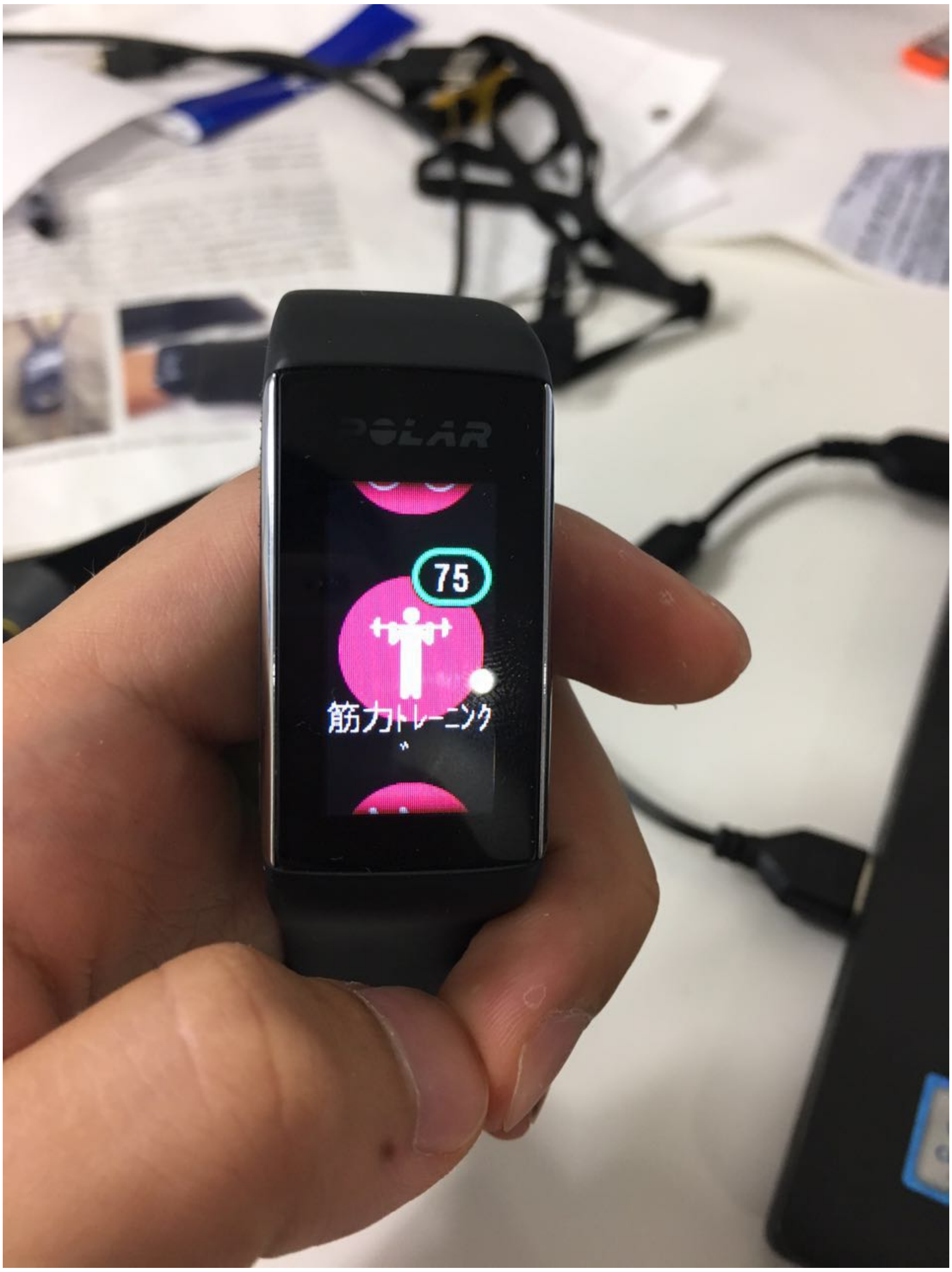


Figure A.14: The option of lifting, that means detect your real-time heart rate while you are lifting

Figure A.15: The option of cycling, that means detect your real-time heart rate while you are cycling.

