# USING A SINES + WAVELETS MIXED DICTIONARY FOR IMPROVING MATCHING PURSUIT-BASED PARAMETRIC AUDIO CODING

P. Vera-Candeas, N. Ruiz-Reyes, M. Rosa-Zurera, J.C. Cuevas-Martinez, J.M. Garcia-Rubia

Electronics and Telecommunication Engineering Department, Polytechnic School, University of Jaén C/ Alfonso X el Sabio, 28, 23700 - Linares, Jaén, Spain phone: +(34) 953648554, fax: +(34) 953648508, email: {pvera, nicolas,jccuevas}@ujaen.es

ABSTRACT 2. SPARSE APPROXIMATIONS: MATCHING T**aphilist**h PURSUIT ligijillige) MasselyMadZa 6]. na**bil**e Toppha w L è spijfth x[n] sate it piletiga  $g_i[n]$  before . Adatriați istaaistat telõjepeet jennt Le H balle Wa istopinel Intega plan bos bijlaalin  $D = \{g_i[n] ; i =$ **bebelefeleb**  $0,1,...,L\}$ fílán  $||g_i[n]|| = 1$ . H, ba elistatione in the second s Ex Majas akabaf **þisjiligfi**ðih x[n] intern b Hitigh inini Tipo ĉia mista  $q_i[n]$  being eltpilitipa  $l^2$  risestep  $D, \mathbf{h}$ inian Atlantia babio 16 Kostation m  $g_i[n]$  tight the x[n] is Telefiti 袖 1. INTRODUCTION ittilikki Panthaighilab m-the they debal Atha eabbfieilaty boble 1, 2, glabble inthe Aide 3, 4]. Alberran  $r^{m}[n] = r^{m+1}[n] + \alpha_{i(m)} \cdot g_{i(m)}[n] \quad m \ge 1$ (1) $\alpha_{i(m)}$  is by a basis of the matrix of t φ. Spa TatalNo  $g_{i(m)}[n]$  taka m-bada  $r^1[n]$  is the ŧn September b x[n]. **etri küüle**h  $r^m[n]$  de B kapi Intip tistipi  $g_i[n] \in D,$  by the **fa**n obilizóbildia m- titit tth ich Mossenes IN ihligi d [3,4,5] jubiji bied ja divid Trijektep  $\alpha_i^m = \frac{\langle r^m[n], g_i[n] \rangle}{\langle g_i[n], g_i[n] \rangle} = \frac{\langle r^m[n], g_i[n] \rangle}{\|g_i[n]\|^2} = \langle r^m[n], g_i[n] \rangle$ (2)bisbisbisficten bh isistétetta Th p£iiiiiiiiiiiiiiiiii  $g_{i(m)}[n]$  tabe m-these Teppen id jebla (ie fabilipadasa ba bibeninjen jejnepoje. By  $g_{i(m)}[n] = g_{i(m)} ||r^{m+1}[n]||^2$ (3)dilibith ien isipisist Talpija legislejabbe bi stv  $\operatorname{Foto}(1) \operatorname{el}(2), \operatorname{is}(3) \operatorname{elet}{\operatorname{Sa}}$ ibh 1) Schubbch leinel **bene**fetw  $g_{i(m)}[n] = \operatorname{gn}_{g_i \in D} |\alpha_i^m|$ (4)peopplaate testel 2) Tatelbych Asala lajabla telemate[1], talahabap Variate m- littan telf isolisiedine.  $r^m[n]$ . biologia Tetefio d  $\langle r^m[n], g_i[n] \rangle \forall g_i[n]$  the particular dependence of the second s b At has been worth hef hatelite **iscis**lab**eg**őbel **ġeŋġe**[6]: Tophag whether isterfitistaidi Thistoffugfis  $\langle r^{m+1}[n], g_i[n] \rangle = \langle r^m[n], g_i[n] \rangle - \alpha_{i(m)} \cdot \langle g_{i(m)}[n], g_i[n] \rangle$ (5) 1) **Sta**water big  $h^{2}$ ) fateplate integration in the second secon  $\langle g_{i(m)}[n], g_i[n] \rangle$  abp da poada Inha Ch 6 Te tiskidda hattibbel  $\langle x[n], g_i[n] \rangle$ ). isticaila is tabafaba(

