RELACS: Reliable Estimator of Local Antagonizing and Counterproductive Sounds

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1 Product purpose

1.1 Problem

Stress is arguably the biggest problem of our society nowadays. It can be very harmful to the health of the individual, as stress can cause problems in both mental and physical health. The effects of living a stressful life can include a reduced urge in reproduction, as well as lowered productivity during work. Throughout the years, many methods have been devised to decrease stress and increase relaxation. The system described onward does not decrease stress or increases relaxation directly, but rather attends the user to the influence of stress-inducing sounds in the environment of the user. When the user is more aware of stressful sounds in its sound environment (also called soundscape) he or she could change or avoid this environment, which might decrease their stress-level.

1.2 Target group

Since stress can be experienced by anyone, we did not feel like limiting our product to a specific target audience. We could say that our user group consists of students, people working in an office, construction workers, and the elderly. The current version of our product is aimed at an English-speaking audience, although in future versions we hope to increase our user-count with a wider selection of languages.

1.3 Improvements

We aim to improve the user awareness of the stress level in their surroundings. By showing users that some of the sounds present in their environment are stress-inducing, we want to improve the awareness of the importance of sound in order to create or find a relaxed environment. We think that a relaxed environment would benefit a person, as productivity is higher when stress is lower.

2 Product description

In the next chapter the complete technical specifications can be found, followed by a performance analysis and a user manual. But first a simple representation of the working of RELACS is given. RELACS is a simple tool to see how stressful a sound-sample is. When a processed recording of 30 seconds is presented to the tool, it calculates the overall percentage of stressfulness of the sample and shows where in the sample the stressful sounds are located. Basically what RELACS does is: sound in, stress analysis out.

3 Technical specifications

The web-app uses a Django front-end to display the results and allow the user to make new recordings. When the user makes a recording it is send to the back-end for processing.

3.1 Back-end

The back-end will first convert the input sound file to sound energy values per frequency over time. This has not yet been implemented in the final product. To extract stressful sounds from the cochleograms, two machine learning techniques are used and their output is combined with a number of factors extracted from sound specific features. The classifiers are trained on the raw energy values as well as on preprocessed values. These involved morphological filtering (erosion and dilation) and foreground-background filters with different time constants.

For the first technique the cochleogram is sliced into windows of about $\frac{3}{4}$ seconds that overlap for 50%. The probability that such a window contains a stressful sound is determined by looking solely at the mean intensity values per frequency band using a naive Bayes classifier.

The second approach consist mainly of a convolutional neural network (CNN). For this approach, first, the cochleogram is preprocessed so that sounds that have a shorter duration than 1 second are supressed. Windows are extracted similarly. From these windows, features are extracted by the CNN. These are used as input for a multilayer perceptron, that outputs a the probability that the window is stressful.

Both of these classifiers return a probability per window, which is subsequently averaged over the two. The resulting probability is then multiplied by two factors.

The first of these factors is calculated as loudness feature. To get this factor first the average sound intensity per frame of the complete recording (so the $\approx$30 second file) is calculated as sum of all the frequency intensities in that frame. Then for every frame, the loudness factor is calculated as $\frac{I_f}{I_{avg}}$, in which I_f is the frame intensity and I_{avg} is the average intensity. The resulting factor thus becomes higher than 1 if the frame is louder than the average frame, and lower than 1 if it is more quiet. Finally per window the average over all its frames are is taken, giving the loudness factor for that window. As a result, if it is multiplied by its stress probability, this probability increases if the window is louder on average than the other windows in the recording.

The second factor is calculated in a similar way, but describes the suddenness of the sound. The transition between the intensities of two frames is compared to the average transition in the recording. If this is higher than average *and* positive (in a negative transition the second frame is less loud than the first, making it not stressful), it is a more sudden than average sound. Again the average over the whole window is taken and multiplied with the probability, so that the probability of it being stress-inducing increases when it contains more than average sudden sounds.

Finally parts of sounds that have an extremely large amplitude with respect to the rest of a window ($> \mu + 2\sigma$) are also marked stressful (setting the probability at 1). This method ensures that, in case our classifier misclassifies a window that is in human eyes almost sure to be stress-inducing, the system will still give correct output. These methods are all combined into an array of stress level probabilities per window. The output of the back-end is thus an array of stress levels per window.

