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Adaptive Subchip Multipath Resolving for Wireless Location Systems

Nabil R. Yousef,[1,2] Ali H. Sayed,[1] and Nima Khajehnouri[1]

[1] *Electrical Engineering Department, University of California, Los Angeles, CA 90095-1594, USA*
[2] *Newport Media Inc., Lake Forest, CA 92630, USA*

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Reliable positioning of cellular users in a mobile environment requires accurate resolving of overlapping multipath components. However, this task is difficult due to fast channel fading conditions and data ill-conditioning, which limit the performance of least-squares-based techniques. This paper develops two overlapping multipath resolving methods (adaptive and nonadaptive), and shows how the adaptive solution can be made robust to the above limitations by extracting and exploiting a priori information about the fading channel. Also the proposed techniques are extended when there are antenna arrays at the base station. Simulation results illustrate the performance of the proposed techniques.

1. INTRODUCTION

Wireless propagation suffers from *multipath* conditions. Under such conditions, the prompt ray may be succeeded by multipath components that arrive at the receiver within short delays. If this delay is smaller than the duration of the pulse shape used in the wireless system (i.e., the chip duration T_c in CDMA systems), then the rays overlap. When this situation occurs, it results in significant errors in the estimation of the time and amplitude of arrival of the prompt ray. Figure 1 illustrates the combined impulse response of a two-ray channel using a conventional pulse shape in a CDMA IS-95 system in two situations. In the second situation, where the pulses overlap, the location of the peak is obviously delayed relative to the location of the prompt ray. Such errors in the time-of-arrival are particularly damaging in wireless location applications (a topic of significant relevance nowadays—see, e.g., [1–18]). In these applications, small errors in the time-of-arrival can translate into many meters in terms of location inaccuracy.

There have been earlier studies in the literature on resolving overlapping multipath components (see, e.g., [19, 20]). However, there are two sources of impairments that introduce significant errors into the resolution accuracy and which need special attention; these sources of error are particularly relevant in the context of mobile-positioning systems. The first impairment is due to the possibility of *fast channel fading*, which prohibits the use of long averaging intervals. This is because the estimation period in wireless location applications can reach up to a few seconds, which may cause the channel between the transmitter and the receiver to vary significantly during the estimation period, even for relatively slow channel variations. The second impairment is the possibility of noise enhancement, which occurs as a result of the *ill-conditioning* of the data matrices involved in most least-squares-based solutions.

In this paper, we develop an adaptive technique for resolving overlapping multipath components over fading channels for wireless location purposes. The technique is relatively robust to fast channel fading and data ill-conditioning. The following are the main contributions of this work.

(1) We first describe a framework for overlapped multipath resolving over fading channels via least squares. The framework will indicate why conventional least-squares techniques may fail for fading channels.

(2) We then point out the ill-conditioning problem that arises from using the pulse-shaping waveform deconvolution matrix. In order to avoid the possibility of noise enhancement as a result of this ill-conditioning, we show how to replace the least-squares operation by an adaptive solution. Still, while it avoids boosting up the noise, the adaptive filter solution might diverge or might converge slowly if not properly designed. To address this difficulty, we use a successive projection technique that incorporates into the design of the adaptive filter all available a priori channel information.

(3) We also describe a procedure for extracting a priori channel information and feeding it into the adaptive filter operation.

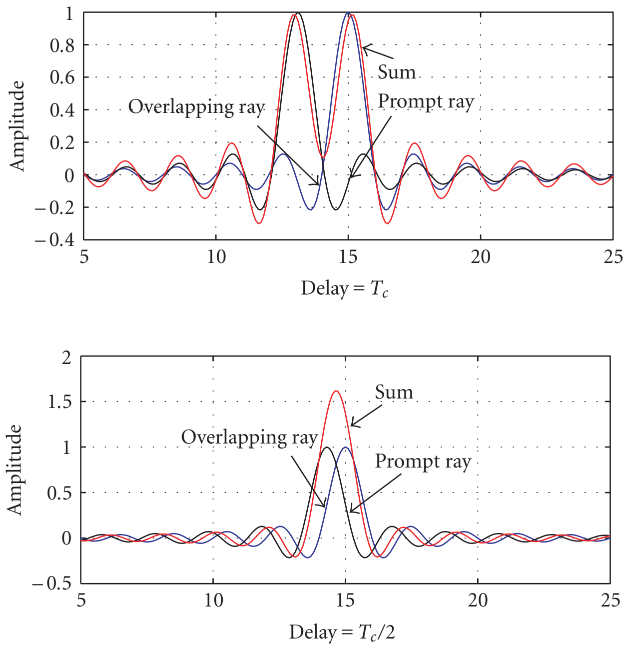


FIGURE 1: Overlapping rays. (a) Delay = T_c. (b) Delay = $T_c/2$.

(4) We then consider the case when there are multiple antennas at the base station and we extend the proposed algorithm for the single antenna case to systems with antenna arrays.

2. PROBLEM FORMULATION

Wireless propagation generally suffers from multipath conditions. A common model for the impulse response sequence of a multipath channel of length L is [21]

$$h(n) = \sum_{l=0}^{L-1} \alpha_l x_l^u(n)\delta(n-l), \tag{1}$$

where the $\{\alpha_l\}$ and $\{x_l^u(n)\}$ are, respectively, the unknown standard deviations (also referred to as gains) and the normalized fading amplitude coefficients (with unit variance); these coefficients model the Rayleigh fading effect of the channel. Several of the gains $\{\alpha_l\}$ might be zero; and a nonzero gain at some $l = l^o$ would indicate the presence of a channel ray at the corresponding delay $n = l^o$. Our strategy will be to estimate the gains $\{\alpha_l\}$, for all values of l, and then compare these values with a threshold. If any α_l is lower than the threshold, then we set it to zero. In model (1), it is assumed that the sampling period for the sequence $\{h(n)\}$ is a fraction of the chip duration, say

$$T_s = \frac{T_c}{N_u} \tag{2}$$

for some integer $N_u > 1$. In other words, the time variable n

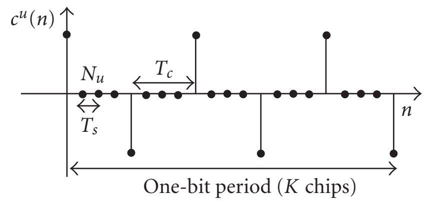


FIGURE 2: Spreading sequence.

refers to multiples of T_s and the superscript u in x_l^u denotes upsampling. By using an upsampled model for the channel impulse response, we will be able to resolve overlapping rays more accurately.

Now consider the problem of estimating the gains $\{\alpha_l\}$ from a received sequence $\{r(n)\}$, which is defined as follows:[1]

$$r(n) = c^u(n) \star p(n) \star h(n) + v(n), \tag{3}$$

where $\{c^u(n)\}_{n=0}^{KN_u-1}$ is a known (*upsampled*) chipping sequence[2] (its entries are 0 or ± 1 when n is an integer multiple of N_u). The integer K denotes the processing gain of the communication system, that is, the ratio between the bit rate and the chip rate—see Figure 2. Moreover, $\{p(n)\}_{n=0}^{P-1}$ is a known pulse-shape impulse response sequence, and $v(n)$ is additive white Gaussian noise of variance σ_v^2. Let $L_r = P + KN_u + L - 1$ denote the total number of samples $\{r(n)\}$. To proceed with the analysis, we introduce the following assumption.