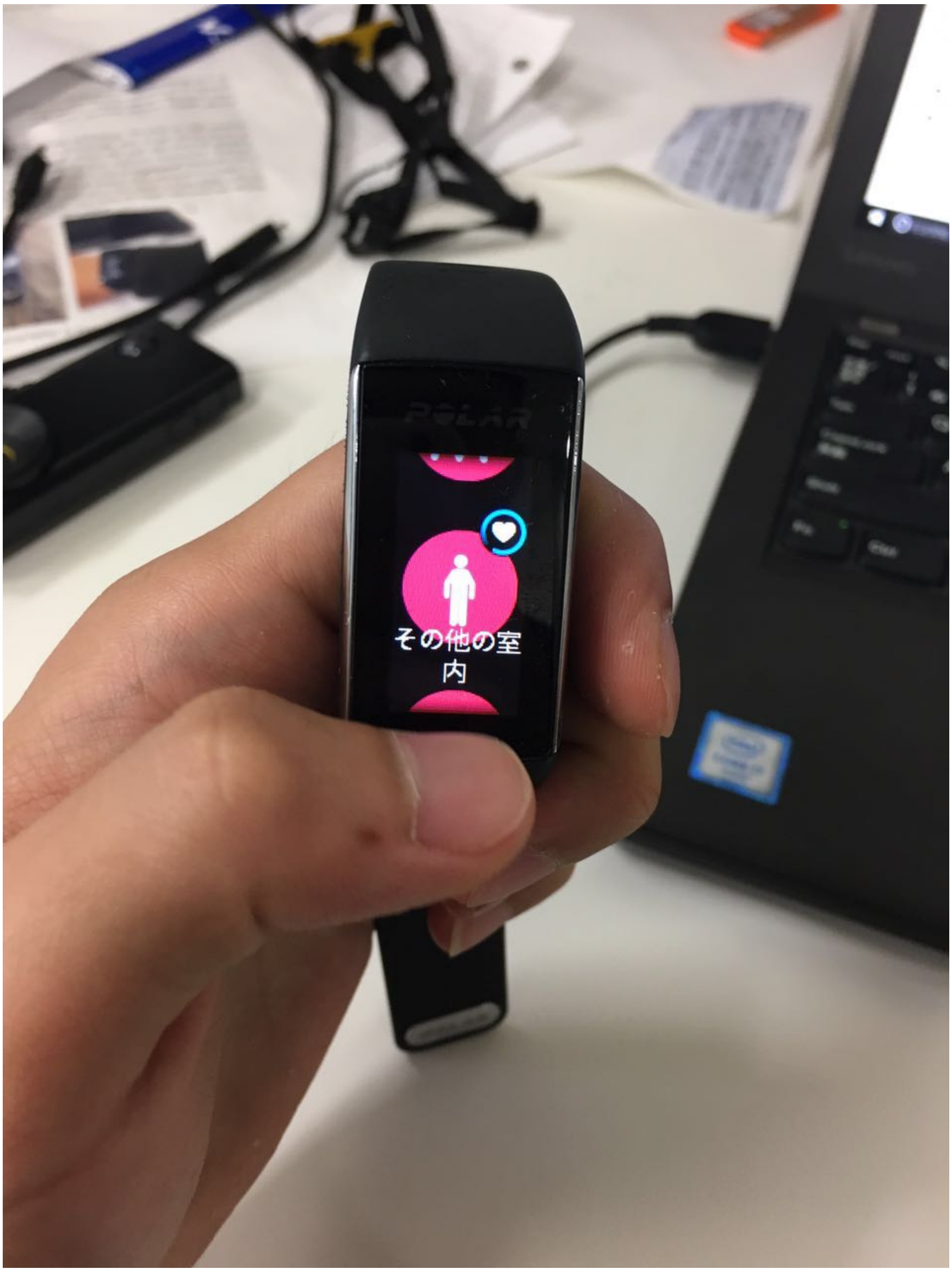


Figure A.16: The option of indoor, that means detect your real-time heart rate while you are doing indoor-activity.

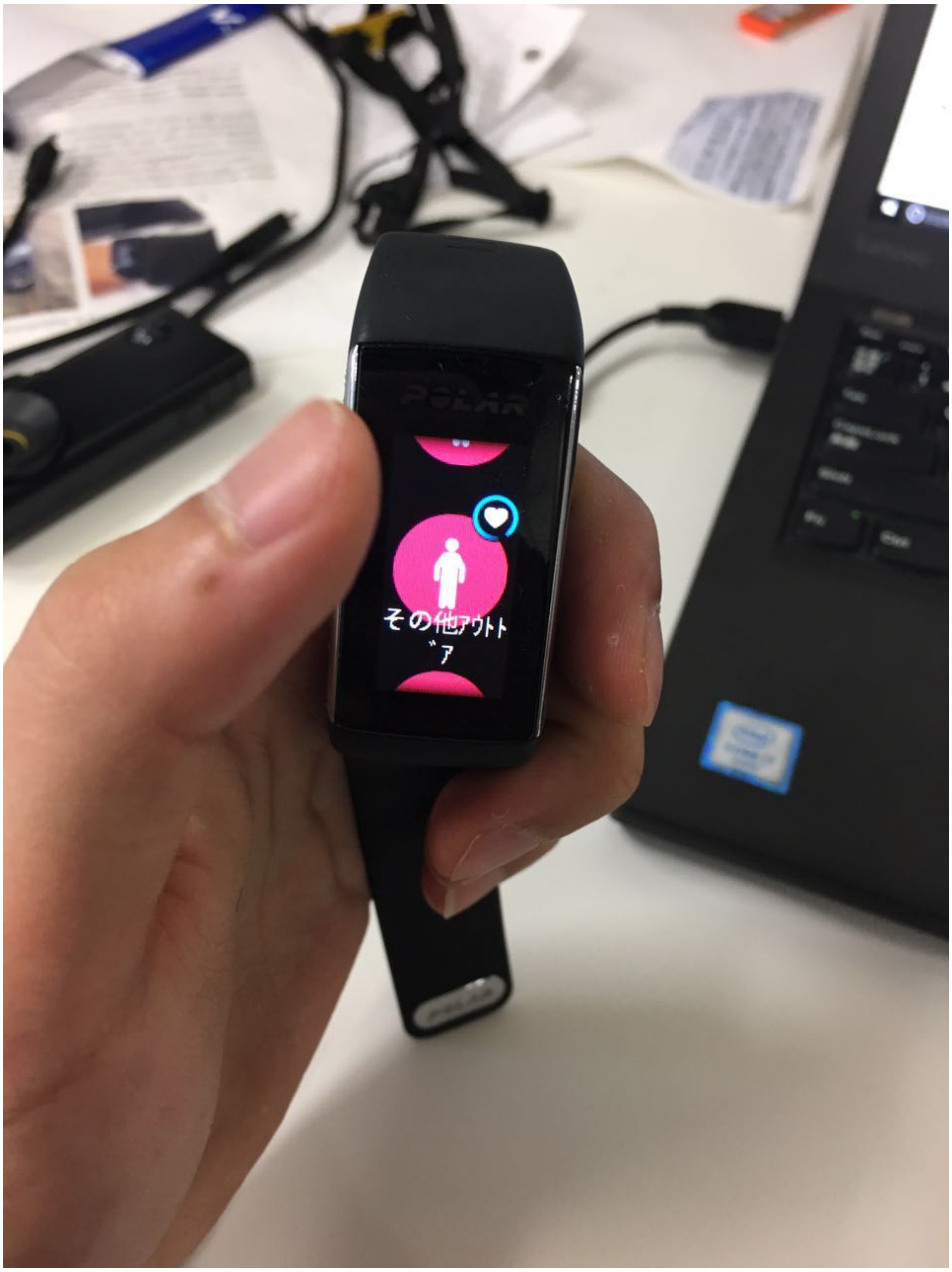


Figure A.17: The option of outdoor, that means detect your real-time heart rate while you are doing outdoor activity.

Figure A.18: The option of groupexercise, that means detect your real-time heart rate while you are doing groupexercise.