3.2 Front-end

After the machine learning is combined into an array of stress levels a threshold level is calculated for the array. All continuous parts in the array that are above this threshold are identified as a stress event or "sound". These sounds are given an individual stress level based on the windows that make up the sound. The front-end will display these sounds as coloured bars under a waveform representation, a coloured bar can be clicked to give more details about the sound.

A file will also be given a global stress level by taking the average stress for each window, this also includes the windows that are not part of any of the sounds. This is displayed separately from the sounds that have been found in the audio file. At the same time a waveform representation is also generated so that the user can relate the sounds that are found to the audio.

4 Performance analysis

This section gives an overview of the performance analysis, discussing the strengths, weaknesses, opportunities and threats of our application.

4.1 Internal factors

4.1.1 Strengths

Perhaps the main strength of RELACS is that it tries to address a highly significant and common problem in society. Stress is one of the most dire problems in the modern western world. Not only does it effect the happiness of many, it also has significant consequences for public health and with it for state and private finances. It is therefore imperative that causes of stress are identified and prevented. Sound may be a relatively 'small' cause for stress, but the contribution of RELACS extends beyond just making people aware of stress-inducing sounds in their environment. It also makes them aware of the fact that they can actively work to decrease their stress level. If the cause is not in their sound environment, the application might have triggered them to remove or reduce other stress-inducing aspects in their live.

Aside from this last aspect, RELACS itself of course only focuses on sound. Its main strength in that respect is its innovative property. There is no other application (of which we are aware) that does anything on stress-inducing sound recognition. There are applications that try to counter stress by producing 'relaxing' or 'anti-stress' sounds. But, while these application may help reduce stress in certain situation, it is often not the absence of relaxing sounds that causes stress, but the presence of stress-inducing sounds. This is where our application comes in, making it potentially more effective than the other available stress and sound related applications.

Another strength of RELACS is that it provides a more or less objective assessment of the stressfulness of the sounds in the environment. The application bases its assessment on the input of multiple users (we could add user feedback to make this *all* of the users). As a result, the sounds it classifies as stressful are likely to be found stressful by a majority of the people. It could therefore be used in objective stressfulness measurements, which could be useful, for example in the case of an employee trying to convince his superiors that the work floor sound environment induces stress. Of course there is the issue that some users would not find certain sounds stressful, while the application indicates them as such. While our current application cannot deal with that issue yet, user customization could be added to counter this issue. A user could then specify whether it would find certain sounds stressful or not, and the system would accommodate for those preferences.

Finally, when we look at the technical aspect of RELACS, we can distinguish a strength in its flexibility. Because of its adaptive back-end, user input could be very well accounted for and used to improve the accuracy of its classifications. The classifiers would only have to be retrained with the new data. You could, for example, release an update to the application every month, until the amount of data is such that changes in classification would not happen anymore. Or, in the light of user customization as discussed above, customized classifiers could be trained which would classify sounds specifically for that user.

4.1.2 Weaknesses

Although RELACS has several strengths, unfortunately the application poses a number of weaknesses as well.

The first weakness starts where the last strength left of. Its flexibility and user customization possibilities are not without consequence. Training our classifier, for example, is something that could never happen client side, since it takes an average pc or laptop about twelve to fourteen hours of time (we dare not say what would happen on a phone). This means that we would have no other choice than doing this server-side. We would thus need a lot of processing power and storage space if every user would require a customized classifier, and of course users do not like waiting for their customized app for half a day.

A major weakness of the existing application (without user customization) is its recognition rate. While we reach a reasonable rate (around 80%), it is still far from human level. This is due to the nature of stress-inducing sounds: while the bulk of it has some clear characteristics, such as loudness and onset, a part is not so clearly distinguishable from other non-stress-inducing sounds. Some stress-inducing sounds are very much dependent on both the character traits and the emotional state of the listener at that time. One person might get very stressed by someone clicking his pen frequently, while the person doing it has no problem with it whatsoever. Our classifier can have trouble with such sounds, based on the data it is trained on. It picks up most of the clear cases now, but the cases in which just the timbre or frequency of the sound is potentially stress-inducing, and not the intensity or onset (so if the sound is not necessarily loud or sudden), the system struggles. With more training data the system might improve on these cases, but this requires more research and testing. Of course it is also the question whether the system should even pick up on those cases, since for humans it is apparently not always a clear case either. Again we see that the option of user customization is one that would probably alleviate this problem.

