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Software for Double-Talk Robust Acoustic Echo Cancellation[1]

Toon van Waterschoot[2] [3], Geert Rombouts[2] and Marc Moonen[2]

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[1]This report is available by anonymous ftp from *ftp.esat.kuleuven.be* in the directory *pub/sista/vanwaterschoot/reports/05-162.pdf*

[2]K.U.Leuven, Dept. of Electrical Engineering (ESAT), Research group SCD(SISTA), Kasteelpark Arenberg 10, B-3001 Leuven, Belgium, Tel. +32 16 321927, Fax +32 16 321970, WWW: *http://homes.esat.kuleuven.be/∼tvanwate/*. E-mail: *toon.vanwaterschoot@esat.kuleuven.be*.

[3]Toon van Waterschoot is a Research Assistant with the I.W.T. (Flemish Institute for Scientific and Technological Research in Industry). This research work was carried out at the ESAT laboratory of the Katholieke Universiteit Leuven, in the frame of the Belgian Programme on Interuniversity Attraction Poles, initiated by the Belgian Federal Science Policy Office IUAP P5/22 ('Dynamical Systems and Control: Computation, Identification and Modelling'), the Concerted Research Action GOA-AMBioRICS and IWT project 040803: 'SMS4PA-II: Sound Management System for Public Address Systems'. The scientific responsibility is assumed by its authors.

Software for Double-Talk Robust Acoustic Echo Cancellation

Toon van Waterschoot*, Geert Rombouts† and Marc Moonen‡

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Abstract

This report comes with a package of MATLAB functions that implement the double-talk robust prediction error (PE) identification algorithms proposed in [1], and with a set of sound signals and room impulse responses (RIR) which were used in the computer simulations described in [1].

1 RIR and sound signals

All simulations described in [1] are performed at a sampling rate $f_s = 8kHz$. The downloadable MATLAB package `RIR.mat` contains two RIR's used in the simulations: `f1` and `f2`, both of length $L_F = n_F + 1 = 1000$ (corresponding to $125ms$). RIR `f1` was extracted from the RIR measurements performed in [2] and is plotted in **Figure 1**. In [1] `f1` is used in the continuous double-talk and temporary double-talk simulation scenarios and in the echo path change scenario before the RIR change. After the RIR change `f2` is used, which is obtained by dividing all elements of `f1` by 2.

The downloadable package `signals.tar.gz` contains the sound signals used in the simulations described in [1], in WAV format (8kHz, 16bit):

- `babblenoise8kmono_doclo.wav`
- `femalespeech8kmono_hermus.wav`

*Corresponding author. Katholieke Universiteit Leuven, ESAT-SCD, Kasteelpark Arenberg 10, B-3001 Leuven, Tel. +32 16 321927, Fax +32 16 321970, E-mail `toon.vanwaterschoot@esat.kuleuven.be`

†Katholieke Universiteit Leuven, ESAT-SCD, Kasteelpark Arenberg 10, B-3001 Leuven, Tel. +32 16 321856, Fax +32 16 321970, E-mail `geert.rombouts@esat.kuleuven.be`

‡Katholieke Universiteit Leuven, ESAT-SCD, Kasteelpark Arenberg 10, B-3001 Leuven, Tel. +32 16 321060, Fax +32 16 321970, E-mail `marc.moonen@esat.kuleuven.be`

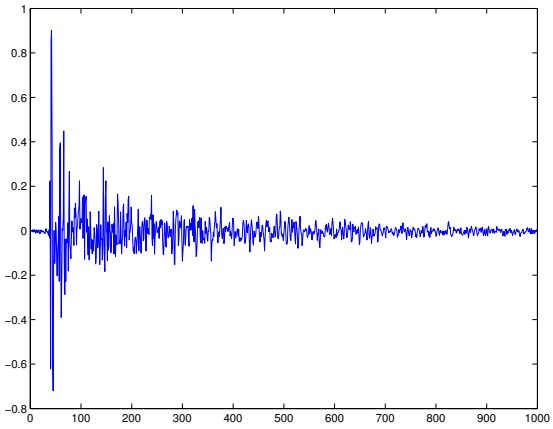

Figure 1: RIR `f1` used in computer simulations described in [1].