Assumption 1. The variations in the fading channel $\{x_l^u(n)\}$ within the duration of the pulse-shaping waveform, $p(n)$ (i.e., within a duration of P samples), are negligible.

This assumption is reasonable for cellular systems even for fast fading channels. For example, for an IS-95 pulse shaping waveform [22], the duration of the pulse shape is equal to $10T_c$, which corresponds to 8 microseconds. The autocorrelation function, $R_{x_l^u}(\tau)$, of the fading sequence $\{x_l^u(n)\}$, at a time shift of 8 μs for a relatively fast mobile station (MS) moving at 60 mph and using a carrier frequency of $f_c = 900$ MHz, is given from [21] by $J_o(2\pi 80 \times 8 \times 10^{-6}) = 0.999994 \approx 1$. This high value for the autocorrelation between fading ray samples, $\{x_l^u(n)\}$, implies that they can be assumed to be constant within the assumed duration. Therefore, we may ignore variations in the coefficients $\{x_l^u(n)\}$ within the pulse-shape duration.

[1] The sampling period for all sequences $\{r(n), h(n), p(n)\}$ is a fraction of the chip duration, $T_s = T_c/N_u$.

[2] In wireless location applications, the received bits can be assumed to be known. This could be achieved by using known transmitted training sequences as in [7]. Another way is to use only received frames of perfect cyclic redundancy check (CRC), or to use the output decoded bits of the Viterbi decoder, which are at a high level of accuracy.

Using Assumption 1 and (1), we can approximate (3) as

$$r(n) \approx \sum_{l=0}^{L-1} \alpha_l([x_l^u(n)c^u(n-l)] \star p(n)) + v(n), \tag{4}$$

that is,

$$r(n) \approx v(n) + p(n) \star \left([x_0^u(n)c^u(n) \cdots x_{L-1}^u(n)c^u(n-L+1)] \begin{bmatrix} \alpha_0 \\ \vdots \\ \alpha_{L-1} \end{bmatrix} \right). \tag{5}$$

Let $\mathbf{A}$ denote $L_r \times KN_u$ pulse-shape convolution matrix (which is lower triangular and Toeplitz):

$$\mathbf{A} = \underbrace{\begin{bmatrix} p(0) & & & & & \\ p(1) & p(0) & & & & \\ p(2) & p(1) & p(0) & & & \\ \vdots & \cdot & \cdot & \ddots & & \\ p(P-1) & \cdot & \cdot & p(1) & p(0) & \\ & p(P-1) & \dots & & p(1) & p(0) \\ & & \ddots & & & \ddots \end{bmatrix}}_{L_r \times KN_u}. \tag{6}$$

Then the sequence that results from the first convolution $p(n) \star [x_0^u(n)c^u(n)]$ can be obtained as the matrix vector product:

$$\mathbf{A} \cdot \underbrace{\begin{bmatrix} x_0^u(0) \cdot c^u(0) \\ x_0^u(1) \cdot 0 \\ x_0^u(2) \cdot 0 \\ \vdots \\ \hline x_0^u(N_u) \cdot c^u(N_u) \\ x_0^u(N_u+1) \cdot 0 \\ x_0^u(N_u+2) \cdot 0 \\ \vdots \\ \hline x_0^u(2N_u) \cdot c^u(2N_u) \\ x_0^u(2N_u+1) \cdot 0 \\ x_0^u(2N_u+2) \cdot 0 \\ \vdots \\ \hline x_0^u((K-1)N_u) \cdot c^u((K-1)N_u) \\ x_0^u((K-1)N_u+1) \cdot 0 \\ x_0^u((K-1)N_u+2) \cdot 0 \\ \vdots \end{bmatrix}}_{KN_u \times 1}. \tag{7}$$

Likewise, the sequence that results from the second convolution $p(n) \star [x_1^u(n)c^u(n-1)]$ can be obtained as the matrix vector product

$$\mathbf{A} \cdot \underbrace{\begin{bmatrix} x_1^u(0) \cdot 0 \\ x_1^u(1) \cdot c^u(0) \\ x_1^u(2) \cdot 0 \\ \vdots \\ \hline x_1^u(N_u) \cdot 0 \\ x_1^u(N_u+1) \cdot c^u(N_u) \\ x_1^u(N_u+2) \cdot 0 \\ \vdots \\ \hline x_1^u(2N_u) \cdot 0 \\ x_1^u(2N_u+1) \cdot c^u(2N_u) \\ x_1^u(2N_u+2) \cdot 0 \\ \vdots \\ \hline x_1^u((K-1)N_u) \cdot 0 \\ x_1^u((K-1)N_u+1) \cdot c^u((K-1)N_u) \\ x_1^u((K-1)N_u+2) \cdot 0 \\ \vdots \end{bmatrix}}_{KN_u \times 1} \tag{8}$$

and so on. We can represent the above results more compactly in matrix form as follows. Introduce the downsampled sequences:

$$\begin{aligned} x_k(j) &\triangleq x_k^u[jN_u + k], \quad k = 0, 1, \dots, L-1, \\ c(j) &\triangleq c^u(jN_u), \quad j = 0, 1, \dots, K-1. \end{aligned} \tag{9}$$

Then we obtain from (4) that

$$\mathbf{r} = \mathbf{A}\mathbf{C}_x\mathbf{h} + \mathbf{v}, \tag{10}$$

where $\mathbf{r}$ is the received vector of length L_r defined as

$$\mathbf{r} \triangleq \text{col}\,[r(0), r(1), \dots, r(L_r - 1)] \tag{11}$$

and $\mathbf{v}$ is the noise vector defined as

$$\mathbf{v} \triangleq \text{col}\,[v(0), v(1), \dots, v(L_r - 1)]. \tag{12}$$

Moreover, $\mathbf{C}_x$ is the $KN_u \times L$ matrix defined as

$$\mathbf{C}_x \triangleq \left[\begin{array}{cccc}
x_0(0)\cdot c(0) & & & \\
0 & x_1(0)\cdot c(0) & & \\
\vdots & 0 & \ddots & x_{L-1}(0)\cdot c(0) \\
0 & \vdots & \ddots & \vdots \\
\hline
x_0(1)\cdot c(1) & 0 & \ddots & 0 \\
0 & x_1(1)\cdot c(1) & \ddots & \vdots \\
\vdots & 0 & \ddots & x_{L-1}(1)\cdot c(1) \\
0 & & \ddots & \vdots \\
\hline
x_0(K-1)\cdot c(K-1) & \vdots & \ddots & \vdots \\
 & x_1(K-1)\cdot c(K-1) & \ddots & \\
 & & \ddots & 0 \\
 & & \ddots & x_{L-1}(K-1)\cdot c(K-1) \\
 & & & \vdots
\end{array}\right] \tag{13}$$

and $\mathbf{h}$ is the unknown path gain vector defined by

$$\mathbf{h} \triangleq \operatorname{col}\left[\alpha_0, \alpha_1, \ldots, \alpha_{L-1}\right]. \tag{14}$$

In summary, the problem we are interested in is that of estimating $\mathbf{h}$ from the received vector $\mathbf{r}$ in (10), with the constraint that the matrix $\mathbf{C}_x$ is not known completely since it depends on the unavailable quantities $\{x_k(j)\}$. To do so, we will exploit the statistical property of the fading quantities $\{x_k(j)\}$.