### 3. MATCHING PURSUIT WITH A MIXED DICTIONARY OF SINES + WAVELETS

 This
 D is bigling if

 Chain
  $D_e$  bigling i

 Chain
  $D_e$  bigling i

 L is  $e_i[n]$  al  $w_i[n]$  efthering i
  $D_w$ .

 kit is
 At the big is

 is by At the big is
  $D_w$  

 glaphelines
 The is

 <

**3.1** Implementation with sets of complex exponentials

Ughps hhýfa húshta tina filiadailis Tafa hydishapta

 $e_i[n] = \frac{1}{\sqrt{N}} \cdot e^{j\frac{2\pi}{2L}n}; \ i = 0, \dots, L-1; n = 0, \dots, N-1 \quad (6)$ The  $\frac{1}{\sqrt{N}}$  is both the L has L has the fight L

bbb(7):

$$r^{m+1}[n] = r^{m}[n] - \alpha_{i(m)}e_{i(m)}[n] - \alpha^{*}_{i(m)}e^{*}_{i(m)}[n] = r^{m}[n] - 2Re\{\alpha_{i(m)}e_{i(m)}[n]\}$$
(7)

$$\alpha_i^m = \frac{\langle r^m[n], e_i[n] \rangle - \langle r^m[n], e_i[n] \rangle^* \cdot \langle e_i^*[n], e_i[n] \rangle}{1 - |\langle e_i^*[n], e_i[n] \rangle|^2} \qquad (8)$$

$$\begin{array}{cccc} \mbox{Uithy} & \alpha_i^m, \mbox{ than} & e_{i(m)} \mbox{ than} \\ \mbox{sch} & m-\mbox{ this trip}(4). \\ \mbox{Tellition} & e_i[n] \in D_e \mbox{ d} \\ \mbox{title option} \end{array}$$

$$\langle x[n], e_i[n] \rangle = \frac{1}{\sqrt{N}} \cdot \sum_{n=0}^{2L-1} x[n] \cdot e^{-j\frac{2\pi}{2L}n} = \frac{1}{\sqrt{N}} \cdot X[i] \quad (1\ 0\ )$$

$$\langle e_{i(m)}[n], e_{i}[n] \rangle = \frac{1}{N} \cdot \sum_{\substack{n=0\\ l}}^{2L-1} e^{-j\frac{2\pi(i-i(m))}{2L}n}$$

$$= \frac{1}{N} \cdot U[\underbrace{(-i(m))}_{L}]$$

$$(11)$$

$$\langle e_{i(m)}^{*}[n], e_{i}[n] \rangle = \frac{1}{N} \cdot \sum_{n=0}^{2L-1} e^{-j\frac{2\pi(i+i(m))}{2L}n}$$
  
=  $\frac{1}{N} \cdot U[\ell(+i(m)))_{2L}]$  (12)

by U[i] šk2 Tstánlep (dalšan Tje tapólyjska ijlókybin 1.) Teba

babbbba2 6 bbbbbga2

**stobetinen** 

u[n].

3.2 Implementation with sets of wavelet functions

L- HEFT dit

laivetestubbilit. deleber = (eip(16)).Tabil  $D = D_w$  isologia **iliji**th P- HIME Pla (WP) in Tripfitie è en la companya de l  $D_w$  doubled P-batiw₽ **é Bio**bistinh e Tetititi  $\{s, p, k\},\$ **lithi** s taajqadh  $p^{-}$ delt k, b Tabasah *m*- th**b** eldev elder bestel

$$\alpha^m_{\{s,p,k\}} = \langle r^m[n], w_{\{s,p,k\}}[n] \rangle \tag{13}$$

$$w_{\{s,p,k\}}[n] = w_{\{s,p\}}[n-2^{p}k]$$
(14)

 $\langle x[n], w_{\{s,p,k\}}[n]\rangle$ 

The fine b x[n]. Ob h

d

$$w_{\{s,p,k\}(m)}[n] = \mathbf{g} \quad \mathbf{m}_{\{spk\} \in D_w} |\alpha^m_{\{s,p,k\}}| \qquad (1\ 5\ )$$

