AVEC 2016 – Depression, Mood, and Emotion Recognition Workshop and Challenge
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ABSTRACT
The Audio/Visual Emotion Challenge and Workshop (AVEC 2016) “Depression, Mood and Emotion” will be the sixth competition event aimed at comparison of multimedia processing and machine learning methods for automatic audio, visual and physiological depression and emotion analysis, with all participants competing under strictly the same conditions. The goal of the Challenge is to provide a common benchmark test set for multi-modal information processing and to bring together the depression and emotion recognition communities, as well as the audio, video and physiological processing communities, to compare the relative merits of the various approaches to audio, video, and physiological processing communities, to compare the relative merits of the various approaches to depression and emotion recognition under well-defined and strictly comparable conditions and establish to what extent fusion of the approaches is possible and beneficial. This paper presents the challenge guidelines, the common data used, and the performance of the baseline system on the two tasks.

Keywords
Affective Computing, Emotion Recognition, Speech, Facial Expression, Physiological signals, Challenge

1. INTRODUCTION
The 2016 Audio-Visual Emotion Challenge and Workshop (AVEC 2016) will be the sixth competition event aimed at comparison of multimedia processing and machine learning methods for automatic audio, video, and physiological analysis of emotion and depression, with all participants competing under strictly the same conditions. The goal of the Challenge is to compare the relative merits of the approaches (audio, video, and/or physiologic) to emotion recognition and severity of depression estimation under well-defined and strictly comparable conditions, and establish to what extent fusion of the approaches is possible and beneficial. A second motivation is the need to advance emotion recognition for multimedia retrieval to a level where behaviomedia systems [38] are able to deal with large volumes of non-prototypical naturalistic behaviour in reaction to known stimuli, as this is exactly the type of data that diagnostic and in particular monitoring tools, as well as other applications, would have to face in the real world.

AVEC 2016 will address emotion and depression recognition. The emotion recognition sub-challenge is a refined re-run of the AVEC 2015 challenge [27], largely based on the same dataset. The depression severity estimation sub-challenge is based on a novel dataset of human-agent interactions, and sees the return of depression analysis, which
was a huge success in the AVEC 2013 [41] and 2014 [40] challenges.

- **Depression Classification Sub-Challenge (DCC):** participants are required to classify whether they are to be classified as depressed or not, where the binary ground-truth is based on the severity of self-reported depression as indicated by the PHQ-8 score for every human-agent interaction. For the DCC, performance in the competition will be measured using the average F1 score for both classes depressed and not depressed. Participants are encouraged to provide an estimate of the severity of depression, by calculating the root mean square error over all HCI experiment sessions between the predicted and ground-truth PHQ-8 score. In addition, participants are also encouraged to report on overall accuracy, average precision, and average recall to further analyse their results in the paper accompanyng their submission.

- **Multimodal Affect Recognition Sub-Challenge (MASC):** participants are required to perform fully continuous affect recognition of two affective dimensions: Arousal, and Valence, where the level of affect has to be predicted for every moment of the recording. For the MASC, two regression problems need to be solved: prediction of the continuous dimensions Valence and Arousal. The MASC competition measure is the Concordance Correlation Coefficient (CCC), which combines the Pearson’s correlation coefficient (CC) with the square difference between the mean of the two compared time series, as shown in 1.

\[
\rho_c = \frac{2\rho \sigma_x \sigma_y}{\sigma_x^2 + \sigma_y^2 + (\mu_x - \mu_y)^2}
\]

where \(\rho\) is the Pearson correlation coefficient between two time series (here prediction and gold-standard), \(\sigma_x^2\) and \(\sigma_y^2\) are the variance of each time series, and \(\mu_x\) and \(\mu_y\) are the mean value of each. Therefore, predictions that are well correlated with the gold standard but shifted in value are penalised in proportion to the deviation.

To be eligible to participate in the challenge, every entry has to be accompanied by a paper presenting the results and the methods that created them, which will undergo peer-review. Only contributions with a relevant accepted paper will be eligible for challenge participation. The organisers reserve the right to re-evaluate the findings, but will not participate in the Challenge themselves.