3. CONVENTIONAL MATCHED FILTERING

Let us examine first what happens if we correlate $r(n)$ and $c^u(n)$ as in

$$g(n) \triangleq \frac{1}{K}\sum_{k=0}^{K-1} r(k)c^{u*}(k-n), \quad n = 0, 1, \ldots, L-1. \tag{15}$$

The result of this correlation (or despreading) operation is given (in vector form) by $(1/K)\mathbf{C}^*\mathbf{r}$, where $\mathbf{C}$ is the following $L_r \times L$ spreading code matrix:

$$\mathbf{C} \triangleq \left[\begin{array}{cccc}
c(0) & & & \\
0 & c(0) & & \\
\vdots & 0 & \ddots & c(0) \\
0 & \vdots & \ddots & \vdots \\
\hline
c(1) & 0 & \ddots & 0 \\
0 & c(1) & \ddots & \\
 & \vdots & \ddots & c(1) \\
\vdots & 0 & \ddots & \vdots \\
\hline
c(K-1) & \vdots & \ddots & \\
 & c(K-1) & \ddots & 0 \\
 & & \ddots & c(K-1) \\
 & & & \vdots
\end{array}\right]. \tag{16}$$

Then from (10), we get

$$\frac{1}{K}\mathbf{C}^*\mathbf{r} = \frac{1}{K}\mathbf{C}^*\mathbf{A}\mathbf{C}_x\mathbf{h} + \frac{1}{K}\mathbf{C}^*\mathbf{v}. \tag{17}$$

When K is large enough, and using the orthogonality property

$$\frac{1}{K}\sum_{j=0}^{K-1} x_k(j)c(j)c^*(j+1) \approx 0, \quad k = 0,1,\ldots,L-1, \tag{18}$$

we obtain the approximation—see Appendix A:

$$\frac{1}{K}\mathbf{C}^*\mathbf{A}\mathbf{C}_x\mathbf{h} \approx \mathbf{A}_L\mathbf{X}_K\mathbf{h}, \tag{19}$$

where $\mathbf{A}_L$ is an $L \times L$ pulse-shaping convolution matrix similar to $\mathbf{A}$, and $\mathbf{X}_K$ is the $L \times L$ diagonal matrix

$$\mathbf{X}_K \triangleq \frac{1}{K}\,\mathrm{diag}\left[\sum_{j=0}^{K-1} x_0(j),\ldots,\sum_{j=0}^{K-1} x_{L-1}(j)\right]. \tag{20}$$

Assuming ergodic processes, and taking the limit as $K \to \infty$ of both sides of the above definition, we obtain

$$\lim_{K\to\infty} \mathbf{X}_K = \mathrm{diag}\left[\,\mathrm{E}x_0(j), \mathrm{E}x_1(j),\ldots,\mathrm{E}x_{L-1}(j)\right]. \tag{21}$$

Thus, unless the channel fading coefficients have static components, we get

$$\lim_{K\to\infty} \mathbf{X}_K = \mathbf{0}. \tag{22}$$

This result causes the output of the correlation process given by (17) to approach zero as $K \to \infty$. Consequently, estimation techniques that are based on correlation (or *matched filtering*) will be *unrobust* when used to estimate the fading channels. This fact explains why it is difficult to obtain accurate location estimates using such techniques.

4. A PARTITIONED LEAST-SQUARES RECEIVER STRUCTURE

We now describe a technique for estimating $\mathbf{h}$ from (10) and which does not require knowledge of the $\{x_k(j)\}$. To begin with, note from (10) that if $\mathbf{C}_x$ were known, then the least-squares estimate for $\mathbf{h}$ could be found by solving

$$\hat{\mathbf{h}} = \arg\min_{\mathbf{h}} \left\|\mathbf{r} - \mathbf{A}\mathbf{C}_x\mathbf{h}\right\|^2 \tag{23}$$

which gives

$$\hat{\mathbf{h}} = \left(\mathbf{C}_x^*\mathbf{A}^*\mathbf{A}\mathbf{C}_x\right)^{-1}\mathbf{C}_x^*\mathbf{A}^*\mathbf{r}. \tag{24}$$

However, $\mathbf{C}_x$ is not known since the $\{x_k(j)\}$ themselves are not known. Thus we proceed instead as follows.

We first partition the received vector $\mathbf{r}$ in (10) into smaller vectors, say $\mathbf{r}_m$, of size NN_u samples each (i.e., each $\mathbf{r}_m$ contains N symbols with N_u samples per symbol). Each $\mathbf{r}_m$ will satisfy an equation of the form

$$\mathbf{r}_m = \mathbf{A}_m\mathbf{C}_x^m\mathbf{h} + \mathbf{v}_m \tag{25}$$

with $\{\mathbf{A}_m, \mathbf{C}_x^m\}$ similar to $\{\mathbf{A}, \mathbf{C}_x\}$ in (10) but of smaller dimensions, and where $\mathbf{v}_m$ is defined by

$$\mathbf{v}_m \triangleq \mathrm{col}\left[\mathbf{v}(mNN_u),\ldots,\mathbf{v}((m+1)NN_u-1)\right]. \tag{26}$$

Then, in view of the earlier discussion, we are motivated to introduce the following algorithm.

(1) Partition the received vector $\mathbf{r}$ into M smaller vectors with NN_u samples each, and such that the mth vector is given by

$$\mathbf{r}_m = \mathrm{col}\left[\mathbf{r}(mNN_u),\ldots,\mathbf{r}((m+1)NN_u-1)\right]. \tag{27}$$

Note that $L_r = MNN_u$.

(2) Introduce the $NN_u \times L$ correlation (despreading) matrix

$$\mathbf{C}_m \triangleq \left[\begin{array}{cccc}
c(mN) & & & \\
0 & c(mN) & & \\
\vdots & 0 & \ddots & c(mN) \\
0 & \vdots & \ddots & \vdots \\
\hline
c(mN+1) & 0 & \ddots & 0 \\
0 & c(mN+1) & \ddots & \vdots \\
\vdots & 0 & \ddots & c(mN+1) \\
0 & \vdots & \ddots & \vdots \\
\hline
c((m+1)N-1) & \vdots & \ddots & \\
 & c((m+1)N-1) & \ddots & 0 \\
 & & \ddots & c((m+1)N-1) \\
 & & & \vdots
\end{array}\right] \tag{28}$$

and the $L \times L$ fading matrix $\mathbf{X}_m$:

$$\mathbf{X}_m \triangleq \frac{1}{N}\operatorname{diag}\left[\sum_{j=n_o}^{(m+1)N-1} x_0(j), \ldots, \sum_{j=n_o}^{(m+1)N-1} x_{L-1}(j)\right], \quad (29)$$

where $n_o = mN$. Now N is usually small enough such that $\sum_{j=n_o}^{(m+1)N-1} x_l(j)$ will not tend to zero and, hence, we will not be faced with the difficulty of having $\mathbf{X}_m \to 0$, as was the case with $\mathbf{X}_k$ (22).