Figure A.19: The option of heartrate, that means detect your current heart rate no matter what you are doing now.

After that, we have to install the application for synchronization, called FlowSync. Fig. A.20 demonstrates the download page, it is very convenient for the user to download when typing flowsync in the google search and find the download link. Once installed, the application will startup as Fig. A.21 shows, it may take some time for starting over. And then, we only need to connect the device and press 'SYNC' button as Fig. A.22 illustrates, the application will read the data in the device and update to its network server. Please make sure the network is working. Wait for the data update completely, we can browse the whole captured data via the website as Fig. A.23. In that page, we can view the entire recorded data. Choose one existing record and we will see the detail of that day as Fig. A.24 represents. In the center of the page, the record is clearly demonstrated as the line chart. You can drag the mouse to see the value roughly. Due to the limitation of screen, the website can not provide every second's data. However, the data can be exported as a CSV file. At the buttom of this page, there is a option for exporting the data as Fig. A.25 interprets. Finally, we obtain the heart rate in a CSV file as Fig. A.26 draws.

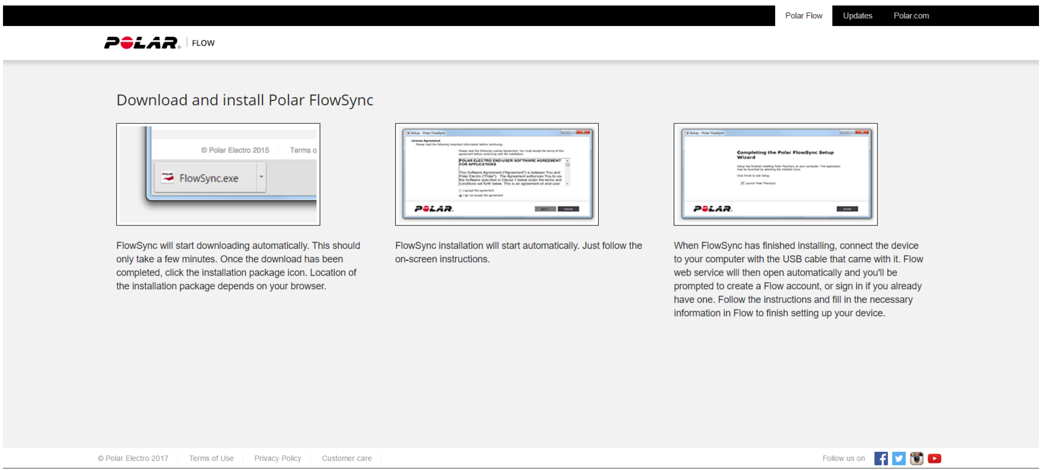


Figure A.20: The page of download FlowSync application, it is very convenient for the user to download when typing flowsync in the google search and find the download link..

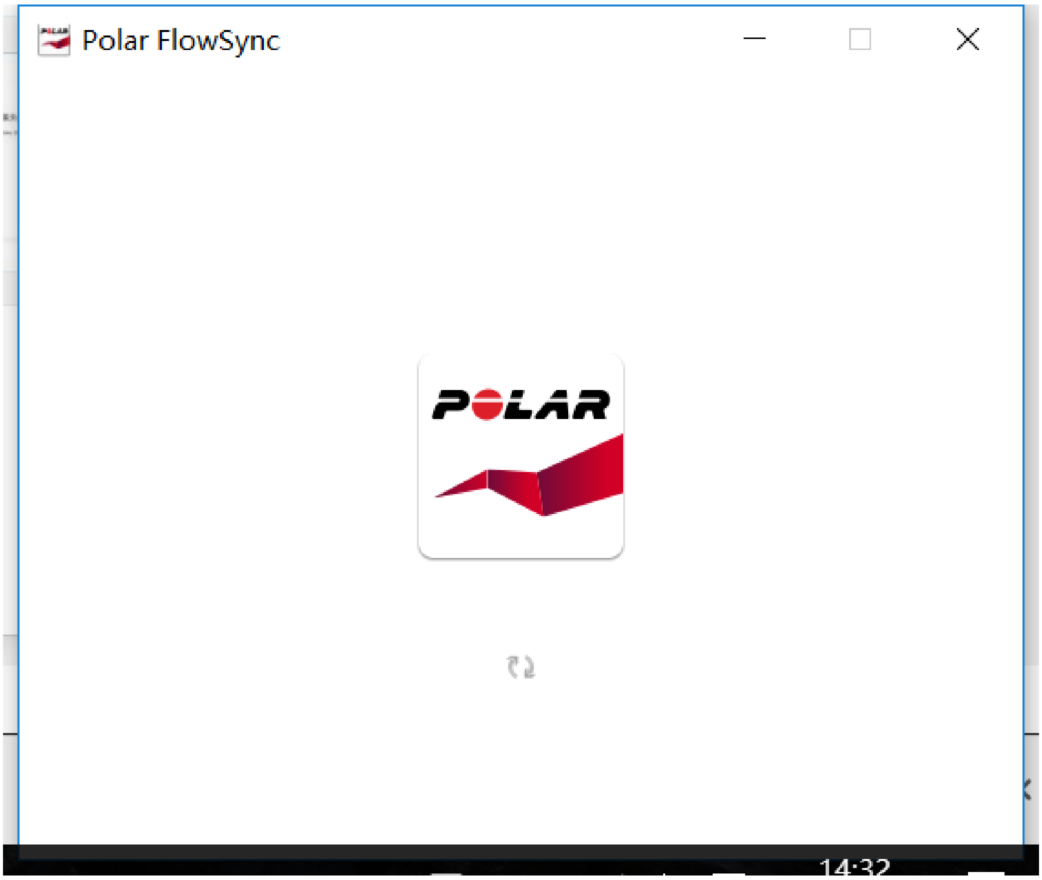


Figure A.21: The startup screenshot of FlowSync, it may take some time for starting over.