## 2. DEPRESSION ANALYSIS CORPUS

The Distress Analysis Interview Corpus - Wizard of Oz (DAIC-WOZ) database is part of a larger corpus, the Distress Analysis Interview Corpus (DAIC) [13], that contains clinical interviews designed to support the diagnosis of psychological distress conditions such as anxiety, depression, and post-traumatic stress disorder. These interviews were collected as part of a larger effort to create a computer agent that interviews people and identifies verbal and nonverbal indicators of mental illness [8]. Data collected include audio and video recordings and extensive questionnaire responses; this part of the corpus includes the Wizard-of-Oz interviews, conducted by an animated virtual interviewer called Ellie, controlled by a human interviewer in another room. Data has been transcribed and annotated for a variety of verbal and non-verbal features.

Information on how to obtain shared data can be found in this location: http://dcapswoz.ict.usc.edu. Data is freely available for research purposes.

### 2.1 Depression Analysis Labels

The level of depression is labelled with a single value per recording using a standardised self-assessed subjective depression questionnaire, the PHQ-8 [21]. This is similar to the PHQ-9 questionnaire, but with the suicidal ideation question removed for ethical reasons. The average depression severity on the training and development set of the challenge is \(M = 6.67\) \((SD = 5.75)\). The distribution of the depression severity scores based on the challenge training and development set is provided in Fig. 1. A baseline classifier that constantly predicts the mean score of depression provides an \(RMSE = 5.73\) and an \(MAE = 4.74\).

### 2.2 Depression Analysis Baseline Features

In the following sections we describe how the publicly available baseline feature sets are computed for either the audio or the video data. Participants can use these feature sets exclusively or in addition to their own features. For ethical reasons, no raw video is made available.

#### 2.2.1 Video Features

Based on the OpenFace [2] framework\(^1\), we provide different types of video features:

- facial landmarks: 2D and 3D coordinates of 68 points on the face, estimated from video
- HOG (histogram of oriented gradients) features on the aligned 112x112 area of the face
- gaze direction estimate for both eyes
- head pose: 3D position and orientation of the head

\(^1\)https://github.com/TadasBaltrusaitis/CLM-framework
In addition to that, we provide emotion and facial action unit continuous measures based on FACET software [23]. Specifically, we provide the following measures:

- **emotion:** {Anger, Contempt, Disgust, Joy, Fear, Neutral, Sadness, Surprise, Confusion, Frustration}
- **AUs:** {AU1, AU2, AU4, AU5, AU6, AU7, AU9, AU10, AU12, AU14, AU15, AU17, AU18, AU20, AU23, AU24, AU25, AU26, AU28, AU43}

### 2.2.2 Audio Features

For the audio features we utilized COVAREP (v1.3.2), a freely available open source Matlab and Octave toolbox for speech analyses [7]. The toolbox comprises well validated and tested feature extraction methods that aim to capture both voice quality as well as prosodic characteristics of the speaker. These methods have been successfully shown to be correlated with psychological distress and depression in particular [32, 33]. In particular, we extracted the following features:

- **Prosodic:** Fundamental frequency (F0) and voicing (VUV)
- **Voice Quality:** Normalized amplitude quotient (NAQ), Quasi open quotient (QOQ), the difference in amplitude of the first two harmonics of the differentiated glottal source spectrum (HH2H), parabolic spectral parameter (PSP), maxima dispersion quotient (MDQ), spectral tilt/slope of wavelet responses (peak-Slope), and shape parameter of the Liljencrants-Fant model of the glottal pulse dynamics (Rp)
- **Spectral:** Mel cepstral coefficients (MCEP0-24), Harmonic Model and Phase Distortion mean (HMPDM0-24) and deviations (HMPDD0-12).

In addition to the feature set above, raw audio and transcripts of the interview are provided, allowing participants to compute additional features on their own. For more details on the shared features and the format of the files participants should also review the DAIC-WOZ documentation 3.