- `malespeech8kmono_zappa.wav`
- `shortbabblenoise8kmono_doclo.wav`
- `shortfemalespeech8kmono_hermus.wav`
- `shortmalespeech8kmono_zappa.wav`

The short signals are used in the Gauss-Newton simulations, and the regular signals in the stochastic gradient simulations. The male speech signal is the far-end signal throughout all simulations. The babble noise signal is the near-end signal in the continuous double-talk simulation scenario, whereas the female speech signal is the near-end signal in the temporary double-talk scenario and in the scenario of the echo path change during double-talk.

2 PE identification algorithms

The downloadable package `algorithms.tar.gz` contains MATLAB functions providing an implementation of the four prediction error identification algorithms described in [1], both with a Gauss-Newton and a stochastic gradient (SG) update:

- `my_2chaf.m`: 2ch-AF algorithm
- `my_pemaf.m`: PEM-AF algorithm
- `my_pemafrow.m`: PEM-AFROW algorithm
- `my_rpe.m`: RPE algorithm
- `sg_2chaf.m`: SG-2ch-AF algorithm

- `sg_pemaf.m`: SG-PEM-AF algorithm
- `sg_pemafrow.m`: SG-PEM-AFROW algorithm
- `sg_rpe.m`: SG-RPE algorithm

All eight functions require six common input variables:

- `u0`: the $N \times 1$ loudspeaker (far-end) signal vector
- `y0`: the $N \times 1$ microphone signal vector
- `n_F`: the RIR model order
- `n_A`: the near-end signal AR model order
- `N`: the data record length = the number of iterations
- `mu_dtd`: an $N \times 1$ binary vector containing the output of a double-talk detector

and return four output variables:

- `F`: an $(n_F + 1) \times N$ matrix containing the RIR estimate of iteration i on its i-th column
- `A`: an $(n_A + 1) \times N$ matrix containing the estimated near-end signal AR model of iteration i on its i-th column
- `Sigma2`: a $1 \times N$ vector containing the estimated near-end excitation signal variance of iteration i on its i-th column
- `r`: an $N \times 1$ vector containing the echo-compensated signal

Below we give the full specification of inputs and outputs for each of the eight functions, and define the function-specific input variables.

The 2ch-AF algorithm with Gauss-Newton update is specified by

```
[F_2ch,A_2ch,Sigma2_2ch,r_2ch]
 = my_2chaf(u0,y0,lambda_2ch,lambda_sigma2_2ch,n_F,n_A,N,mu_dtd)
```

with the function-specific input variables defined as

- `lambda_2ch`: the exponential forgetting factor for estimation of the full 2ch-AF parameter vector of length `n_F + 2n_A + 1`
- `lambda_sigma2_2ch`: the exponential forgetting factor for estimation of the near-end excitation signal variance

The PEM-AF algorithm with Gauss-Newton update is specified by

```
[F_AF,A_AF,Sigma2_AF,r_AF]
 = my_pemaf(u0,y0,lambda_f_AF,lambda_a_AF,n_F,n_A,N,mu_dtd)
```

with the function-specific input variables defined as

- `lambda_f_AF`: the exponential forgetting factor for estimation of the RIR
- `lambda_a_AF`: the exponential forgetting factor for estimation of both the near-end signal model and the near-end excitation signal variance

The PEM-AFROW algorithm with Gauss-Newton update is specified by

```
[F_ROW,A_ROW,Sigma2_ROW,r_ROW]
 = my_pemafrow(u0,y0,lambda_f_ROW,n_F,n_A,N,M,P,mu_dtd)
```

with the function-specific input variables defined as

- `lambda_f_ROW`: the exponential forgetting factor for estimation of the RIR
- `M`: the number of samples denoting the linear prediction window length
- `P`: the number of samples denoting the linear prediction window hop size (defined as the window length minus the window overlap)

