# Application for pre-processing and visualization of electrodermal activity wearable data

# Application for pre-processing and visualization of electrodermal activity wearable data

K. Suoja[1], J. Liukkonen[1], J. Jussila[1,2], H. Salonius[1], N. Venho[1], V. Sillanpää[2], V. Vuori[2] and N. Helander[2]
[1]Moodmetric, Tampere, Finland
[2]Industrial and Information Management, Tampere University of Technology, Tampere, Finland

*Abstract*— **Using sensors to gather physiological data about users can provide valuable insights that are not available merely using traditional measures. Electrodermal activity (EDA) can act as an indicator for both physiological and psychological arousal. Measuring arousal has several application areas. For instance, prolonged and often recurring high arousal levels can indicate that a person is suffering from chronic stress. At the other extreme, for example, in elderly care constant low arousal levels can signal that the senior citizens are not getting enough activity and attention from the care personnel. In the context of events, measurement of arousal can indicate when the persons get excited and when they are more calm. This study presents a pilot study of EDA measurements conducted during a trade fair. Providing timely and meaningful information for a group of people being measured, however, requires pre-processing the data and creating visualizations that enable both individual and collective level sense-making of the results. The aim of this study was to develop a process and an open source application that can automatically pre-process large amounts of data from wearable sources, and create visualizations, to be used in events for immediate sense-making.**

*Keywords*— **wearable, electrodermal activity, data pre-processing, visualization, health informatics**

## I. Introduction

Using sensors to gather physiological data about users can provide valuable insights that are not available merely using traditional measures [1]. Electrodermal activity (EDA) measurement is one way to obtain signals of physiological reactions. Recently portable EDA devices have become available, which make EDA measurement appealing for both psychological research and clinical use [2]. In psychological research, wearable EDA sensors allow experiments to take place in more ecologically valid settings [3], while in health care wearable EDA sensors enable continuous physiological monitoring at a relatively low cost [4] [2].

EDA reflects the activity of the sympathetic nervous system and can be measured through the changes in electrical conductance of the skin [5]. The sweat glands activate as a response to the unconscious actions of the human body regulated by the autonomic nervous system. The sweat glands are exclusively innervated by the sympathetic nervous system [6], which makes skin conductance an ideal measure for sympathetic activation in contrast to other physiological measures (e.g. the heart rate) that are influenced by both the sympathetic and the parasympathetic nervous systems [7]. EDA can serve as indicator of both physiological and psychological arousal, and by extension, a measure of cognitive and emotional activity [8].

The Moodmetric smart ring used in the study is a biosensor measuring EDA from the palmar site of the wearer's hand. Palmar sites of the hands or the feet are typically used for EDA measurement, because that is where the density of sweat glands is the highest (>2000/cm2) [4]. The ring transfers the EDA reading from the ring's memory to a smartphone application by Bluetooth (BT). Therefore, the user is not constrained to stay within the range of a base station, because the ring acts both as a data forwarding and data logging device. This enables unrestricted continuous measurement regardless of location. The earlier prototype of the Moodmetric ring has been tested by the Finnish Institute of Occupational Health and founded as a valid tool for field studies [8].

The aim of this study was to develop a process and an open source application that can automatically pre-process large amounts of wearable data, and create visualizations, which can be used in events for instant individual and collective level sense-making. A pilot study of EDA measurements were conducted during a trade fair in order to test and further develop the application.

## II. Materials and Methods

The EDA measurement data was gathered from 10 users during one day (ca. 8-10 hours) in a trade fair. The wearable devices were worn by sales representatives marketing their company and its services to buyers within 15 minute "speed dating" slots of one-on-one sales meetings. These sort of events are usually somewhat hectic and require ongoing focus and attention from the sales personnel aiming to present their offerings to a potential customer in a rather short time-slot. It can be presumed that the circumstances cause arousal to some extent, which made the sales personnel an interesting research group for EDA measurement.

The wearable devices were delivered to the users in the beginning of the day followed by a short briefing of its use to ensure the acquiring of good quality data. During the day the users were briefly interviewed and asked if they could pinpoint a time of an extremely good and extremely bad sales encounter they may have had so far. This was done in order to be able in the analysis phase to examine whether those moments would stand out in the EDA measurement data of each user. At the end of the day the wearable devices were collected from the users with a promise to deliver a concise analysis of the user's data and its implications later on. The rings were labeled to ensure that the ring data would be connected to the exact user and their interview. The next section reports processing and visualizing gathered EDA data from the trade fair by using example data visualization from data of one user.