### 3. EMOTION ANALYSIS CORPUS

The Remote Collaborative and Affective Interactions (RECOLA) database [29] was recorded to study socio-affective behaviours from multimodal data in the context of computer-supported collaborative work [28]. Spontaneous and naturalistic interactions were collected during the resolution of a collaborative task that was performed in dyads and remotely through video conference. Multimodal signals, i.e., audio, video, electro-cardiogram (ECG) and electro-dermal activity (EDA), were synchronously recorded from 27 French-speaking subjects. Even though all subjects speak French fluently, they have different nationalities (i.e., French, Italian or German), which thus provides some diversity in the expression of emotion.

Data is freely available for research purposes, information on how to obtain the RECOLA database can be found on this location: http://diuf.unifr.ch/diva/recola.

### 2.2 Emotion Analysis Baseline Features

#### 2.2.1 Video Features

Facial expressions play an important role in the communication of emotion [9]. Features are usually grouped in two types of facial descriptors: appearance and geometric based [39]. For the video baseline features set, we computed

### 3.1 Emotion Analysis Labels

Regarding the annotation of the dataset, time-continuous ratings (40 ms binned frames) of emotional arousal and valence were created by six gender balanced French-speaking assistants for the first five minutes of all recordings, because participants discussed more about their strategy — hence showing emotions — at the beginning of their interaction.

To assess inter-rater reliability, we computed the intraclass correlation coefficient (ICC(3,1)) [36], and Cronbach’s α [5]; ratings are concatenated over all subjects. Additionally, we computed the root-mean-square error (RMSE), Pearson’s CC and the CCC [22]; values are averaged over the C7 pairs of raters. Results indicate a very strong inter-rater reliability for both arousal and valence, cf. Table 1. A normalisation technique based on the Evaluator Weighted Estimator [14], is used prior to the computation of the gold-standard, i.e., the average of all ratings for each subject [26].

This technique has significantly (p < 0.001 for CC) improved the inter-rater reliability for both arousal and valence; the Fisher Z-transform is used to perform statistical comparisons between CC in this study.

The dataset was divided into speaker disjoint subsets for training, development (validation) and testing, by stratifying (balancing) on gender and mother tongue, cf. Table 2.

#### Table 1: Inter-rater reliability on arousal and valence for the 6 raters and the 27 subjects of the RECOLA database; raw or normalised ratings [26].

<table>
<thead>
<tr>
<th></th>
<th>RMSE</th>
<th>CC</th>
<th>CCC</th>
<th>ICC</th>
<th>α</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arousal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw</td>
<td>.344</td>
<td>.400</td>
<td>.277</td>
<td>.775</td>
<td>.800</td>
</tr>
<tr>
<td>Normalised</td>
<td>.218</td>
<td>.446</td>
<td>.370</td>
<td>.811</td>
<td>.802</td>
</tr>
<tr>
<td><strong>Valence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw</td>
<td>.263</td>
<td>.496</td>
<td>.431</td>
<td>.827</td>
<td>.856</td>
</tr>
<tr>
<td>Normalised</td>
<td>.174</td>
<td>.492</td>
<td>.478</td>
<td>.844</td>
<td>.829</td>
</tr>
</tbody>
</table>

#### Table 2: Partitioning of the RECOLA database into train, development, and test sets.

<table>
<thead>
<tr>
<th>#</th>
<th>train</th>
<th>dev</th>
<th>test</th>
</tr>
</thead>
<tbody>
<tr>
<td>female</td>
<td>6</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>male</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>French</td>
<td>6</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Italian</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>German</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>age μ (σ)</td>
<td>21.2 (1.9)</td>
<td>21.8 (2.5)</td>
<td>21.2 (1.9)</td>
</tr>
</tbody>
</table>
bioacoustics signals are known to be well correlated with emotion [20, 19], despite not being directly perceptible the way audio-visual are. Although there are some controversies about peripheral physiology and emotion [31, 18], we believe that autonomic measures should be considered along with audio-visual data in the realm of affective computing, as they do not only provide complementary descriptions of affect, but can also be easily and continuously monitored with wearable sensors [30, 24, 4].