The by equation is the set of th

$$\langle w_{\{s_1,p_1,k_1\}}, w_{\{s_2,p_2,k_2\}} \rangle = \begin{cases} \delta[k_2 - k_1] & s_1 = s_2, \\ p_1 = p_2 \\ 0 & s_2 \neq \lfloor \frac{s_1}{2p_1 - p_2} \rfloor \\ w_{\{s,p\}}[k_2 - 2^p k_1] & s_2 = \lfloor \frac{s_1}{2p_1 - p_2} \rfloor \\ (16) \\ p \end{bmatrix}$$

 $\{e_i[n], w_{\{s,p,k\}}[n]\}$  the

3.3 Implementation with the mixed dictionary Within  $D = D_e + D_w)$ , by  $\{\alpha_i^m, \alpha_{\{s,p,k\}}^m\}$  is

jenka istpiky chijden in Telepoplijkoja (8) c(13), giltentes terkeja je Octoby steph tepettes terketationetation terketationetationetation terketationetationetation terketationetationetation terketationetationetationetation terketationetationetationetationetationetation terketationeta

```
Pe jao bibibiji
bid bid
Taks oblabble
ist eisteldepfeldete
be jest fielde
```

3.3.1 Correlation between two complex exponentials.

Quobasba ЬĐ **bëbbbbb** fibbbh FFT. Тh 6  $e_i[n] \in D_e$  night hhian is(11) el(12) itis8.1. Totth  $e_i[n]$ ,  $i_{\mathbf{p}}(9)$  is d **bliebb**n

3.3.2 Correlation between a complex exponential and a wavelet function when the complex exponential is chosen.

Inter detation the dibblegiste anden iq 7). Tidijahap **pho bibipi**n  $e_{i(m)}[n]$  abbs  $w_{\{s,p,k\}}[n] \in D_w$  in static (9). Then ensityheDFT hatelensityn h

 $\langle e_{i(m)}[n], w_{\{s,p,k\}}[n] \rangle = \sum_{n=0}^{N-1} \frac{1}{\sqrt{N}} e^{j\frac{2\pi}{2L}n} w_{\{s,p,k\}}[n] =$  $\frac{1}{\sqrt{N}}W^*_{\{s,p,k\}}[i(m)]$ 

(17)L- gDFT  $W_{\{s,p,k\}}[i(m)]$  is the set of the set o h  $\frac{i(m)}{2L}$ . The  $\delta w_{\{s,p,k\}}[n]$  ables b2 L- bDFT 6666  $\overline{w}_{\{s,p,k\}}[n]$  has obadabbijp  $w_{\{s,p,k\}}[n] = L - \mathbf{b}$ d Madada  $\begin{array}{c} & \widetilde{w}_{\{s,p\}}[n-2^{p}k] \,, \\ & \mathrm{DFT} \, \mathbf{b} \quad w_{\{s,p\}}[n] \,. \end{array}$ bbbbb2 Tebe 62 L- hDFT ob tskisted Telepha entitientitentite

 $D_w$  is plo

3.3.3 Correlation between two wavelet functions.

Waadabid **Hitthin** til Inkas tas beben  $w_{\{s,p,k\}}[n] \in D_w$  hypholds el aemp(16). Noba ido (16), **biqub fig** hand have been a second 6

3.3.4 Correlation between a complex exponential and a wavelet function when the wavelet function is chosen.

Texture 
$$w_{\{s,p,k\}(m)}[n]$$
 divide  $e_i[n] \in D_e$ :

 $\langle w_{\{s,p,k\}(m)}[n], e_i[n] \rangle = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} w_{\{s,p,k\}(m)}[n] e^{-j\frac{2\pi}{2L}n} =$  $\frac{1}{\sqrt{N}}W_{\{s,p,k\}(m)}[i]$ 

(18)L- HEFT 6  $W_{\{s,p,k\}(m)}[i]$  into 2 þ.  $w_{\{s,p,k\}}[n]$  $\frac{i}{2L}$ . In the ta L- DFT  $w_{\{s,p,k\}}[n]$  it by the filfs Asimben 183. 3. 2, hanian abdybbbbbb  $w_{\{s,p,k\}}[n] = w_{\{s,p\}}[n-2^pk].$ ł.