(3) Multiply each vector $\mathbf{r}_m$ from the left by $(1/N)\mathbf{C}_m^*$, with $m = 0, 1, \ldots, M-1$. The correlated (despreaded) output is denoted by

$$\mathbf{y}_m = \frac{1}{N}\mathbf{C}_m^*\mathbf{r}_m. \quad (30)$$

At the same time N is large enough to get uncorrelated shifted spreading sequences, so that similar to (19), $\mathbf{y}_m$ can be approximated by

$$\mathbf{y}_m \approx \mathbf{A}_L\mathbf{X}_m\mathbf{h} + \frac{1}{N}\mathbf{C}_m^*\mathbf{v}_m. \quad (31)$$

(4) Let $\mathbf{z}_m = \mathbf{X}_m\mathbf{h}$. The despreaded vector $\mathbf{y}_m$ can be used to estimate $\mathbf{z}_m$ in the least-squares sense by solving

$$\hat{\mathbf{z}}_m = \arg\min_{\mathbf{z}_m} ||\mathbf{y}_m - \mathbf{A}_L\mathbf{z}_m||^2 \quad (32)$$

which yields

$$\hat{\mathbf{z}}_m = \left(\mathbf{A}_L^*\mathbf{A}_L\right)^{-1}\mathbf{A}_L^*\mathbf{y}_m = \frac{1}{N}\left(\mathbf{A}_L^*\mathbf{A}_L\right)^{-1}\mathbf{A}_L^*\mathbf{C}_m^*\mathbf{r}_m. \quad (33)$$

(5) Introduce the vector $\hat{\beta}$ (averaged over all estimates $\hat{\mathbf{z}}_m$):

$$\hat{\beta} = \frac{1}{M}\sum_{m=0}^{M-1}\begin{bmatrix} |\hat{\mathbf{z}}_m(0)|^2 \\ |\hat{\mathbf{z}}_m(1)|^2 \\ \vdots \\ |\hat{\mathbf{z}}_m(L-1)|^2 \end{bmatrix}. \quad (34)$$

For simplicity of notation, we will write $|\mathbf{x}|^2$ to denote a vector whose individual entries are the squared norms of the entries of $\mathbf{x}$:

$$|\mathbf{x}|^2 \triangleq \begin{bmatrix} |\mathbf{x}(0)|^2 \\ |\mathbf{x}(1)|^2 \\ \vdots \\ |\mathbf{x}(L-1)|^2 \end{bmatrix}. \quad (35)$$

Using this notation, we can write

$$\hat{\beta} = \frac{1}{M}\sum_{m=0}^{M-1}\left|\frac{1}{N}\left(\mathbf{A}_L^*\mathbf{A}_L\right)^{-1}\mathbf{A}_L^*\mathbf{C}_m^*\mathbf{r}_m\right|^2. \quad (36)$$

The entries of $\hat{\beta}$ will be shown in the sequel to be related to estimates of the desired gains $\{\alpha_l\}$—see (49).

4.1. Parameter optimization and bias equalization

Assume that the length of the received data is large enough ($L_r \to \infty$). Then expression (36) becomes

$$\hat{\beta} = \lim_{M\to\infty}\frac{1}{M}\sum_{m=0}^{M-1}\left|\frac{1}{N}\left(\mathbf{A}_L^*\mathbf{A}_L\right)^{-1}\mathbf{A}_L^*\mathbf{C}_m^*\mathbf{r}_m\right|^2. \quad (37)$$

As $M \to \infty$, the averaging process may be approximated by the expectation operation so that

$$\hat{\beta} \approx \mathrm{E}\left|\frac{1}{N}\left(\mathbf{A}_L^*\mathbf{A}_L\right)^{-1}\mathbf{A}_L^*\mathbf{C}_m^*\mathbf{r}_m\right|^2. \quad (38)$$

Using (30) and (31) gives

$$\hat{\beta} = \mathrm{E}\left|\mathbf{X}_m\mathbf{h} + \frac{1}{N}\left(\mathbf{A}_L^*\mathbf{A}_L\right)^{-1}\mathbf{A}_L^*\mathbf{C}_m^*\mathbf{v}_m\right|^2 \quad (39)$$

which can rewritten as

$$\hat{\beta} = \mathrm{E}\left|\mathbf{X}_m\mathbf{h} + \frac{1}{N}\mathbf{A}_L^\dagger\mathbf{v}_m'\right|^2, \quad (40)$$

where

$$\mathbf{v}_m' = \mathbf{C}_m^*\mathbf{v}_m \quad (41)$$

and the pseudo-inverse matrix $\mathbf{A}_L^\dagger$ is given by

$$\mathbf{A}_L^\dagger = \left(\mathbf{A}_L^*\mathbf{A}_L\right)^{-1}\mathbf{A}_L^*. \quad (42)$$

For mathematical tractability of the analysis, we introduce the following assumptions.

Assumption 2. The sequence $\{v'(n)\}$ is identically statistically independent (i.i.d) and is independent of each of the fading channel normalized gain sequences $\{x_l^u(n)\}$.

Although the sequence $\{v'(n)\}$ is not i.i.d, the assumption is a reasonable approximation in view of the fact that the entries of $\{v(n)\}$ are i.i.d, and in view of the orthogonality of the spreading sequences. The argument in Appendix B, for example, shows that $v'(i)$ and $v'(j)$ are uncorrelated for $i \neq j$. Assumption 2 is instead requiring the noises to be independent. It follows from (41) that $\sigma_{v'}^2 = N\sigma_v^2$.

Assumption 3. The fading channel normalized amplitudes $\{x_k(j)\}$ are statistically independent of each other.

This assumption is typical in the context of wireless channel modeling [21]. Using (40), the elements of the vector $\hat{\beta}$ are individually given by

$$\hat{\beta}(l) = \mathrm{E}\left|\frac{\alpha_l}{N}\sum_{j=mN}^{(m+1)N-1} x_k(j) + \frac{1}{N}\sum_{i=0}^{L-1}\left(\mathbf{A}_L^\dagger(l,i)\mathbf{v}'(i)\right)\right|^2. \quad (43)$$

Expanding, using Assumptions 2 and 3, and following the same procedure used in [23, 24], it can be verified that

$$\hat{\beta}(l) = B_f(l)\alpha_l^2 + B_v(l), \quad (44)$$

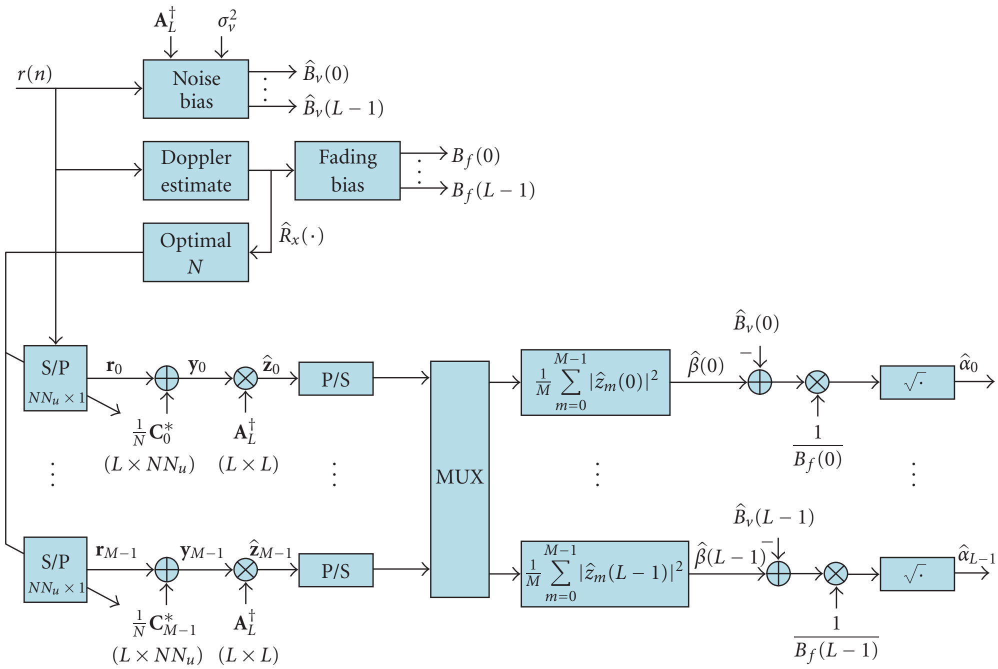


FIGURE 3: A least-squares multipath searcher using data partitioning.

