SenseHub: an integrated web application for sensory analyses

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Abstract. This paper discusses the development and evaluation of SenseHub, a web application based on R statistical language, which is specially tailored to answer unprecedented growth in sensory science. Design of experiment, analyses for panel performance, and analyses for twenty-one sensory methods (covering discriminative, descriptive, affective, and optimisation methods) are available in SenseHub. A total of 35 subjects participated in evaluating the performance of SenseHub versus another statistical software on analysing a sensory data. The example dataset was obtained from another study utilising QDA method on 12 perfumes evaluated by 103 panellists using 21 sensory descriptors. In this study, the participants were asked to answer ten questions about data interpretation followed by 11 questions about satisfaction. Time spent for analysis was recorded. Results show that the participants could answer 87.06% questions correctly when using SenseHub while only 76.25% correct answers were achieved when using Minitab ($t_{44.94} = 2.36; P < 0.05$). Furthermore, the average analysis and interpretation time spent using SenseHub is quicker than Minitab, 11.53 versus 19.73 minutes ($t_{53.27} = 3.61; P < 0.05$). Finally, SenseHub has higher average satisfaction scores than Minitab in all eleven criteria (two sample t-test, P = 5.70x10^{-9} to 5.77 x 10^{-4}). The average satisfaction scores of SenseHub ranged from 84.57 (user interface) to 90.34 (suitability) while the scores of Minitab ranged from 58.20 (understandable) to 69.49 (data import). In short, SenseHub is not only equipped with powerful statistical tools but also considering user experience thus make it promising as an application for sensory analyses.

1. Introduction
In the past few decades, significant growth in sensory science is observed [1-3]. Sensory science becomes crucial not only for maintaining existing product quality but also for seeking a whole new product in the new product development process [4]. Even more, the scope of sensory science has developed from covering product properties into now also covering consumer science [1]. Due to high competitiveness in the food industry, many companies demand sensory information be obtained in rapid pace without neglecting data accuracy and quality. It then triggered the born of new sensory methods in the past ten years [1, 2].

However, the rapid growth in sensory methods was not followed by significant development in sensory analysis tools. Up to author’s knowledge, many known sensory analysis tools such as RedJade, Compusense, SensTools, PanelCheck, and so forth do not accommodate exclusive analysis for unconventional sensory methods. While some of them have features for advance sensory method, as in XLSTAT and EyeQuestion, they are only available in high price. Even tough general statistical softwares may also be used for performing analysis for advance sensory methods, they are not easily

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operated and not intuitive for users who are unfamiliar with statistical procedures. Furthermore, the outputs of analysis from general statistical software tend to be very extensive for sensory analysis. It makes the general statistical software not ideal for sensory analysis purpose.

Luckily, in R statistical language there are some packages specially created to provide analysis for both conventional and new sensory methods. Currently, several R packages have been developed exclusively and available for sensory analysis purposes, i.e. SensR [5] for mainly discriminative test analysis, BradleyTerry2 [6] for Bradley-Terry model, FactoMiner [7] for multivariate analysis which helpful in descriptive test analysis, and SensoMineR which provides very extensive analysis for sensory methods [8]. In general, the outputs generated from these packages are the essential information needed in sensory interpretation. Therefore, unlike the general statistical software, they are more suitable for sensory analysis purpose.

Unfortunately, working in R together with its packages demands the user to know how to write a script of code. This required ability needs investment to learn, thus making R not so user-friendly and fast to use on an industrial basis. Based on these motivations, this study was conducted to develop new software based on the powerful R statistical language to accommodate analysis for both conventional and new sensory methods available. Evaluation and comparison with existing general statistical software were also performed to measure the performance and user experience.