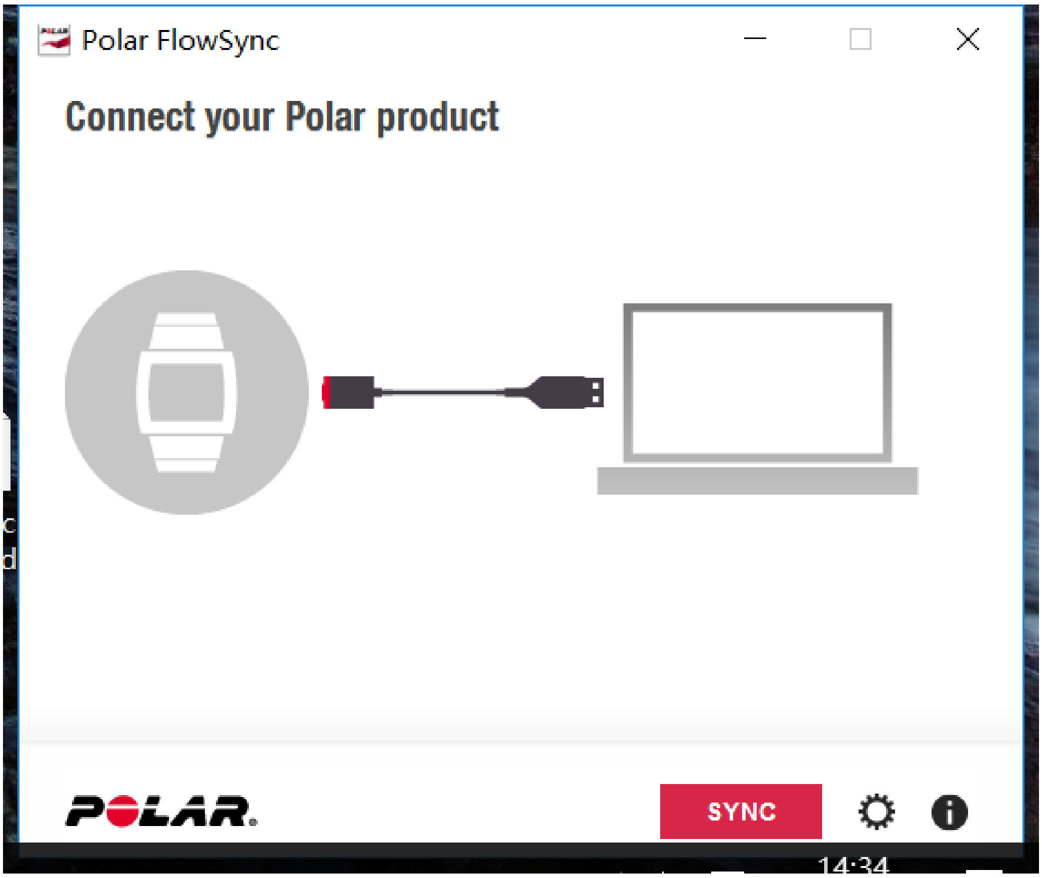


Figure A.22: The connection screenshot of FlowSync. Once connecting the device to the computer and clicking the 'sync' button, the application will read the data in the device and update to its network server.

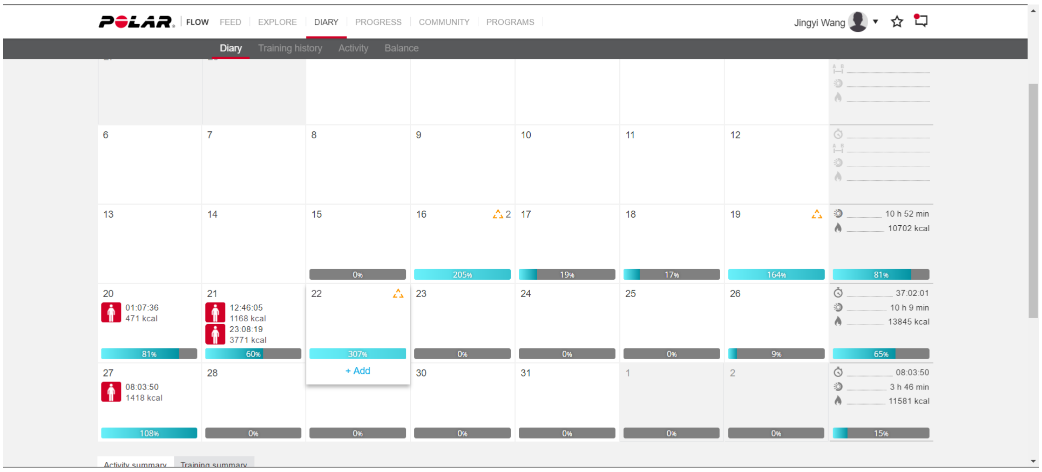


Figure A.23: The overview of updated heart rate data. We can browse the whole captured data via the website. In that page, we can view the entire recorded data.

Figure A.24: The screenshot of one-day heart rate data. In the center of the page, the record is clearly demonstrated as the line chart. You can drag the mouse to see the value roughly.