where $B_f(l)$ and $B_v(l)$ are, respectively, given by

$$B_f(l) = \frac{R_{x_k}(0)}{N} + \sum_{i=1}^{N-1} \frac{2(N-i)R_{x_k}(i)}{N^2},$$
$$B_v(l) = \frac{\sigma_v^2}{N} \sum_{i=0}^{L-1} \left[\mathbf{A}_L^\dagger(l,i)\right]^2. \tag{45}$$

In the above, $R_{x_k}(i)$ is the autocorrelation function of each of the fading channel coefficients, that is,

$$R_{x_k}(|i|) = \mathrm{E}\, x_k(j)x_k^*(j-i). \tag{46}$$

Expression (44) shows that $\hat{\beta}(l)$ includes a multiplicative fading bias $B_f(l)$ and an additive noise bias $B_v(l)$. Now consider the case of identical autocorrelation functions for all channel rays, say $R_x(i)$, and define the SNR gain

$$S_G(l) \triangleq \frac{B_f(l)}{B_v(l)} = \frac{1}{\sigma_v^2 \sum_{i=1}^{L} \mathbf{A}_L^{\dagger 2}(l,i)} \left(R_x(0) + \sum_{i=1}^{N-1} \frac{2(N-i)R_x(i)}{N} \right). \tag{47}$$

This expression suggests an optimal choice for N by maximizing it with respect to N. A similar approach was used in [23, 24] and N_{opt} is found by solving the following equation:

$$\sum_{i=1}^{N_{\text{opt}}-1} iR_x(i) = 0. \tag{48}$$

Once the $\{B_f(l), B_v(l)\}$ have been estimated, they can be used to correct $\hat{\beta}(l)$ in order to estimate the channel gains $\{\hat{\alpha}_l\}$:

$$\hat{\alpha}_l = \sqrt{C_f(l)\left(\hat{\beta}(l) - \hat{B}_v(l)\right)}, \tag{49}$$

where

$$C_f(l) = \frac{1}{\hat{B}_f(l)}. \tag{50}$$

The estimates $\hat{B}_v(l)$ and $\hat{B}_f(l)$ can be obtained by using the same procedure given in [23, 24]. Figure 3 shows the resulting multipath searcher. The Doppler estimate depicted in Figure 3 is required during the determination of $R_x(i)$ and, hence, N_{opt} and the fading bias coefficient $\hat{B}_f(l)$ [25]. Figure 4 shows the SNR gain for different values of Doppler frequencies. Moreover, N_{opt} for different values of Doppler frequencies has been shown in Figure 5.

4.2. *Difficulties*

The main problem facing the least-squares multipath searcher of Figure 3 is the ill-conditioning of the pulse-shaping matrix $\mathbf{A}_L$, which increases with the sampling resolution. Figure 6 plots the condition number of the matrix $\mathbf{A}_L$ (in dB) versus the oversampling factor N_u.

The ill-conditioning of $\mathbf{A}_L$ results in noise enhancement, which in turn reduces the estimation accuracy. In the next sections, we explain how to use an *adaptive filter* solution in order to avoid the least-squares step and, more specifically, avoid the boosting up of the noise. In order to enhance the robustness of the adaptive solution, we will further show how

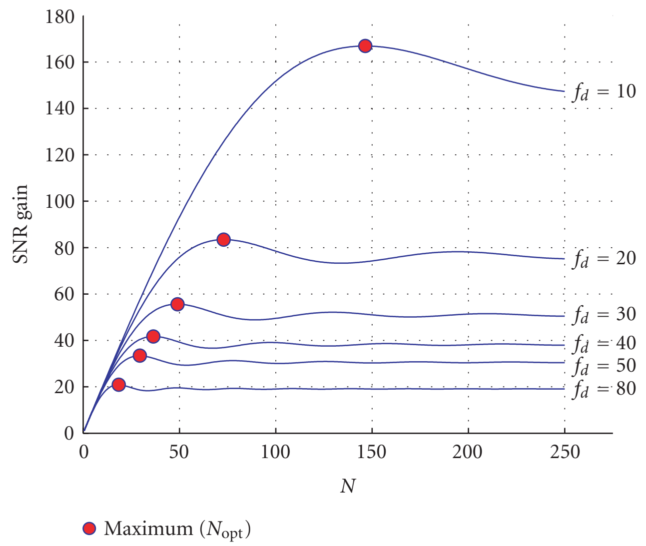


FIGURE 4: SNR gain versus N for $K = 256$ and $T_c = 8.138$ microseconds and for different Doppler frequencies.

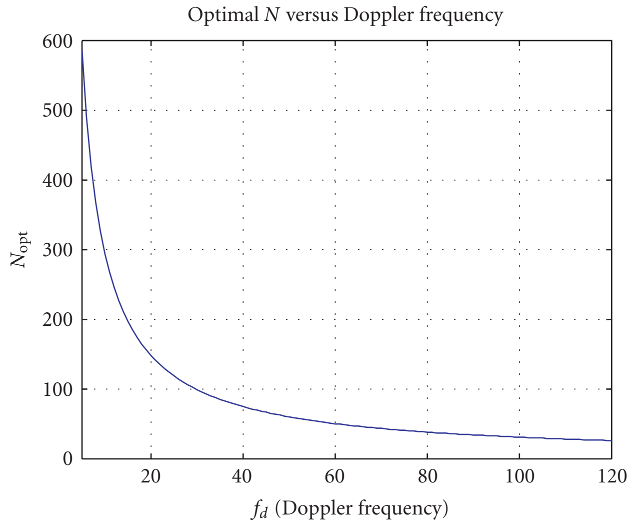


FIGURE 5: Optimum N for $K = 256$ and $T_c = 8.138$ microseconds.

to extract and incorporate into the design of the adaptive solution a priori knowledge about the multipath channel.

5. AN ADAPTIVE PROJECTION TECHNIQUE

We now describe an adaptive projection technique for channel estimation that exploits a priori information about the channel for enhanced accuracy. The technique replaces the least squares of Section 4 by an adaptive filter. The proposed method can be described as follows.

Recall that we need to solve least-squares problems of the form (32), that is,

$$\hat{\mathbf{z}}_m = \arg\min_{\mathbf{z}_m} \left\| \mathbf{y}_m - \mathbf{A}_L \mathbf{z}_m \right\|^2 \tag{51}$$

for successive values of m, where

$$\mathbf{y}_m = \frac{1}{N} \mathbf{C}_m^* \mathbf{r}_m. \tag{52}$$

We will denote the entries of the successive $\mathbf{y}_m$ by $\{d_m(i)\}$. Clearly, the solution of (51) can also be approximately attained by training an adaptive filter that uses the $\{d_m(i)\}$ as reference data and the rows of the $L \times L$ matrix $\mathbf{A}_L$ as regression data. We will denote the rows of $\mathbf{A}_L$ by $\{\mathbf{u}_i\}$. Since $\mathbf{A}_L$ has only L rows, the adaptive filter is cycled repeatedly through these regression rows until sufficient convergence is obtained. In addition, it is explained in Appendix C how we can extract useful information about the channel such as its region of support (i.e., the region over which the channel taps are most likely to exist) and the largest amplitude that any of its peaks can achieve. This information can be exploited by the adaptive solution as explained below in order to enhance the accuracy and the resolution of the resulting multipath searcher. Thus the adaptive implementation can be described as follows.