As baseline features, we extracted features from both ECG and EDA signals with overlapping (step of 40 ms) windows. The ECG signal was firstly band-pass filtered ([3 – 27] Hz) with a zero-delay 6th order Butterworth filter [26], and 19 features were then computed: the zero-crossing rate, the four first statistical moments, the normalised length density, the non-stationary index, the spectral entropy, slope, mean frequency plus 6 spectral coefficients, the power in low frequency (LF, 0.04-0.15 Hz), high frequency (HF, 0.15-0.4 Hz) and the LF/HF power ratio. Additionally, we extracted the heart rate (HR) and its measure of variability (HRV) from the filtered ECG signal [26]. For each of those two descriptors, we computed the two first statistical moments, the arithmetic mean of rising and falling slope, and the percentage of rising values, which provided 10 features in total.

An EDA reflects a rapid, transient response called skin conductance response (SCR), as well as a slower, basal drift called skin conductance level (SCL) [6]. Both, SCL (0–0.5 Hz) and SCR (0.5–1 Hz) are estimated using a 3rd order Butterworth filter, 8 features are then computed for each of those three low-level descriptors: the four first statistical moments, the spectral entropy, slope, energy is computed and 6 temporal features are included: the rate of loudness peaks per second, mean length and standard deviation of continuous voiced and unvoiced segments and the rate of voiced segments per second, approximating the pseudo syllable rate. Overall, the acoustic baseline features set contains 88 features.

3.2.3 Physiological Features

Physiological signals are known to be well correlated with emotion [20, 19], despite not being directly perceptible the way audio-visual are. Although there are some controversies about peripheral physiology and emotion [31, 18], we believe that autonomic measures should be considered along with audio-visual data in the realm of affective computing, as they do not only provide complementary descriptions of affect, but can also be easily and continuously monitored with wearable sensors [30, 24, 4].

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4. CHALLENGE BASELINES

For transparency and reproducibility, we use standard and open-source algorithms for both sub-challenges. We describe below how the baseline system was defined and the results we obtained for each modality separately, as well as on the fusion of all modalities.

4.1 Depression

The challenge baseline for the depression classification sub-challenge is computed using the scikit-learn toolbox. In particular, we fit a linear support vector machine with stochastic gradient descent, i.e. the loss is computed on a sample at a time and the model is sequentially updated. We validated the model on the development set and conducted a grid search for optimal hyper-parameters on the development set of both the audio data and video data separately. Features of both modalities are taken from the provided challenge baseline features. Classification and training was performed on a frame-wise basis (i.e., at 100 Hz for audio.

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Table 3: Baseline results for depression classification. Performance is measured in F1 score for depressed and not depressed classes as reported through the PHQ-8. In addition, precision and recall are provided. Values for class not depressed are reported in brackets.

<table>
<thead>
<tr>
<th>Partition</th>
<th>Modality</th>
<th>F1 score</th>
<th>Precision</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development</td>
<td>Audio</td>
<td>.462 (.682)</td>
<td>.316 (.938)</td>
<td>.857 (0.54)</td>
</tr>
<tr>
<td>Development</td>
<td>Video</td>
<td>.500 (.896)</td>
<td>.600 (.867)</td>
<td>.428 (.928)</td>
</tr>
<tr>
<td>Development</td>
<td>Ensemble</td>
<td>.500 (.896)</td>
<td>.600 (.867)</td>
<td>.428 (.928)</td>
</tr>
<tr>
<td>Test</td>
<td>Audio</td>
<td>.410 (.582)</td>
<td>.267 (.941)</td>
<td>.889 (.421)</td>
</tr>
<tr>
<td>Test</td>
<td>Video</td>
<td>.583 (.851)</td>
<td>.467 (.938)</td>
<td>.778 (.790)</td>
</tr>
<tr>
<td>Test</td>
<td>Ensemble</td>
<td>.583 (.851)</td>
<td>.467 (.938)</td>
<td>.778 (.790)</td>
</tr>
</tbody>
</table>

Table 4: Baseline results for depression severity estimation. Performance is measured in mean absolute error (MAE) and root mean square error (RMSE) between the predicted and reported PHQ-8 scores, averaged over all sequences.