## III. Application for Data Processing and Visualization

### A. The need for the application

Basic application for processing and visualizing Moodmetric ring data is available on iOS mobile devices and Android devices. Existing application provides sufficient basic functionality for monitoring and tracking personal activity for one individual. However, Moodmetric rings are also used in many research projects, where data is recorded from several individuals that are wearing the ring and participating in similar activities. After the recording period, each individual's data need to be collected from the mobile application to enable their processing and combining for research purposes. The data pre-processing and combining phase has been most time-consuming phase requiring tedious manual work from the researchers. A clear need has been identified to automate this phase to save the time for actual research tasks. Automated pre-processing also improves the reliability of the data-analysis while also preventing possible human errors due to the manual work.

Solution for this need is an application which is capable of handling several database files produced by the mobile application for each ring and research target group member. Database files are downloaded from the mobile devices to a PC/Mac folder used as input data location for the application. The default data collection approach consists of ring-mobile device pairs, where database files can be simple downloaded from the mobile device to the input folder.

The developed application for efficiently pre-processing multiple ring data is an R-Script available as Open Source from GitHub: https://github.com/KariSuoja/MoodmetricDataViz. User needs, in minimum, to download and install R free software environment to be able to use the tool.

### B. Using the application

The user's EDA data is stored in the ring and as a first step this data is read via BT connection into a dedicated mobile application. The application stores the data locally into a relational database, from where the EDA data needs to be transferred into file storage in a personal computer/laptop. Database files which will be processed are stored to the input folder of the application. Database files need to be named unambiguously for identification and appropriately to the research project to ensure participants' privacy. Given database names are used for identifying data in output files produced by the tool. It is recommended to use generic names like User1, User2, etc.

The data processing and visualization tool loops through all the stored database files, pre-processes the content, calculates further usable data values based on measurement data and generates easily understandable visualization from the data. The user of the tool can beforehand define, which measurement time interval is in his special interest and from that time interval the tool provides easily readable, compact visualization.

The output files are written in separate folder where there is one summary Excel workbook for all given measurement data and dedicated Excel workbooks for each database input files. The data in the workbooks are separated in worksheets based on the content, figures have their own worksheet, graphs their own and each of the actual numeric information is in their own sheet. The naming of the output files follows the naming of the given input database files. The process is illustrated in Figure 1.

The measurement data contains typically breaks due to various human reasons (people take the ring off the finger for a short period of time for washing their hands, etc.), which need to be taken into account in data processing. Tool identifies the breaks, makes the calculations accordingly and pays attention to them especially in visualization of the measurements and in numeric results. The tool also adds in the worksheets the length of the actual sample data i.e. the total amount of sample minutes (breaks taken into account).

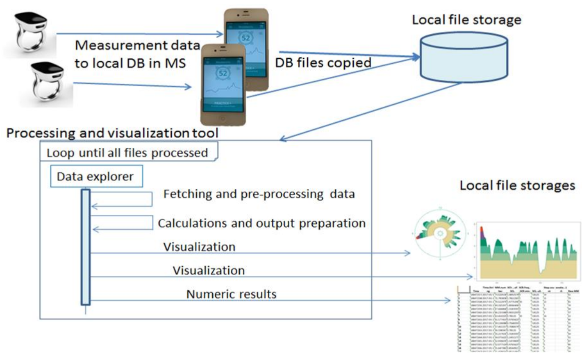


Fig. 1 Process of EDA data processing and visualization.

## C. *Data outputs*

Data outputs include a trend curve, a flower diagram and the data in table form for the selected processing period.

Data visualizations are produced as multiple overlapping polygons. In the visualization, starting from top to bottom, the first polygon will fill the whole area of measurements with indicative color of the highest measurement level (red in this example). The next polygon will fill the area of measurements with overlapping color representative of the second highest measurement level, e.g. in this case the red color will remain visible in areas where the measurement value is higher than the predefined maximum value for second level indicated as purple color. This procedure will be repeated for the other levels.

The first data visualization using the previously described visualization procedure, trend curve is produced for each participant to visualize the Moodmetric MM level value variation during the selected time period. Trend curve is filled with colors from red to beige to emphasize the MM level (Fig. 2).