2. Research Methods

2.1. Development Phase

Literature in regards to sensory method and analysis were collected as the basic reference of SenseHub. The inclusion criterion applied was any kind of literature about sensory method and analysis which has been published in the last ten years, which included books, articles, papers, and software documentations. The main sources of literature were taken from Google Scholar, ScienceDirect, The Comprehensive R Archive Network (CRAN), and RStudio documentation. It is important to mention that since the main language which would be used in SenseHub was R statistical language, therefore the documentations of sensory analysis using R were mainly taken into consideration.

In regards to sensory methods, the discriminative, descriptive, affective, and optimization methods would be covered in SenseHub. It is also worth to mention that the scopes were not limited to conventional sensory methods only. Unconventional method, the quick-and-dirty sensory methods were also taken into consideration due to their popularity impracticality. Several rapid sensory methods which had been following popularity growth in the last five to ten years were also included in SenseHub together with the established sensory methods.

SenseHub underwent thorough development phases which reflected by several pre-releases before its first release. Feedbacks and comments in regards to analytical issues and user experiences were
collected from the colleagues experienced in sensory science during the alpha and beta testing. Therefore, the first SenseHub release which would be then evaluated (in the next phase) had been following many improvements in both back-end and front-endsides.

2.2. Evaluation phase
A simulation session was conducted at Department of Agricultural Product Technology of Universitas Brawijaya to evaluate the performance of SenseHub and measure user experience when using it for sensory analysis. Minitab was chosen as the comparative statistical software since it mainly used for data analyses at Department of Agricultural Technology of Universitas Brawijaya.

A total of 35 participants gave informed concern to participate in the simulation session. The inclusion criterion was that they had experience in handling and analysing sensory data at least once before. The participants were instructed to perform analysis and interpretation using SenseHub and Minitab in randomised order on an example dataset. The example dataset was obtained from study conducted by Worchetal [9] and described in Table 1.

| Property        | Description                                                                 |
|-----------------|-----------------------------------------------------------------------------|
| Method          | Quantitative Descriptive Analysis (QDA)                                     |
| Sample          | Angel, AromaticsElixir, ChanelN5, Cinema, CocoMademoiselle, J’adore EP,    |
|                 | J’adore ET, L’instant, Lolita Lempicka, Pleasures, Pure Poison, Shalimar  |
| Sensory descriptors | Intensity, Freshness, Jasmin, Rose, Camomille, Fresh lemon, Vanilla, Citrus, |
| Number of panelist | Anis, Sweet fruit, Honey, Caramel, Spicy, Woody, Leather, Nutty, Musk, Animal, |
|                 | Earthy, Incense, Green                                                      |

The participants were asked to fill out basic information covering gender, age and education level. They also needed to indicate what application or statistical software they usually used to perform sensory analyses. Subsequently, a questionnaire consisted often questions related to data analysis and interpretation followed by 11 question related to user satisfaction were asked. List of questions presented in the questionnaire is presented in Table 2. Finally, the time spent on performing data analyses and interpretation by each participant per application/software was also recorded.

2.3 Data analysis
Descriptive statistic was used to present the demographic information of the participants. In regards to analysis and interpretation questionnaire, the answers given by the participants were checked with the answers key. Score 1 was assigned for each correct answer, while score 0 was assigned for an incorrect answer. Next, the total score for each participant was divided by the total number of questions and presented as the percentage of correct answers (by multiplication with 100%).

Subsequently, the percentage of correct answers together with user satisfaction scores and the time spent for analysis were then analyzed using two-sample t-test analysis. Significant differences would be indicated by P-value lower than 0.05 (95% confidence level was used). All data cleaning and analyses were performed using the R statistical language version 3.4.4.
3. Results and Discussion

3.1. Description of SenseHub

SenseHub is built on top of R statistical language version 3.4.4 [10] with Shiny [11] as the framework for building graphical-user-interface (GUI) application. R has been gaining popularity as a language for statistical analysis. Not only including plenty of options for basic statistical analyses, but R also offering a possibility for more sophisticated statistical analyses as often required in sensory data analysis. SenseHub takes the advantages many powerful R packages for back-end computation and front-end aesthetic.