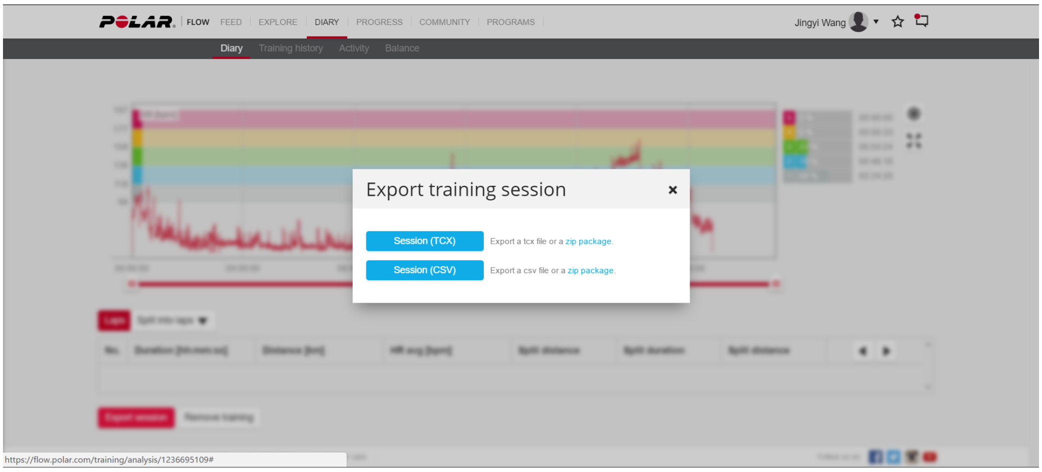
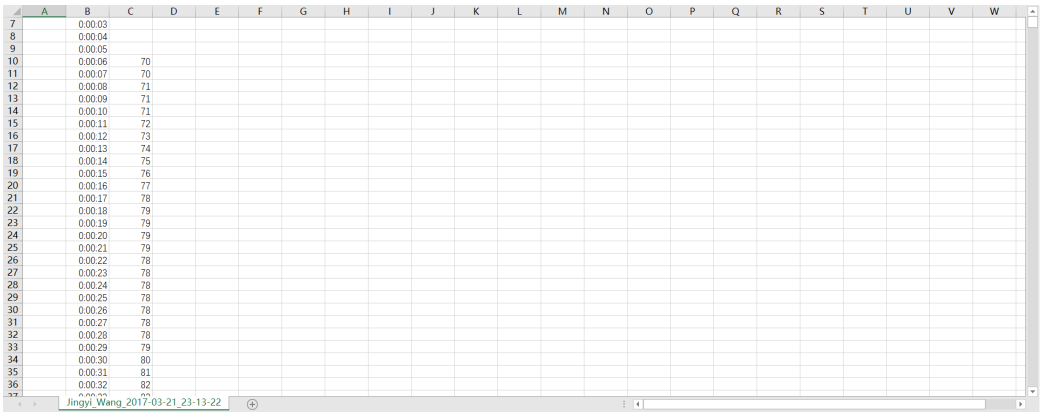


Figure A.25: The screenshot of export heart rate data. At the buttom of one-day page, there is a option for exporting the data, and press that 'export' button.



	A	B	C
7		0:00:03	
8		0:00:04	
9		0:00:05	
10		0:00:06	70
11		0:00:07	70
12		0:00:08	71
13		0:00:09	71
14		0:00:10	71
15		0:00:11	72
16		0:00:12	73
17		0:00:13	74
18		0:00:14	75
19		0:00:15	76
20		0:00:16	77
21		0:00:17	78
22		0:00:18	79
23		0:00:19	79
24		0:00:20	79
25		0:00:21	79
26		0:00:22	78
27		0:00:23	78
28		0:00:24	78
29		0:00:25	78
30		0:00:26	78
31		0:00:27	78
32		0:00:28	78
33		0:00:29	79
34		0:00:30	80
35		0:00:31	81
36		0:00:32	82

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Figure A.26: The screenshot of heart rate data file.

A.2 Process data

Based on Li Xu and Jiaya Jia Two-Phase Sparse Kernel Estimation for Robust Motion Deblurring, they have developed a software for images processing. Fig.A.27 is the screenshot of the entire Robust Motion Deblurring system. And then, Fig.A.28 explains the system has already loaded the pro-

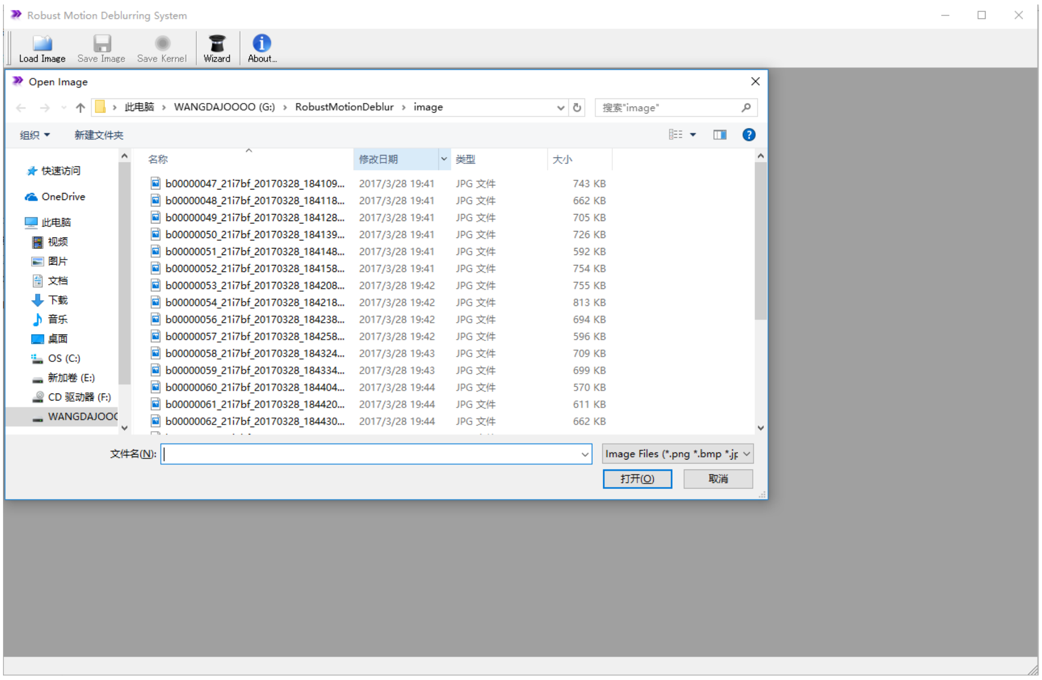


Figure A.27: The overview of Robust Motion Deblurring system.

cessing image. Ultimately, Fig.A.29 demonstrateds the result of employing robust motion deblurring.

After completing the collection of pictures, all the pictures should be preprocessed with this method, get the next step in the need for images. The following Fig.A.30 explains how their algorithm works.

As for heart rate data, we can use excel to process it by calculating the average of every 30 secons. And the result is shown as Fig.A.31.