The RPE algorithm with Gauss-Newton update is specified by

```
[F_RPE,A_RPE,Sigma2_RPE,r_RPE]
 = my_rpe(u0,y0,lambda_f_RPE,lambda_a_RPE,n_F,n_A,N,mu_dtd)
```

with the function-specific input variables defined as

- `lambda_f_RPE`: the exponential forgetting factor for estimation of the RIR
- `lambda_a_RPE`: the exponential forgetting factor for estimation of both the near-end signal model and the near-end excitation signal variance

The SG-2ch-AF algorithm with stochastic gradient update is specified by

```
[F_sg2ch,A_sg2ch,Sigma2_sg2ch,r_sg2ch]
 = sg_2chaf(u0,y0,mu_sg2ch,alpha_sg2ch,lambda_a_sg2ch,
            lambda_sigma2_sg2ch,n_F,n_A,N,mu_dtd)
```

with the function-specific input variables defined as

- `mu_sg2ch`: the step size for estimation of the convolution of the RIR with the near-end signal model (length `n_F + n_A + 1`)
- `alpha_sg2ch`: the regularization parameter for estimation of the convolution of the RIR with the near-end signal model
- `lambda_a_sg2ch`: the exponential forgetting factor for estimation of the near-end signal model
- `lambda_sigma2_sg2ch`: the exponential forgetting factor for estimation of the near-end excitation signal variance

The SG-PEM-AF algorithm with stochastic gradient update is specified by

```
[F_sgAF,A_sgAF,Sigma2_sgAF,r_sgAF]
 = sg_pemaf(u0,y0,mu_sgAF,alpha_sgAF,lambda_a_sgAF,n_F,n_A,N,
            mu_dtd)
```

with the function-specific input variables defined as

- `mu_sgAF`: the step size for estimation of the RIR
- `alpha_sgAF`: the regularization parameter for estimation the RIR
- `lambda_a_sgAF`: the exponential forgetting factor for estimation of both the near-end signal model and the near-end excitation signal variance

The SG-PEM-AFROW algorithm with stochastic gradient update is specified by

```
[F_sgROW,A_sgROW,Sigma2_sgROW,r_sgROW]
 = sg_pemafrow(u0,y0,mu_sgROW,alpha_sgROW,n_F,n_A,N,M,P,mu_dtd)
```

with the function-specific input variables defined as

- `mu_sgROW`: the step size for estimation of the RIR
- `alpha_sgROW`: the regularization parameter for estimation the RIR
- `M`: the number of samples denoting the linear prediction window length
- `P`: the number of samples denoting the linear prediction window hop size (defined as the window length minus the window overlap)

The SG-RPE algorithm with stochastic gradient update is specified by

```
[F_sgRPE,A_sgRPE,Sigma2_sgRPE,r_sgRPE]
 = sg_rpe(u0,y0,mu_sgRPE,alpha_sgRPE,lambda_a_sgRPE,n_F,n_A,N,
          mu_dtd)
```

with the function-specific input variables defined as

- `mu_sgRPE`: the step size for estimation of the RIR
- `alpha_sgRPE`: the regularization parameter for estimation the RIR
- `lambda_a_RPE`: the exponential forgetting factor for estimation of both the near-end signal model and the near-end excitation signal variance

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Toon van Waterschoot is a Research Assistant with the IWT (Flemish Institute for Scientific and Technological Research in Industry). This research work was carried out at the ESAT laboratory of the Katholieke Universiteit Leuven, in the frame of the Belgian Programme on Interuniversity Attraction Poles, initiated by the Belgian Federal Science Policy Office IUAP P5/22 ('Dynamical Systems and Control: Computation, Identification and Modelling'), the Concerted Research Action GOA-AMBioRICS and IWT project 040803: 'SMS4PA-II: Sound Management System for Public Address Systems'. The scientific responsibility is assumed by its authors.

References

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[2] J. R. Hopgood, "Acoustic impulse response database," ©CEDAR Audio. Available from `http://www-sigproc.eng.cam.ac.uk/oldhomes/jrh1008/public_html/Resources/ImpulseResponses/index.html`.