| Code | Question |
|------|----------|
| Q1   | How many panellists participated in the study? |
| Q2   | Please list the samples that tested in the study. |
| Q3   | What are the sensory descriptors used to evaluate the sample? |
| Q4   | How many sensory descriptors show significant difference between sample? (P < 0.05) |
| Q5   | How many sensory descriptors do not show significant difference between sample? (P > 0.05) |
| Q6   | Please indicate the four sensory descriptors that are most discriminative. |
| Q7   | Which sample has the highest intensity in ‘woody’? |
| Q8   | How many dimensions or principal components are extracted from Principal Component Analysis (PCA)? |
| Q9   | How much is the cumulative frequency of the first three dimensions or principal components? |
| Q10  | Which samples have closest sensory characteristic similarity with L’instant? |
| Q11  | How easy is it to import a data set? |
| Q12  | How easy is it to setup the parameters? |
| Q13  | How easy is it to get basic information about the imported dataset? |
| Q14  | How intuitive is the user interface? |
| Q15  | How quick is the computation speed? |
| Q16  | How concise is the output of the statistical analysis? |
| Q17  | How understandable is the output of the statistical analysis? |
| Q18  | How easy is it to transfer the results into another document (word document, excel document, etc)? |
| Q19  | How good is the quality of the basic plots/graphs produced? |
| Q20  | How suitable is the application/software for sensory analyses? |
| Q21  | Please indicate the overall score for this application/software. |

Sensory methods keep growing in both number and quality due to the need of understanding the product and consumer in an ideal manner. Furthermore, the need of quick yet accurate technique also triggered the development of sensory methods in the past decades. In SenseHub, plenty of analyses for sensory methods are included. Unlike the conventional statistical software, in SenseHub options of analyses are presented per sensory methods which cover discriminative, descriptive, and affective test. Furthermore, to accommodate the vast developments in sensory science, rapid sensory methods are also included in SenseHub together with conventional sensory methods (Table 3).

SenseHub is deployed as a free/libre open source software (FLOSS) web application and accessible at s.id/sensehub basic. The benefit of serving SenseHub as a web application is that it will be accessible in a multi-platform operating system (GNU/Linux, Windows, OSX, BSD, Android, IOS) as long there is an internet connection and will not require any installation on user’s computer. More importantly,
since SenseHub is developed as an open-source application, the source code is then made available at github.com/SensolutionID/sensehub basic with MIT license. It is worth to mention that the interface of SenseHub is presented in Bahasa Indonesia so that users from Indonesia can easily operate and understand it.

Table 3. Summary of sensory analyses available in SenseHub [11-16].

| Category          | Sensory method                                      | Statistical analysis                                      |
|-------------------|-----------------------------------------------------|----------------------------------------------------------|
| Experimental setup| Design of experiments, Panel performance analysis   | Williams Latin Square Design, Analysis of variance (ANOVA) |
| Discriminative test| 2-Alternatives Force Choice (2AFC), 3-Alternatives Force Choice (3AFC), Duo-Trio, Triangle, Tetrad, Hexad, Two-out-of-Five | One-proportion test                                      |
| Descriptive test  | Quantitative Descriptive Analysis (QDA), Flash Profiling (FP), Free-Choice Profiling (FCP), Rate-all-that-Apply (RATA), Check-all-that-Apply (CATA), RATA as CATA, Sorting Task, Napping | Analysis of Variance (ANOVA), Chi-squared test, Cochran Q test, Friedman test, Principal Component Analysis (PCA), Correspondence Analysis (CA), Factorial Approach for Sorting Task (FAST), Multiple Factors Analysis (MFA) |
| Affectivetest     | Acceptance test, Paired-Preference, Multiple Paired-Preference Ranking, Hedonic Rating | One-proportion test, Bradley-Terry Model, Friedman test, Analysis of Variance (ANOVA), Principal Component Analysis (PCA) |
| Optimisation      | Just-about-Right (JAR) method                       | Analysis of Variance (ANOVA), Penalty Analysis           |