(1) The received signal $r(n)$ is applied to a bank of matched filters $\mathbf{C}_m^*$ in order to generate the vectors $\{\mathbf{y}_m\}$.

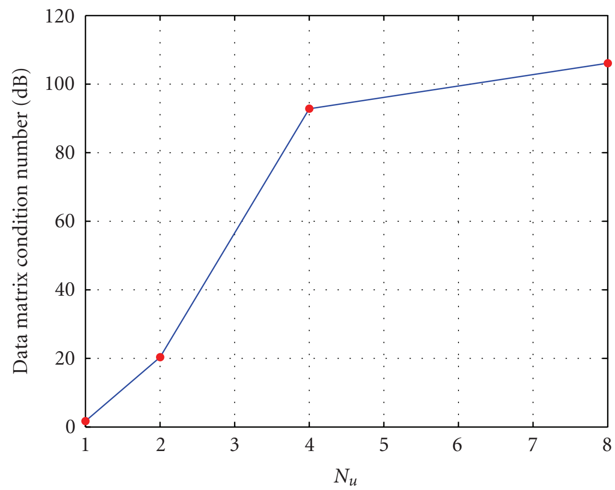


FIGURE 6: Condition number of $\mathbf{A}_L$ versus N_u.

(2) A parallel-to-serial converter is applied to each $\mathbf{y}_m$ in order to form the reference sequence $\{d_m(i)\}$.

(3) An adaptive filter of weight vector $\mathbf{w}_i^m$ is used to estimate $\mathbf{z}_m$ at the ith iteration (i.e., $\mathbf{w}_i^m$ is the estimate of $\mathbf{z}_m$ at iteration i). The regression vector $\mathbf{u}_i$ is obtained from the rows of $\mathbf{A}_L$. The adaptive filter is iterated repeatedly in a cyclic manner over the rows of $\mathbf{A}_L$ until sufficient performance is attained.

(4) In addition, at every N_p iterations, the weight vector of the adaptive filter is checked and, if necessary, a projection step $\mathcal{P}$ is performed in order to guarantee that the filter taps are consistent with the a priori information that is available about the channel taps. For instance, if we know that the channel has only two nonzero taps, then we zero out all taps except for the largest two taps (recall that since $\mathbf{z}_m = \mathbf{X}_m \mathbf{h}$, and since $\mathbf{X}_m$ is a diagonal matrix, then zero taps

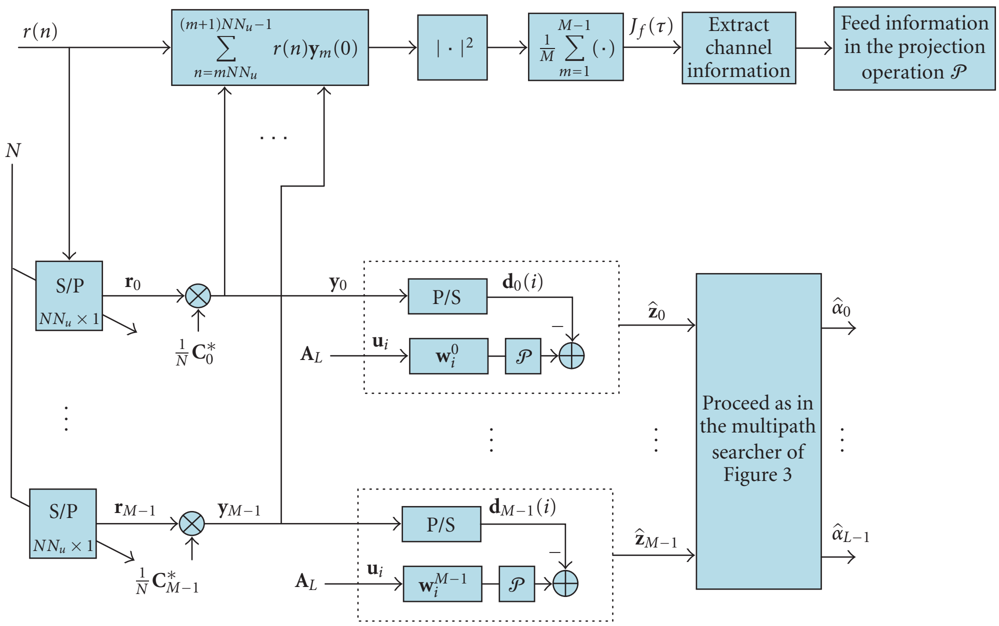


FIGURE 7: An adaptive multipath resolving scheme using successive projections.

in $\mathbf{h}$ translate into zero taps in the estimates of $\mathbf{z}_m$). Specifically, the adaptive filter weight vector $\mathbf{w}_i^m$ is updated as follows:

$$\mathbf{w}_i^m = \begin{cases} \mathbf{w}_{i-1}^m + \mu(i)\mathbf{u}_i^*\left[d_m(i) - \mathbf{u}_i\mathbf{w}_{i-1}^m\right] & \text{for } i \neq N_p, 2N_p, \ldots, \\ \mathcal{P}\left\{\mathbf{w}_{i-1}^m + \mu(i)\mathbf{u}_i^*\left[d_m(i) - \mathbf{u}_i\mathbf{w}_{i-1}^m\right]\right\} & \text{for } i = N_p, 2N_p, \ldots. \end{cases} \tag{53}$$

Here $\mu(i)$ is a step-size parameter, $\mathcal{P}$ refers to the projection procedure, and N_p is an integer greater than or equal to one and less than or equal to the total number of iterations performed.

(5) The successive projections are based on information obtained from the upper branch of the block diagram in Figure 7. The first branch extracts information about the channel region of support and maximum amplitude. This information is extracted by noncoherently averaging the output of the matched filter bank to form $J_f(\tau)$. The adaptive filter weight vector is successively projected onto the set of possible elements satisfying the constraints (e.g., tap locations and amplitudes should lie within the ranges specified by the a priori information). The adaptive filter weight vector is iterated till it reaches steady state. For instance, when the upper branch finds 3 taps, it gives a rough estimation for the location and amplitude of these taps. The projection scheme within the adaptive filter blocks checks the number of nonzero taps in $\mathbf{w}_i$, and forces the taps that are out of the detected range by the upper branch to zero.

5.1. Simulation results

The robustness of the proposed algorithm in resolving overlapping multipath components is tested by computer simulations. In the simulations, a typical IS-95 signal is generated, pulse shaped, and transmitted through various multipath channels. The total power gain of the channel components is normalized to unity. Figure 8 is a sample simulation that compares the output of the proposed adaptive algorithm to the output of the block least-squares multipath resolving technique of Section 4 for a two-ray fading multipath channel. The first plot shows the considered two-ray channel in the simulation. The second and third plots, respectively, show the output of block least-squares and block regularized least-squares stages. It is clear that both least-squares techniques lead to significant errors in the estimation of the time and amplitude of arrival of the first arriving ray. The last plot shows the output of the proposed estimation scheme. It is clear that the proposed algorithm is more accurate than least-squares techniques. Here we may add that it was noted that the algorithm converges in around 30–50 runs. In this simulation, we have assumed 128 spreading sequences ($K = 128$), each chip is upsampled by order of 8 ($N_u = 8$), the upsampled receiving vector is partitioned into 8 subblocks ($M = 8$), the receiving SNR before despreading is -15 dB and finally the adaptive filter step size is 0.7 ($\mu = 0.7$).