4.2 External factors

It is interesting to discuss the performance of the application on itself, but of course eventually the market decides whether it is worth anything. Let us discuss possible opportunities the market could offer us and threats that RELACS would have to face.

4.2.1 Opportunities

One possible opportunity might involve a cooperation with companies and municipalities to improve the soundscapes of working environments. We could then customize the application for the specific company and train our system on sounds that are typical for its working environment.

In that same line we could launch different options in our software, specified to various environments. People tend to react differently to sounds and tolerate sounds on different levels in different environments. In a home, for example, a drilling sounds is usually experienced as stress-inducing, while a construction worker would not be bothered by it at the workplace.

Another opportunity involves a possible extension of our product. Implementing source recognition would make it easier to implement user costumization by allowing users to enter which sources they find stressful. Our system could tweak its results accordingly by giving different weights to different sources. This could lessen the current weaknesses our product has.

4.3 Threats

Probably the biggest threat RELACS would face if brought to market, is that its uses would not get recognized by the majority of users. At first glance, the application does seem somewhat redundant: "Why would an app have to tell me about stress-inducing sounds in my environment? I can very well discern those on my own." This is a reasonable objection. It is therefore a valid concern that people might not think beyond this objection. Our response to this threat is twofold.

First, if we would bring this application to market, we would have to promote our product very effectively and efficiently, such that this question would be immediately countered, if a potential user would stumble across our application.

Second, even if the potential user decides to dismiss our application on the basis of this remark, we would still have reached one of our goals, albeit to a lesser extent. This would be the case, because although in the end he did not use our application, the mere fact that he was confronted with the idea of potential stress-inducing sounds in his environment, might make him more aware of these sounds and hence one of our goals (creating awareness) would be met.

Another threat is of course user dissatisfaction with the classification results. It might be the case that users disagree with our assessment of their sound environment. In such a case a user would probably be quick to hit the 'erase' button, discarding it as not working. It is therefore imperative that the software contains some form of user input to improve the system, while also making clear that if the user uses it more often, the system should get better. Of course an average user would not use it until it works, but perhaps reinstall it after a while to see whether it has improved.

5 User manual

Currently, RELACS only works web-based and with .hdf5 files as input. At the homepage a list of previous analyses can be found, with their respective stressful-percentages. This can be used to compare samples taken at a specific place, but at different times. As can be seen in figure 1, the overview page contains the previous added recordings with their average stress scores.

Processed files can be further inspected by clicking on them, which brings the user to the results page (see figure 2). The results page contains the name of the recording as well as a visual representation of the .wav file to help place the stress clusters into context. Underneath, a series of highlights are

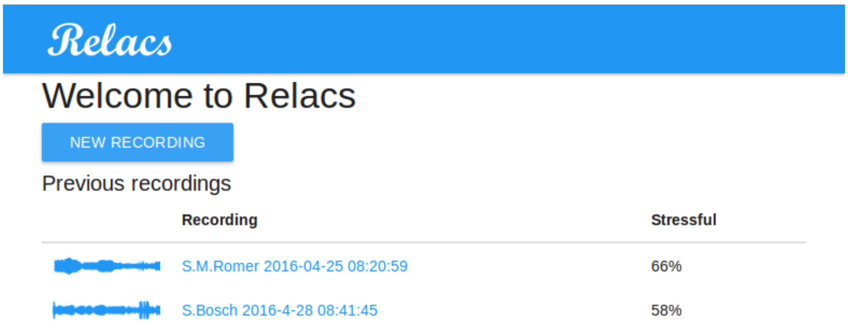

Figure 1: Screenshot of the overview page of the website, which contains previous recordings with previews of their respective .wav file, as well as the file name and the overall stress-level. At the current state of the project the 'NEW RECORDING' button only acts as a place holder.