3.2 Evaluation
As before mentioned, in SenseHub plenty of analyses for various sensory methods are available. Unfortunately, it made the comparison of SenseHub with other statistical softwares for all available sensory methods was not feasible. Therefore, in this study evaluation was carried out by using QDA data set only. QDA is considered as the fundamental descriptive method and commonly conducted for evaluating a product. Therefore the QDA data set was then used as the test/example. Participants were invited to a simulation session for conducting data analyses and interpretation. Demographic information of the participants involved in this study is presented in Table 4.
**Table 4.** Baseline characteristics of the participants involved in the study.

| Characteristic                              | Value                                                                 |
|---------------------------------------------|----------------------------------------------------------------------|
| Total number of participants                | 35 subjects                                                          |
| Gender                                      | 85.71% Female, 14.29% Male                                           |
| Age                                         | Average 25.89 years old, in range of 20-52 years old                 |
| Education level                             | 62.86% Bachelor, 28.57% Master, 8.57% Doctorate                      |
| Analytical software ever used*              | 8.57% MS.Excel, 85.71% Minitab, 2.85% PanelCheck, 25.71% SPSS,       |
|                                            | 8.57% XLSTAT                                                          |

*Sum >100% as participants could have used multiple statistical softwares

Even though both SenseHub and Minitab could yield correct answers more than 70%, it is evident that more correct answers could be obtained by using SenseHub than by using Minitab (averages are 87.06% versus 76.25%, \( t_{44} = 2.36; P < 0.05 \)). These results hint that the participants were able to extract more information from SenseHub better thus could answer the questions correctly.

To measure efficiency, the time spent for data analysis (from importing data set until setting up parameters) and interpretation (answering questions as mentioned in previously) are recorded. In average it took 11.53 minutes for data analysis and interpretation using SenseHub while it took 19.73 minutes using Minitab (\( t_{53} = 36.1; P < 0.05 \)). It is apparent that the duration was about 1.7 times longer when using Minitab than that of SenseHub. However, in this study, the proportion of time allocated for setting up parameters in software and answering questions (interpretation of results) could not be examined further.

![Figure 2. Satisfaction scores of SenseHub and Minitab averaged over total number of participants.](image)

Eleven questions in regards to user experience during performing data analysis and interpretation were asked. It is clearly observed that in all criteria (Figure 2), satisfaction scores given for SenseHub are significantly higher than that for Minitab (two sample t-test, \( P = 5.70 \times 10^{-9} \) - 5.77 \( \times \) 10^{-9}). SenseHub has the highest satisfaction scores in 'suitable for sensory analysis' (90.34) and 'concise results' (90.02). Meanwhile, Minitab has the highest satisfaction scores in 'easy to import dataset' (69.49) and 'suitability for sensory analysis' (68.94). More specifically, SenseHub as evident dominances over Minitab in 'concise results', 'easy-to-understand results', and 'provide a summary of dataset' with scores gap of 31.4, 31.3, and 28.9 respectively. The overall scores are 89.60 for
SenseHub versus 62.23 for Minitab. Therefore, it indicates that SenseHub has potential and promising to be an application for sensory analysis which not only powerful but also more preferred by users.

4. Conclusion
In conclusion, SenseHub was developed by taking advantages of the powerful R statistical language together with plenty of R packages. Sensory methods available in SenseHub are not limited to conventional methods only, yet it also covers various quick and dirty sensory methods which vastly grow in few decades. In total there are 21 sensory methods analyses included in SenseHub with scopes covering experimental setup, discriminative, descriptive, affective, and optimisation method. Moreover, SenseHub has superiority over general statistical software for sensory analysis. Not only that SenseHub produces the essential information for sensory interpretation, but also offers better user experiences as reflected in high satisfaction scores compared to general statistical software.

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