Figure 9 shows the estimation time delay absolute error and amplitude mean square error of the prompt ray in overlapping multipath propagation scenarios versus the estimation period (T). The simulations are performed for various values of the maximum Doppler frequency (f_d) and channel amplitude ratio. The results show a good ability of the proposed adaptive algorithm to resolve overlapping multipath components. In this simulation, we have assumed 128 spreading sequences ($K = 128$), each chip is upsampled by order of 8 ($N_u = 8$), the upsampled receiving vector is partitioned into 8 subblocks ($M = 8$), the receiving SNR before despreading is -15 dB and the adaptive filter step size

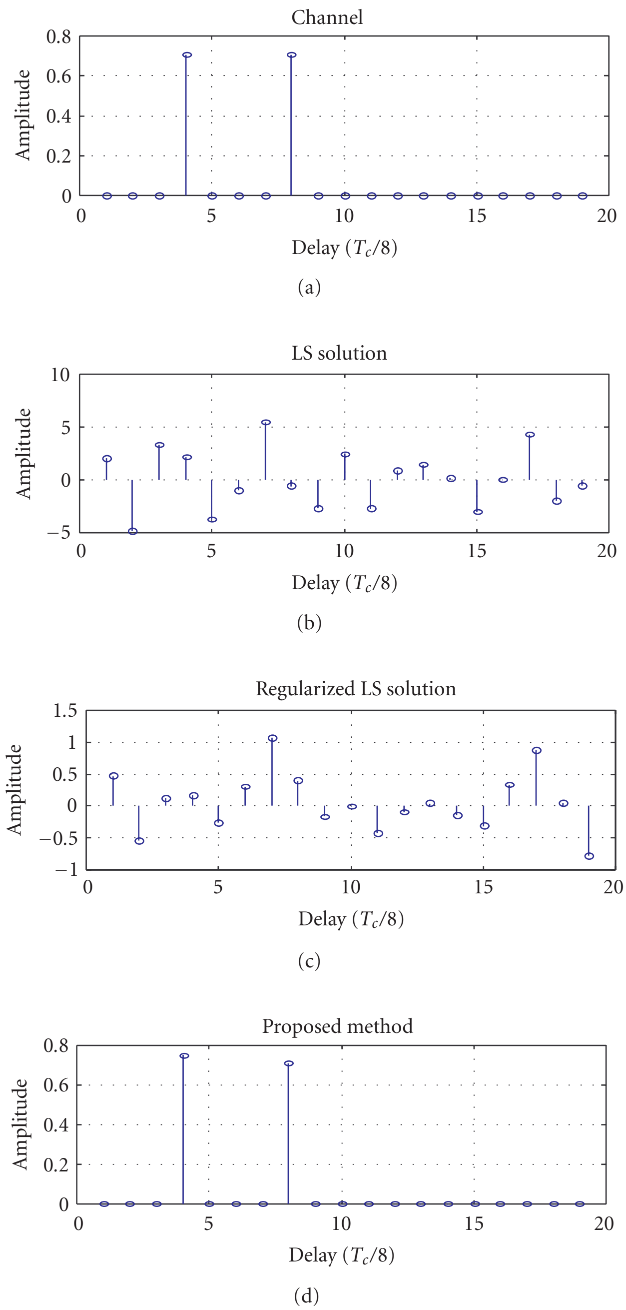


Figure 8: Simulation results ($K = 128$, $N_u = 8$, $M = 8$, and $\mu = 0.7$).

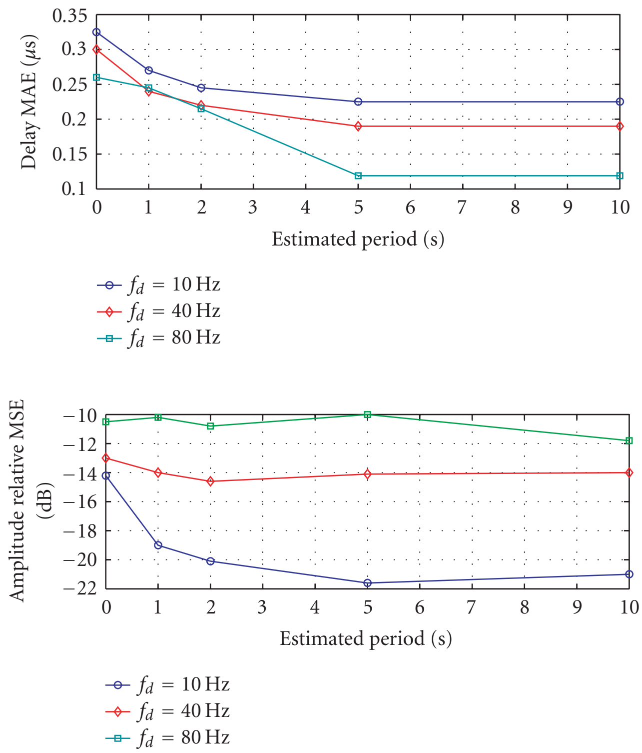


Figure 9: Simulation results for fading channels in **Figure 8** ($K = 128$, $N_u = 8$, $M = 8$, and $\mu = 0.7$).

is 0.7 ($\mu = 0.7$). Please note that different fading frequencies change the effective again after despreading according to (47).

6. RECEPTION WITH AN ANTENNA ARRAY

Using an antenna array at the base station can improve the location estimation by providing both the TOA and AOA information. An antenna array receiver integrates multiuser detection and beamforming with rake reception in order to mitigate multiuser interference, cochannel interference and fading.

Thus consider an N_a-element antenna array at the base station. In this case, the channel model (1) is replaced by

$$\mathbf{h}(n) = \sum_{l=0}^{L-1} \alpha_l x_l^u(n)\delta(n-l)\mathbf{a}(\theta_l), \tag{54}$$

where $\mathbf{h}(n)$ is now an $N_a \times 1$ vector, $\mathbf{a}(\theta_l)$ is the $N_a \times 1$ array response as a function of the AOA of the lth multipath and it is given by

$$\mathbf{a}(\theta_l) = \left[1, e^{j2\pi(d/\lambda)\sin(\theta_l)}, \dots, e^{j2\pi((M-1)d/\lambda)\sin(\theta_l)}\right]^T. \tag{55}$$

Here, θ_l is the AOA of the received signal over the lth multipath, d is the antenna spacing, and λ is the wavelength corresponding to the carrier frequency. Likewise, the received signal in (3) is replaced by

$$\mathbf{r}(n) = c^u(n) \star p(n) \star \mathbf{h}(n) + \nu(n), \tag{56}$$

where $\mathbf{r}(n)$ is now an $N_a \times 1$ vector. We can again use the arguments of Section 3 to replace (10) by

$$\mathbf{R} = \mathbf{A}\mathbf{C}_x\mathbf{A}_\theta\mathbf{H} + \mathbf{V}, \tag{57}$$

where $\mathbf{R}$ is an $L_r \times N_a$ received matrix defined as

$$\mathbf{R} \triangleq \left[\mathbf{r}_1, \mathbf{r}_2, \dots, \mathbf{r}_{N_a}\right] \tag{58}$$

and $\mathbf{r}_n$ is the received vector of length L_r over the nth antenna array, that is,

$$\mathbf{r}_n = \text{col}\left[r_n(0), r_n(1), \dots, r_n(L_r - 1)\right], \quad n = 1, 2, \dots, N_a. \tag{59}$$