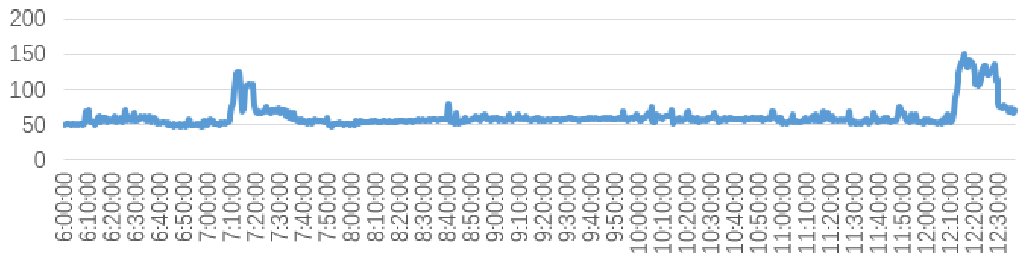


Figure A.31: The part of normalized heart rate data corresponding to the previous data, which is captured by the participant.

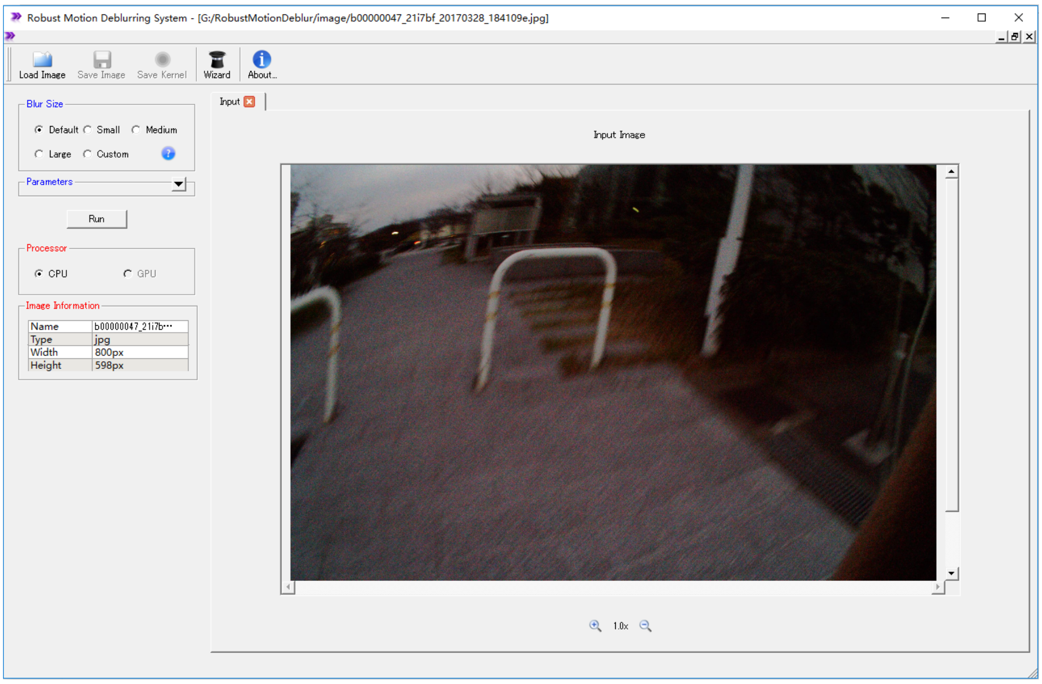


Figure A.28: The screenshot of deblurring system after selecting the intended image.

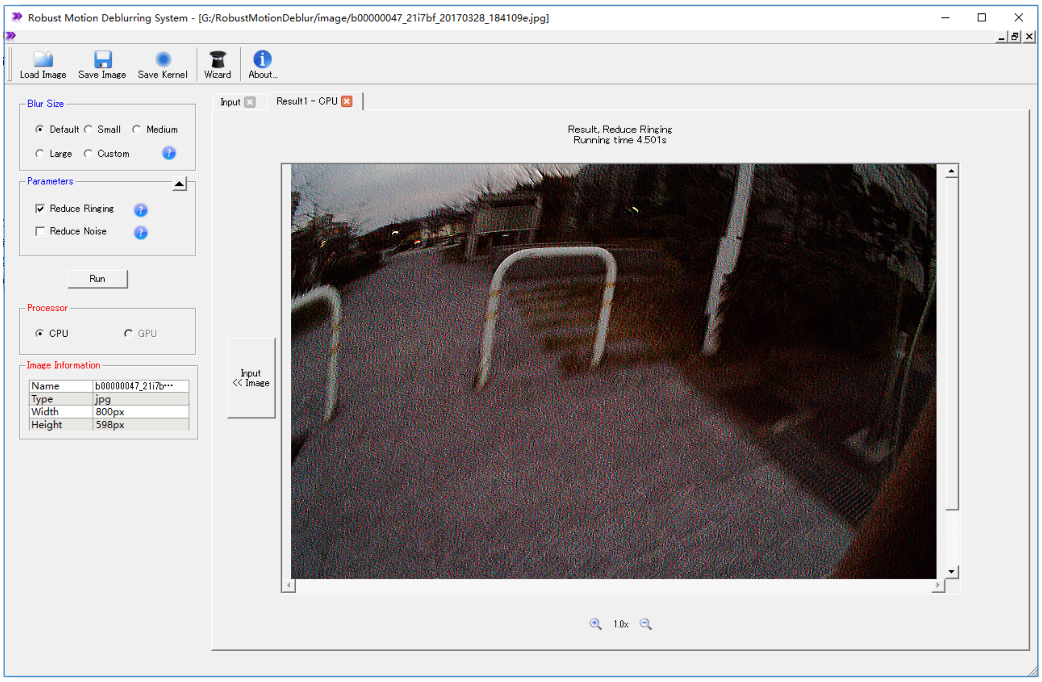


Figure A.29: The screenshot of deblurring system after processing the intended image.