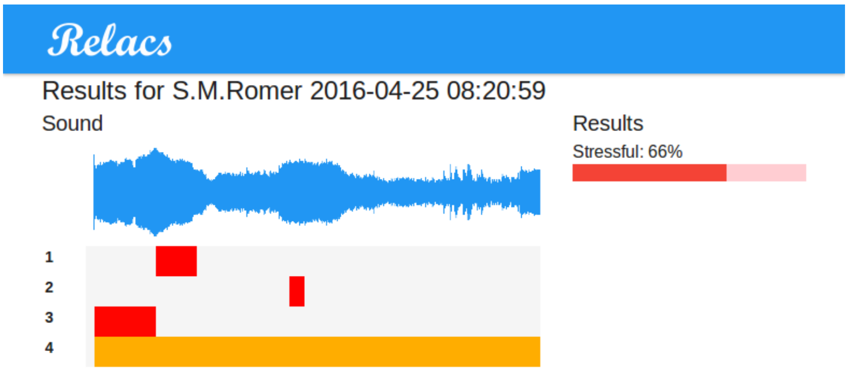

Figure 2: Screenshot of the results page of the website for one of the previous recordings. The results page consists of the file name, visual representation of the file, stress clusters bars, average stress level and a return button to the overview page, located at the top.

presented, which signify the clusters of sounds with a particular stress level. Red, yellow and colours in between are used to depict the stress level of a particular cluster, from high to low respectively. Figure 4 shows a variety of stress levels in the clusters. Each cluster bar can be expanded by clicking on the respective bar, revealing its stress level through a stress ratio-bar and a percentage as is visible in figure 3. On the right of the page the overall stressfulness of the audio file can be found, which is the average of the entire sound fragment and not that of only the clusters.

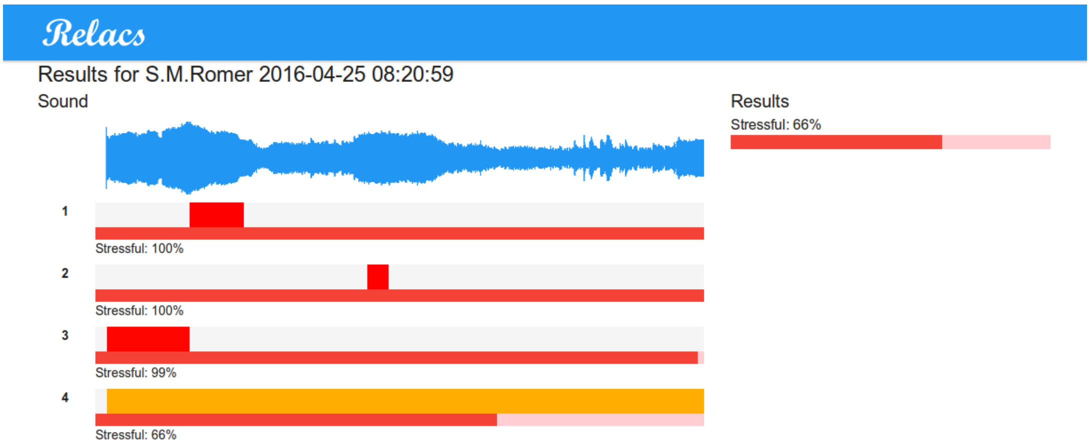

Figure 3: Screenshot of the results page with expanded stress cluster bars, revealing a visual representation of their respective stress level, as well as a percentage.

6 Pitch sheets

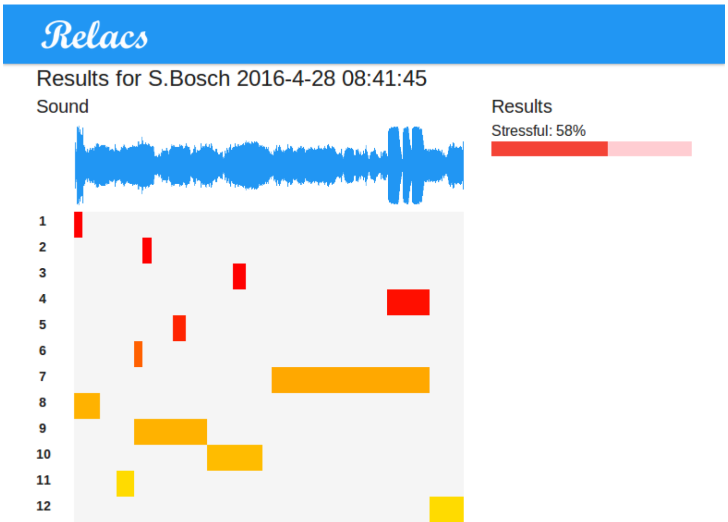

Figure 4: Additional screenshot of the results of another audio file, showing a larger number of stress cluster bars with a greater range of stress levels.