<table>
<thead>
<tr>
<th>Partition</th>
<th>Modality</th>
<th>RMSE</th>
<th>MAE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development</td>
<td>Audio</td>
<td>6.74</td>
<td>5.36</td>
</tr>
<tr>
<td>Development</td>
<td>Video</td>
<td>7.13</td>
<td>5.88</td>
</tr>
<tr>
<td>Development</td>
<td>Audio-Video</td>
<td>6.62</td>
<td>5.52</td>
</tr>
<tr>
<td>Test</td>
<td>Audio</td>
<td>7.78</td>
<td>5.72</td>
</tr>
<tr>
<td>Test</td>
<td>Video</td>
<td>6.97</td>
<td>6.12</td>
</tr>
<tr>
<td>Test</td>
<td>Audio-Video</td>
<td>7.05</td>
<td>5.66</td>
</tr>
</tbody>
</table>

and 30Hz for video); temporal fusion was conducted through simple majority voting of all the frames within an entire screening interview. For both modalities we conducted a grid search for the following parameters: loss function \( \in \{ \text{logarithmic}, \text{hinge loss} \} \), regularization \( \in \{ L1, L2 \} \), and \( \alpha \in \{ 1e1, 1e0, \ldots , 1e - 5 \} \). For the audio data the optimal identified hyper-parameters are loss function = hinge loss, regularization = L1, and \( \alpha = 1e - 3 \). For the video data the optimal identified hyper-parameters are loss function = logarithmic, regularization = L1, and \( \alpha = 1e0 \). The ensemble of audio and video was computed through a simple binary fusion of a logical AND. The test performance was computed on a classifier trained using the found optimal parameters from the grid search. Since the positive outputs of the video modality are a subset of those of the audio the ensemble classifier’s performance is exactly the same as the video modality for both the development and test sets. Results are summarized in Table 3.

In addition to classification baseline, we also computed a regression baseline using random forest regressor. The only hyper-parameter in this experiment was the number of trees \( \in 10, 20, 50, 100, 200 \) in the random forest. For both audio and video the best performing random forest has trees \( = 10 \). Regression was performed on a frame-wise basis as the classification and temporal fusion over the interview was conducted by averaging of outputs over the entire screening interview. Fusion of audio and video modalities was performed by averaging the regression outputs of the unimodal random forest regressors. The performance for both root mean square error (RMSE) and mean absolute error (MAE) for development and test sets is provided in Table 4.

Table 5: Size of the window \( W \) in seconds used to extract features on the different modalities, and delay \( D \) in seconds applied to the gold-standard, according to the emotional dimension, i.e., arousal (A), and valence (V); parameters were obtained as the result of an optimisation of the performance measured as CCC on the development partition.

<table>
<thead>
<tr>
<th>Modality</th>
<th>Arousal</th>
<th>Valence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audio</td>
<td>( W_A )</td>
<td>( D_A )</td>
</tr>
<tr>
<td>Video-appearance</td>
<td>4</td>
<td>2.8</td>
</tr>
<tr>
<td>Video-geometric</td>
<td>6</td>
<td>2.4</td>
</tr>
<tr>
<td>ECG</td>
<td>4</td>
<td>0.4</td>
</tr>
<tr>
<td>HRHRV</td>
<td>8</td>
<td>0.0</td>
</tr>
<tr>
<td>EDA</td>
<td>8</td>
<td>0.0</td>
</tr>
<tr>
<td>SCL</td>
<td>4</td>
<td>0.0</td>
</tr>
<tr>
<td>SCR</td>
<td>4</td>
<td>0.8</td>
</tr>
</tbody>
</table>