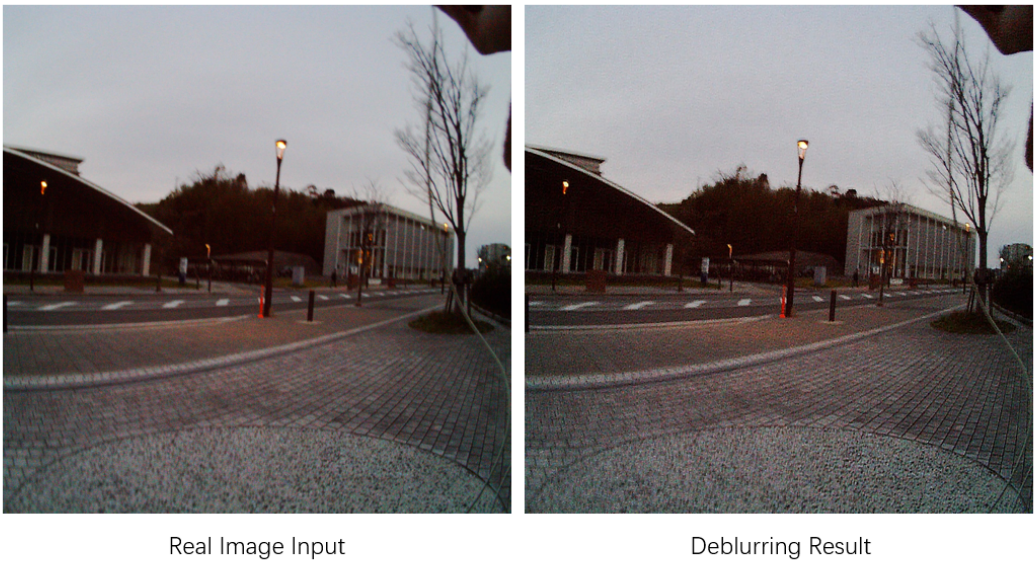


Figure A.30: Lifelog image input (L) and processed image after deblurring (R), which is captured by the participant outside the campus.

And then, we could extract a series of image flows in accordance with the sudden change of heart rate data after normalization. Fig.A.32 depicts how the heart rate and image are combined and screened out of the extracting of the part. The top part shows the heart rate after normalization and synchronization, and the bottom part explains the image flow that user captured during the exact period. Once those two information are aligned, it is easy to know the correspondence between pictures and heart rate. In this figure, the highlight parts explain the prompt changes of heart rate, which also indicates the processing part.

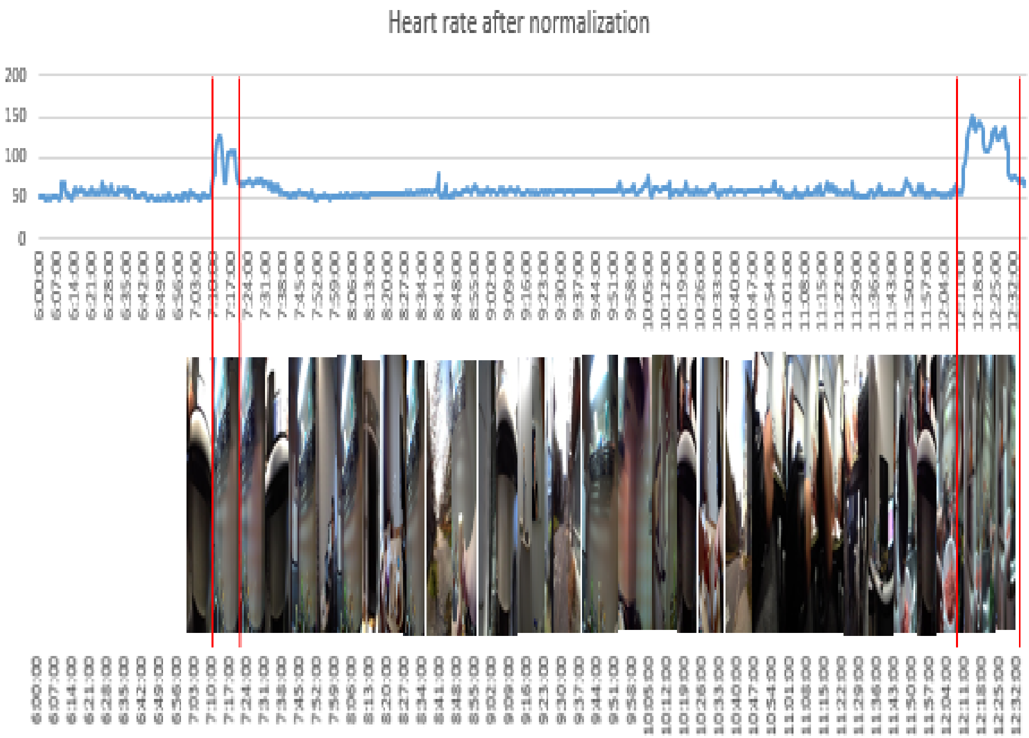
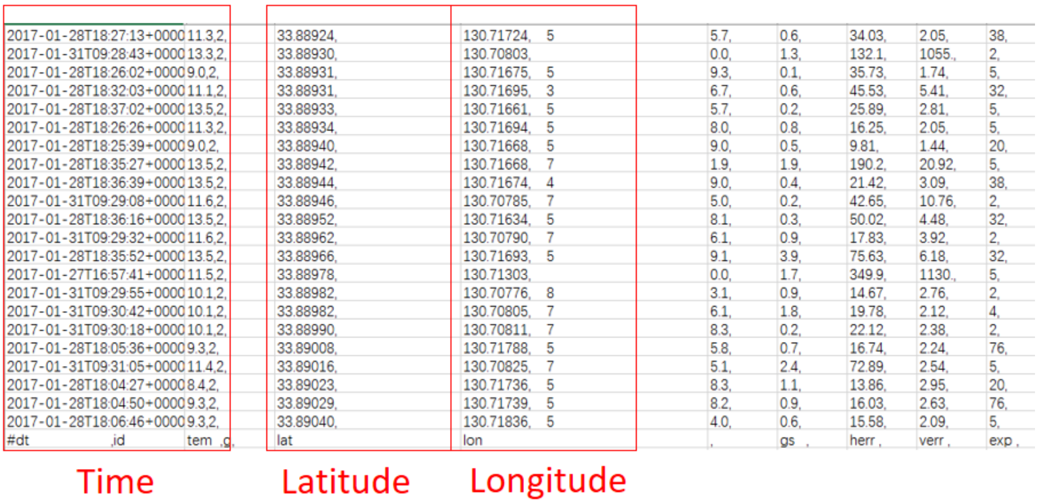


Figure A.32: According to the temporal information, we synchronize heart rate data with the captured images.