Tosp kaidelin  $D = D_e + D_w) \, isgl$ to to cillar ( hallatalekingan 1) Tel2  $e_i[n] \in D_e; \stackrel{L^-}{2}$ h DFTs 66666 ToppologWP top  $(w_{\{s,p\}}[n]);$ 3) The L- borns  $w_{\{s,p\}}[n] \in D_w.$ 

L-

Water black dilutibo teinellijteja biljan. del Foipp byp sedelete (1) Us aladalokalad kw (2) Cidiji jih (3) Gene (3) hilly bit hip Tøv **boldita** Fei hilliph **defite** 



(a) Audio fragment containing a signal onset. (b) Fiell : Sinusoids and wavelets extracted from the audio frame by the first approach. (c) The same components extracted by the second approach. (d) Idem by the third approach.

Asaba babibba disiditio CH ₩Ŵ(¢) jajeto beje beljejen i tav jan (H b boxistere Thipbohashan ŧl. bisis biarcos ch idsta 2 % fibbefibiel Fig2 **baddig**aion itidijas Tas fø2 skulfel . Titl isjelolsjin Teienia hiybeipis kabba stelyteste Ra tette **beitetete** la bli til bla To**ebpbbbg** abakta intende big interaction with



Fig2: Audio fragment containing a micro-transient

#### **fairling bich**

je On bidghobne Sex peite MPIG bloch efty This bach in This bach is fibige 50 % (p23 - selfigh (N = 1024) el L = 4096. Wy philliphi it is belongist is belon

**Th** 1: PREFERENCE FOR MIXED DICTIONARY-VS-CASCADED DICTIONARIES (%).

Бр.	P6(%)
li ji	100
Cas	100
Phip	5 2
Bg	4 6
C	100
Rate	7 0
dap T	56
Obaje	6 0
Capp	100

Mashbeldd s **by Externation** bo Inka £k"k edődágjaja alp latisticija blebientsistel Folgst ida, bisobabilia teletapi Teletinab 1 ett **dati** Ne sidilidaden statesistices is**jej**i Tin Siljo tapide[4]. Fig3 kkp trighter by the state of  $\dot{tepidepin}$  [4]. Lipt ∦ÅLŠEŘA [8] ∦h Tapila bal end



 $\label{eq:stability} {\bf Fg}: \qquad MUSHRA \ listening \ test \ results \ showing \ mean \ grading \ and \ 95\% \ confidence \ interval.$ 

It sofia hand in the sofia han

## 5. CONCLUSIONS

[

[

ſ

[

ſ

ſ

ſ

[

## REFERENCES

1.Ş. LiaddJ. Spn "A Sak-Tak⊨Nos
Aid Fap 6 Da Cipanel
$T_{Ph}PhShMa, Pp4781,  105th$
$AES \ Convention,  SaFe(USA),  1998.$
2)H Physical Mental The Second
( $\mathbf{l}_{\mathbf{k}}$ , $\mathbf{k}$ 3, $\mathbf{p}$ 201 - 204, 2000.
3 E Spa "Polojeđanja
<b>d</b> , 114th AES Convention: Workshop on recent developments in MPEG-4 audio, M2003.
41P. Va. N. Baz M. Bas J. Cipatel P. J. Ba "Statistical Methods
<b>it bridi</b> , Pp6 176, 116th AES
Convention, $B_{2}(C_{pn}) = 2004$ .
5°, T. S. Vandin: H.Y. Mg, "A6 Javes 5 Jaka briddel, Proc. ICASSP, Iba((T)ar,
$\mathbf{p} \ 877 - 880, \ 2000.$
6S] MandZ. Zag "MagPistoken
أية IEEE Transactions on Signal
$Processing, \ b \ 41, \ p \ 3397 - 3415, \ Det 993.$
71P. Ve. N. Ha. M. Re. D. Marel F.
Leo "The Add Mapping
a Vis Il Jub Phr Aid Citit ,
IEEE Signal Processing Letters, b 11, n 3, 2004
8 JTUR "Michigan
ellako celes (MISERA)",
$\overrightarrow{ITU-R}$ Recommend, <b>E</b> 1534, 2001.