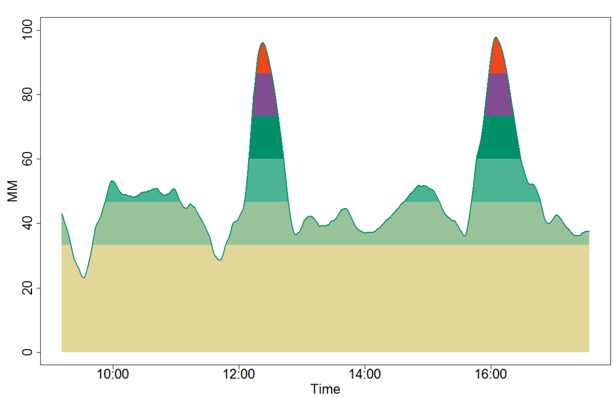


Fig. 2 Trend curve

The second data visualization produces the Flower diagram, which follows the same principles as the mobile application in presenting Moodmetric MM level as twelve hours sets. One set is for daytime i.e. from 6:00 to 18:00 and another for nighttime i.e. from 18:00 to 6:00. The data processing tool creates as many twelve-hour diagrams as needed to cover the given time period. Color coding for Flower diagram is identical to the coding on trend curves (Fig. 3).

The application converts the MM value data to polar coordinate values for plotting the Flower diagram, each of the twelve-hour sets representing a full circle. Polar coordinate values are calculated separately for each color coding zones taking in account of the maximum value of each zone. The application produces the Flower diagram by plotting the calculated polar coordinate values as polygons starting from the highest color coding zone.

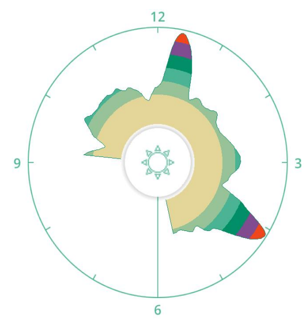


Fig. 3 Flower Diagram

The application provides the MM value data used for trend curve and Flower diagram also in numeric format for further processing and analyzing as needed for the research project (Table 1). In addition to the MM values the Excel work sheet for numeric values includes: time stamp, activations per minute / skin reactions per minute (SCR frequency), % of SCL value (SCV value), raw level of conductance of the skin (SCL), step count and MM value as received from the Moodmetric ring.

Table 1 Data in table form.

| | Time | Time String | MM Value | SCV (% of SCL) | SCR freq. (SCR/min) | SCL (uS) | Step count | Raw MM |
|---|---|---|---|---|---|---|---|---|
| 1 | 1484723495 | 2017-01-18 09:11 | 43,12 | 1,64 | 1 | 2,60 | 8 | 67 |
| 2 | 1484723555 | 2017-01-18 09:12 | 42,26 | 1,46 | 0 | 2,23 | 21 | 60 |
| 3 | 1484723615 | 2017-01-18 09:13 | 41,21 | 1,25 | 2 | 2,23 | 11 | 51 |
| 4 | 1484723675 | 2017-01-18 09:14 | 40,18 | 0,93 | 30 | 2,60 | 16 | 38 |
| 5 | 1484723735 | 2017-01-18 09:15 | 39,25 | 0,85 | 2 | 2,60 | 4 | 35 |
| 6 | 1484723795 | 2017-01-18 09:16 | 38,39 | 0,63 | 2 | 2,60 | 8 | 26 |
| 7 | 1484723855 | 2017-01-18 09:17 | 37,10 | 0,88 | 30 | 3,91 | 22 | 36 |
| 8 | 1484723915 | 2017-01-18 09:18 | 35,95 | 1,15 | 2 | 3,91 | 1 | 47 |
| 9 | 1484723975 | 2017-01-18 09:19 | 34,62 | 0,88 | 2 | 5,21 | 7 | 36 |
| 10 | 1484724035 | 2017-01-18 09:20 | 33,23 | 0,90 | 0 | 3,91 | 0 | 37 |
| 11 | 1484724095 | 2017-01-18 09:21 | 31,71 | 0,71 | 0 | 3,91 | 0 | 29 |
| 12 | 1484724155 | 2017-01-18 09:22 | 30,19 | 0,56 | 1 | 5,21 | 1 | 23 |
| 13 | 1484724215 | 2017-01-18 09:23 | 28,98 | 0,59 | 0 | 5,21 | 2 | 24 |
| 14 | 1484724275 | 2017-01-18 09:24 | 28,03 | 0,71 | 0 | 5,21 | 11 | 29 |
| 15 | 1484724335 | 2017-01-18 09:25 | 27,24 | 0,63 | 0 | 5,21 | 1 | 26 |
| 16 | 1484724395 | 2017-01-18 09:26 | 26,54 | 0,56 | 0 | 5,21 | 0 | 23 |
| 17 | 1484724455 | 2017-01-18 09:27 | 25,97 | 0,93 | 1 | 5,21 | 7 | 38 |
| 18 | 1484724515 | 2017-01-18 09:28 | 25,21 | 0,93 | 0 | 5,21 | 0 | 38 |
| 19 | 1484724575 | 2017-01-18 09:29 | 24,34 | 0,66 | 0 | 5,21 | 0 | 27 |
| 20 | 1484724635 | 2017-01-18 09:30 | 23,60 | 0,42 | 0 | 5,21 | 0 | 17 |