Finally, make the extraction parts into episodic events. Fig.A.33 is highlighted that only two parts are processed, the definition of the events given by user himself.

Figure A.33: After unifying both heart rate data and images, extract episodic events based on the sudden change of heart rate obtained by participant.

With respect to the Spatial Frequency Approach, the most important thing is to associate location spot with images. First of all, we have to export the GPS information by the Autographer as Fig.A.34 illustrates. Secondly, call Google Map API and import the GPS information for generating heat map as Fig.A.35 explains. Ultimately, match the image with location spot according to the temporal information as Fig.A.36 presents.



2017-01-28T18:27:13+0000 11.3,2,	33.88924,	130.71724,	5	5.7,	0.6,	34.03,	2.05,	38,
2017-01-31T09:28:43+0000 13.3,2,	33.88930,	130.70803,		0.0,	1.3,	132.1,	1055.,	2,
2017-01-28T18:26:02+0000 9.0,2,	33.88931,	130.71675,	5	9.3,	0.1,	35.73,	1.74,	5,
2017-01-28T18:32:03+0000 11.1,2,	33.88931,	130.71695,	3	6.7,	0.6,	45.53,	5.41,	32,
2017-01-28T18:37:02+0000 13.5,2,	33.88933,	130.71661,	5	5.7,	0.2,	25.89,	2.81,	5,
2017-01-28T18:26:26+0000 11.3,2,	33.88934,	130.71694,	5	8.0,	0.8,	16.25,	2.05,	5,
2017-01-28T18:25:39+0000 9.0,2,	33.88940,	130.71668,	5	9.0,	0.5,	9.81,	1.44,	20,
2017-01-28T18:35:27+0000 13.5,2,	33.88942,	130.71668,	7	1.9,	1.9,	190.2,	20.92,	5,
2017-01-28T18:36:39+0000 13.5,2,	33.88944,	130.71674,	4	9.0,	0.4,	21.42,	3.09,	38,
2017-01-31T09:29:08+0000 11.6,2,	33.88946,	130.70785,	7	5.0,	0.2,	42.65,	10.76,	2,
2017-01-28T18:36:16+0000 13.5,2,	33.88952,	130.71634,	5	8.1,	0.3,	50.02,	4.48,	32,
2017-01-31T09:29:32+0000 11.6,2,	33.88962,	130.70790,	7	6.1,	0.9,	17.83,	3.92,	2,
2017-01-28T18:35:52+0000 13.5,2,	33.88966,	130.71693,	5	9.1,	3.9,	75.63,	6.18,	32,
2017-01-27T16:57:41+0000 11.5,2,	33.88978,	130.71303,		0.0,	1.7,	349.9,	1130.,	5,
2017-01-31T09:29:55+0000 10.1,2,	33.88982,	130.70776,	8	3.1,	0.9,	14.67,	2.76,	2,
2017-01-31T09:30:42+0000 10.1,2,	33.88982,	130.70805,	7	6.1,	1.8,	19.78,	2.12,	4,
2017-01-31T09:30:18+0000 10.1,2,	33.88990,	130.70811,	7	8.3,	0.2,	22.12,	2.38,	2,
2017-01-28T18:05:36+0000 9.3,2,	33.89008,	130.71788,	5	5.8,	0.7,	16.74,	2.24,	76,
2017-01-31T09:31:05+0000 11.4,2,	33.89016,	130.70825,	7	5.1,	2.4,	72.89,	2.54,	5,
2017-01-28T18:04:27+0000 8.4,2,	33.89023,	130.71736,	5	8.3,	1.1,	13.86,	2.95,	20,
2017-01-28T18:04:50+0000 9.3,2,	33.89029,	130.71739,	5	8.2,	0.9,	16.03,	2.63,	76,
2017-01-28T18:06:46+0000 9.3,2,	33.89040,	130.71836,	5	4.0,	0.6,	15.58,	2.09,	5,
#dt ,id tem ,g,	lat	lon		,	gs ,	herr ,	verr ,	exp ,

Figure A.34: The screenshot of excel file of GPS information provided by Autographer.

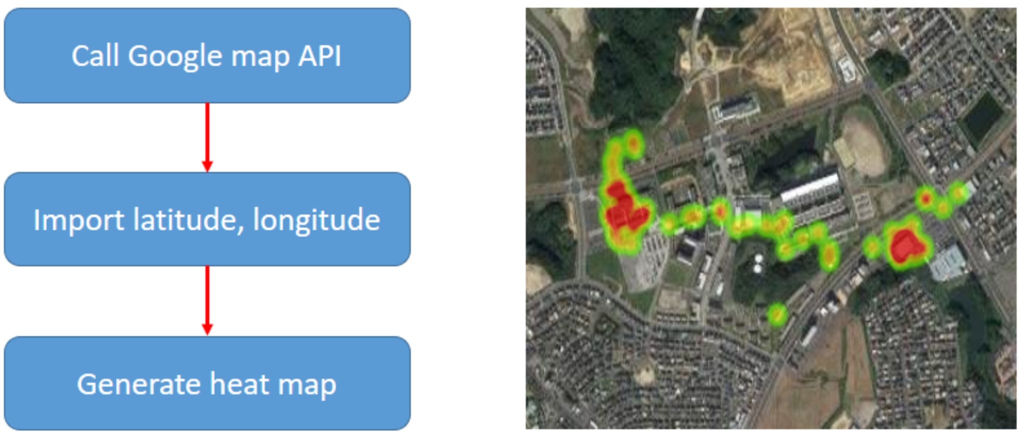


Figure A.35: The procedure of generating heatmap calling Google API (L) and the result of heatmap processing Google API (R).

Figure A.36: The prototype of reviewing system: The entire heatmap including all the location spots and the highlight spot indicates the spot that the user is browsing (L) and the corresponding image to the specific spot (R).