4.2 Affect

Mono-modal emotion recognition was first investigated separately for each modality. Baseline features were extracted as previously described, with a window size \( W \) ranging from four to 14 seconds, and a step of two seconds. The window was centred, i.e., the first feature vector was assigned to the center of the window (\( W/2 \)), and duplicated for the previous frames; the same procedure was applied for the last frames. For video data, frames for which the face was not detected were ignored. For EDA, SCL, and SCR, test data from the subject #7 was not used, due to issue during the recording of this subject (sensor was partially detached from the skin). Two different techniques were investigated to standardise the features: (i) online (standardisation parameters \( \mu \) and \( \sigma \) are computed on the training partition and used on all partitions), and (ii) speaker dependent (\( \mu \) and \( \sigma \) are computed and applied on features of each subject). In order to compensate time reaction of the raters, a time delay \( D \) is applied to the gold-standard, by shifting back in time the values of the time-series (last value was duplicated), with a delay ranging from zero to eight seconds, and a step of 400ms.

As machine learning, we used a linear Support Vector Machine (SVM) to perform the regression task with the liblinear library [12]; the L2-regularised L2-loss dual solver was chosen (option -s 12) and a unit bias was added to the feature vector (option -B 1), all others parameters were kept
ity and emotional dimension, and shows that, a significant improvement has been made for all modalities compared to the AVEC 2015 baseline [27], except for the EDA features. In agreement with the state-of-the-art, audio features perform significantly better than any other modality on arousal, and video features on valence. Interestingly, emotion prediction from the HRHRV signal performs significantly better than with the original ECG signal, and it is ranked as the most relevant physiological descriptor for arousal, when taken alone.

Multimodal emotion recognition is performed with three different late-fusion models, because frames might be missing on the video, and EDA related features; (i) audio-ECG, used for missing video and EDA; (ii) audio-ECG-EDA-video, used for missing video; (iii) audio-ECG-EDA-video, used otherwise. In order to keep the complexity low, and estimate the contribution of each modality in the fusion process, we build the fusion model by a simple linear regression of the predictions obtained on the development partition, using Weka 3.7 with default parameters [16]. Obtained predictions were then post-processed with the same approach used for the mono-modal predictions.

\[
P_{\text{Pred}} = \epsilon_m + \sum_{i=1}^{N} \gamma_i \times P_{\text{Pred}_i}(i),
\]

where \(P_{\text{Pred}_i}(i)\) is the mono-modal prediction of the modality \(i\) from the \(N\) available ones (ranging from two to eight), \(\gamma_i\) and \(\epsilon_m\) are regression coefficients estimated on the development partition, and \(P_{\text{Pred}}\) is the fused prediction.

Performance is reported in Table 6. Results show that, the baseline for the AVEC 2016 MASC is highly competitive, with the performance obtained on valence for the test partition being slightly better than the top-performer of AVEC.
In order to depict the contribution of each modality in the prediction of emotion, we normalised the linear regression coefficients that were learned for the multimodal fusion model (iv) into a percentage:

\[
C_i = 100 \times \frac{\gamma_i}{\sum_{k=1}^{N} \gamma_k}
\]

where \(C_i\) is the contribution of the modality \(i\) in percentage, and \(\gamma_k\) are the regression coefficients of the multimodal fusion model; \(N = 8\).

Results show that, even if the mono-modal performance can be low for a given modality and emotion, e.g., EDA for arousal or SCR for valence, cf. Table 6, all modalities contribute, to a certain extent, to the prediction of arousal and valence in the fusion scenario, cf. Figure 2. This is especially the case for SCR features on arousal and for SCL features on valence, which did not perform well when used in isolation, but contribute even outperformed appearance features in the fusion model.

5. CONCLUSION

We introduced AVEC 2016 – the third combined open Audio/Visual Emotion and Depression recognition Challenge. It comprises two sub-challenges: the detection of the affective dimensions of arousal and valence, and the estimation of a self-reported level of depression. This manuscript describes AVEC 2016’s challenge conditions, data, baseline features and results. By intention, we opted to use open-source software and the highest possible transparency and realism for the baselines by refraining from feature space optimisation and optimising on test data. This should improve the reproducibility of the baseline results.

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6. REFERENCES