## IV. Future Development

Currently the application limits the calculations and visualizations of EDA data to max 24 hours, which the end user preselects in the start of the application. This limitation is set to avoid extensive data dumps to end user disk as by default the measurement data rate is one sample per minute. When EDA data is processed from a much longer time interval (e.g. one year) there is need to delicately compress the results especially for visualization. These needs will be addressed in future updates of the tool. This desktop tool functionality is also planned to be provided via cloud.

## V. Discussion and Conclusions

As wearable sensors increase in popularity researchers will have the opportunity to access a wealth of new physiological and psychological data sets. Large scale measurement projects, however, require efficient collection and pre-processing of data that is often time-consuming and subject to human errors. For this purpose an open source application for data processing and visualization was developed. The use of the tool is illustrated by a pilot study of EDA measurements during trade fair.

Although the open source application was developed for processing and visualization of Moodmetric EDA data, the introduced process (Fig. 1) and source code can be applied to a variety of wearables, which seek to visualize health data to the user. The novel type of multiple overlapping polygon visualization introduced in the study and illustrated as Trend (Fig. 2) and Flower diagram (Fig. 3), can be used to depict various indexes calculated from user data. Furthermore, the tried and tested processes of collecting, processing and visualization of wearable data can serve as a model for researchers conducting in the wild studies with wearables.

## Conflict of Interest

The paper includes authors that represent the company developing the wearable device used to measure EDA. These authors were involved in the development of the research instrument that was released as open source application. However, the pilot study and the analysis of research results was performed by authors affiliated with the university that have no commercial or any other conflicting interests.

## References


1. Gaskin, J, Jenkins, J, Meservy, T, Steffen, J and Payne, K, (2017) Using Wearable Devices for Non-invasive, Inexpensive Physiological Data Collection. In Proceedings of the 50th Hawaii International Conference on System Sciences.
2. Cowley, B, Filetti, M, Lukander, K, Torniainen, J, Henelius, A, Ahonen, L, Barral, O, Kosunen, I, Valtonen, T, Huotilainen, M, Ravaja, N, Jacucci, G (2016) The Psychophysiology Primer: a guide to methods and a broad review with a focus on human-computer interaction. Foundations and Trends in Human-Computer Interaction, vol. 9, no. 3-4, pp. 150–307.
3. Betella, A, Zucca, R, Cetnarski, R, Greco, A, Lanata, A, Mazzei, D, Tognetti, A, Arsiwalla, X, Omedas, P, Rossi, D, Verschure, P (2014) Inference of human affective states from psychophysiological measurements extracted under ecologically valid conditions. Frontiers in neuroscience, 8:286, January 2014. ISSN 1662-4548. doi: 10.3389/fnins.2014.00286.
4. Pantelopoulos, A, Bourbakis N.G., (2010) A Survey on Wearable Sensor-Based Systems for Health Monitoring and Prognosis. IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), 40(1):1–12, January 2010. ISSN 1094-6977. doi: 10.1109/TSMCC.2009.2032660.
5. Vardasca, R.Â.R (2012) The effect of work related mechanical stress on the peripheral temperature of the hand (Doctoral dissertation, University of Glamorgan).
6. Boucsein, W (1992) Electrodermal activity. New York: Plenum.
7. Setz, C., Arnrich, B., Schumm, J., La Marca, R., Tröster, G. and Ehlert, U., (2010). Discriminating stress from cognitive load using a wearable EDA device. IEEE Transactions on information technology in biomedicine, 14(2), pp.410-417.
8. Torniainen, J, Cowley, B, Henelius, A, Lukander, K, Pakarinen, S (2015) Feasibility of an Electrodermal Activity Ring Prototype as a Research Tool, Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE 2015 Aug 25, pp. 6433-6436



Enter the information of the corresponding author:

Author: Jari Jussila
Institute: Tampere University of Technology
Street: Korkeakoulunkatu 10
City: Tampere
Country: Finland
Email: jari.j.jussila@tut.fi