Concept

Recognize **stress**

Increase **user awareness** of stress

*Decrease **stress***

Relacs

Reliable **E**stimator of **L**ocal **A**gonizing and **C**ounterproductive **S**ounds

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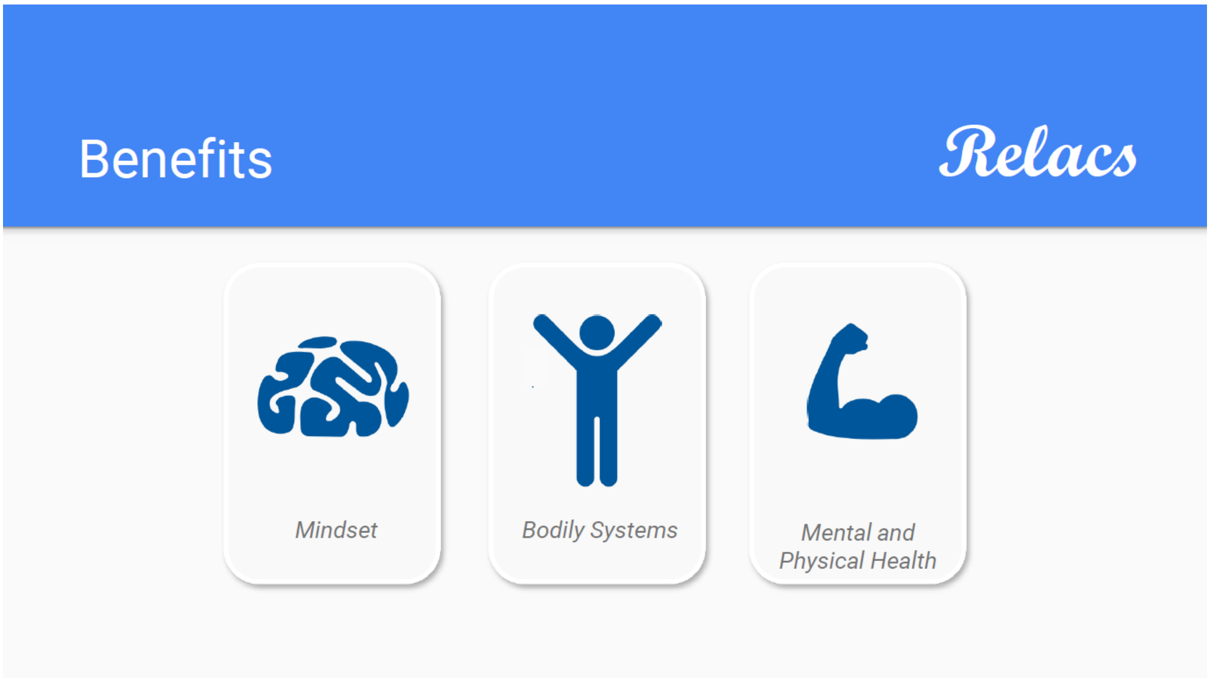
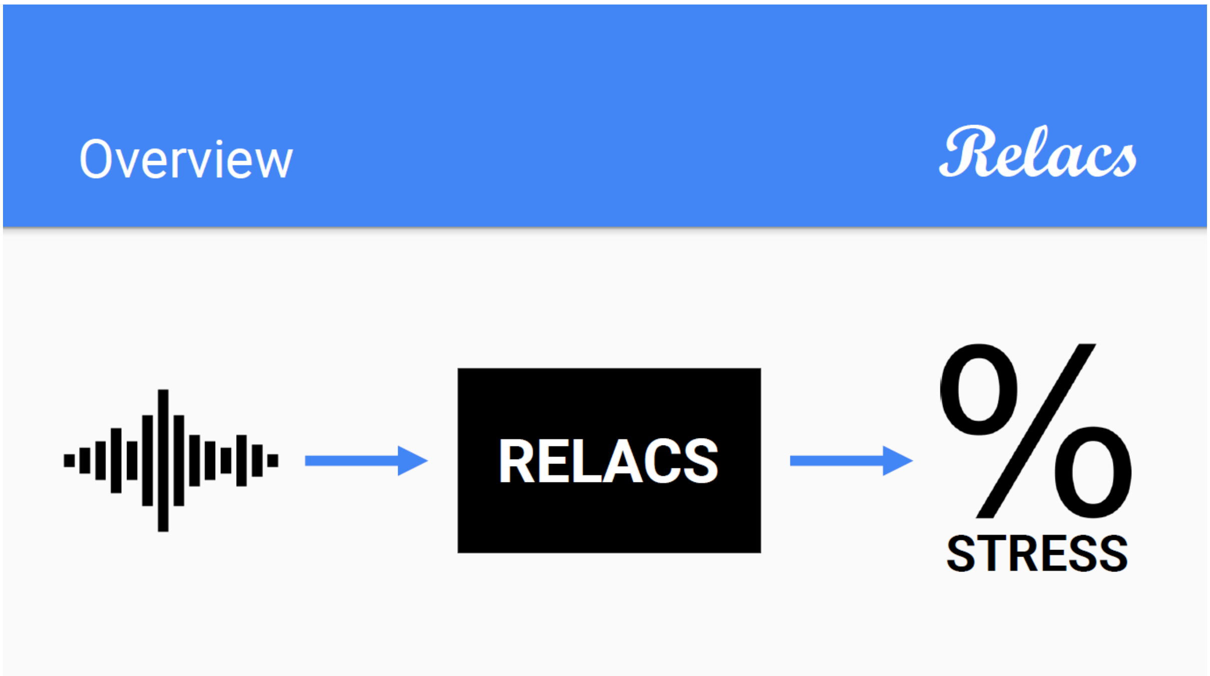

Benefits
Relacs
Mindset
Bodily Systems
Mental and
Physical Health

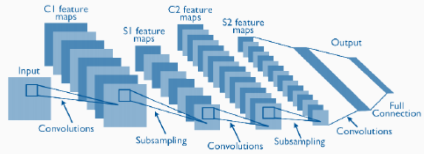

Overview
Relacs
RELACS
%
STRESS

Overview

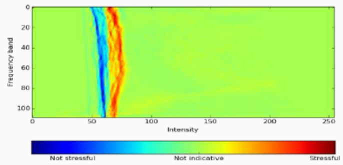
Relacs

RELACS

Convolutional Neural Network



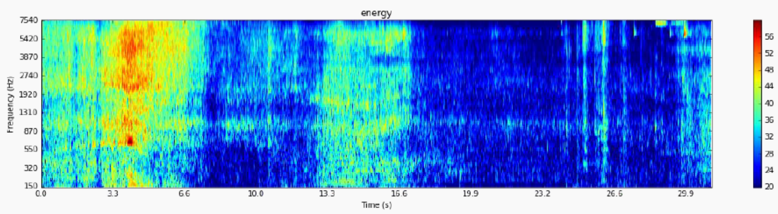
Sound Specific Features



Demonstration

Relacs

Recording 1

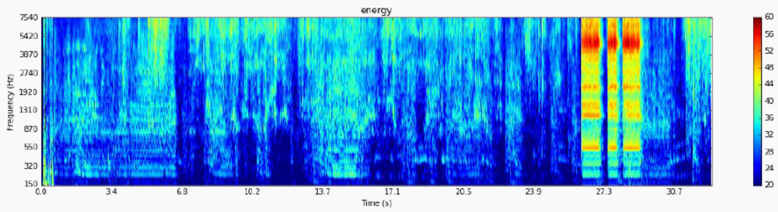


Spectrogram 1

Demonstration

Relacs

Recording 2



Spectrogram 2

Future directions

Relacs

User ***Customization***

Source ***Recognition***

In-app ***Recording***