Moreover, $\mathbf{V}$ is the noise matrix

$$\mathbf{V} \triangleq \left[\mathbf{v}_1, \mathbf{v}_2, \dots, \mathbf{v}_{N_a}\right], \tag{60}$$

where $\mathbf{v}_n$ is the noise vector at the nth antenna array,

$$\mathbf{v}_n = \text{col}\left[v(0), v(1), \dots, v(L_r - 1)\right], \quad n = 1, 2, \dots, N_a \tag{61}$$

and $\mathbf{H}$ is an $LN_a \times N_a$ Toeplitz path gain matrix whose first column is determined by

$$\mathbf{h} = \text{col}\left[\alpha_0, \alpha_1, \dots, \alpha_{L-1}, 0, 0, \dots, 0\right]. \tag{62}$$

Finally $\mathbf{A}_\theta$ is an $L \times LN_a$ matrix that contains the array responses:

$$\mathbf{A}_\theta \triangleq \left[\mathbf{A}_{\theta,1}, \mathbf{A}_{\theta,2}, \dots, \mathbf{A}_{\theta,N_a}\right], \tag{63}$$

where

$$\mathbf{A}_{\theta,n} = \begin{bmatrix} e^{j2\pi((n-1)d/\lambda)\cos(\theta_0)} & & \\ & \ddots & \\ & & e^{j2\pi((n-1)d/\lambda)\cos(\theta_{L-1})} \end{bmatrix}, \quad n = 1, 2, \dots, N_a. \tag{64}$$

The problem we are interested in is that of estimating the $\{\alpha_l\}$ from the received matrix $\mathbf{R}$ in (58).

6.1. *The partitioned adaptive receiver*

As in Section 4, we partition $\mathbf{R}$ into smaller matrices, $\mathbf{R}_m$, of size $NN_u \times N_a$ each. The matrix $\mathbf{R}_m$ will then satisfy an equation of the form

$$\mathbf{R}_m = \mathbf{A}_m \mathbf{C}_x^m \mathbf{A}_\theta \mathbf{H} + \mathbf{V}_m \tag{65}$$

with $\{\mathbf{A}_m, \mathbf{C}_x^m\}$ similar to $\{\mathbf{A}, \mathbf{C}_x\}$ in (10) but of smaller dimensions, and where $\mathbf{V}_m$ is defined by

$$\begin{aligned} \mathbf{V}_m &= \left[\mathbf{v}_{m,1}, \dots, \mathbf{v}_{m,N_a}\right], \\ \mathbf{v}_{m,n} &= \text{col}\left[\mathbf{v}_n(mNN_u), \dots, \mathbf{v}_n((m+1)NN_u - 1)\right], \\ n &= 1, 2, \dots, N_a. \end{aligned} \tag{66}$$

Then, in view of the earlier discussion, we can use the same algorithm that we used in the case of single antenna.

(1) Partition the received matrix $\mathbf{R}$ into M smaller $NN_u \times N_a$ matrices $\mathbf{R}_m$ with NN_u samples on each column given by

$$\mathbf{r}_{m,n} = \text{col}\left[\mathbf{r}_n(mNN_u), \dots, \mathbf{r}_n((m+1)NN_u - 1)\right]. \tag{67}$$

(2) Introduce the $NN_u \times L$ correlation (despreading) matrix and the $L \times L$ fading matrix $\mathbf{X}_m$ as defined in (29).

(3) Multiply vec($\mathbf{R}_m$) from the left by $(1/N)\mathbf{C}_{\theta,m}^*$, with $m = 0, 1, \dots, M-1$, where $\mathbf{C}_{\theta,m}$ is the $NN_u \times LN_a$ matrix defined by

$$\mathbf{C}_{\theta,m} = \mathbf{C}_m\left[\mathbf{A}_{\theta,1}, \mathbf{A}_{\theta,2}, \dots, \mathbf{A}_{\theta,N_a}\right]. \tag{68}$$

The correlated (despreaded) output is denoted by

$$\mathbf{y}_m = \frac{1}{N}\mathbf{C}_{\theta,m}^* \,\text{vec}\,(\mathbf{R}_m). \tag{69}$$

When N is large enough, and similar to (31), $\mathbf{y}_m$ can be approximated by

$$\mathbf{y}_m \approx \mathbf{A}_L \mathbf{X}_m \mathbf{h} + \frac{1}{N}\mathbf{C}_{\theta,m}^* \,\text{vec}\,(\mathbf{V}_m). \tag{70}$$

The resulting signal $\mathbf{y}_m$ in (70) is similar to the signal in (31), albeit with higher SNR due to the use of the antenna array. Therefore, the proposed estimation algorithm (32)–(49) for the single antenna case can be used as well.

The system model for the resulting multiantenna adaptive receiver is illustrated in Figure 10.

6.2. *Estimating the array response*

We still need to estimate the array response matrix $\mathbf{A}_\theta$. For the received signal $\mathbf{R}$ in (57) of size $L_r \times N_a$, we define a correlation matrix, as in (17), as follows:

$$\mathbf{Y} = \frac{1}{K}\mathbf{C}^*\mathbf{R} = \frac{1}{K}\mathbf{C}^*\mathbf{A}\mathbf{C}_x\mathbf{A}_\theta\mathbf{H} + \frac{1}{K}\mathbf{C}^*\mathbf{V}, \tag{71}$$

where $\mathbf{C}$ was defined in (16) and K is the length of the spreading sequence. Now replace $\mathbf{A}_\theta\mathbf{H}$ by $\mathbf{Z}$, so that

$$\begin{aligned} \mathbf{Y} &= \underbrace{\frac{1}{K}\mathbf{C}^*\mathbf{A}\mathbf{C}_x}_{P}\mathbf{Z} + \frac{1}{K}\mathbf{C}^*\mathbf{V}, \\ \mathbf{Y} &= P\mathbf{Z} + \frac{1}{K}\mathbf{C}^*\mathbf{V}. \end{aligned} \tag{72}$$

The least-square estimate of $\mathbf{Z}$ is given by

$$\hat{\mathbf{Z}} = \left(P^*P\right)^{-1}P^*\mathbf{Y}. \tag{73}$$

Now, in order to estimate $\mathbf{A}_\theta$ from $\hat{\mathbf{Z}}$, we need an estimate of the channel matrix $\mathbf{H}$. It can be estimated from (74) by noting that the matrix $\mathbf{A}_{\theta,1}$ (the first $L \times L$ block of $\mathbf{A}_\theta$) is an identity matrix, so that

$$\begin{aligned} \mathbf{y}_1 &= \frac{1}{K}\mathbf{C}^*\mathbf{A}\mathbf{C}_x\mathbf{A}_\theta\mathbf{h} + \frac{1}{K}\mathbf{C}^*\mathbf{v}_1 \\ &= \frac{1}{K}\mathbf{C}^*\mathbf{A}\mathbf{C}_x\mathbf{A}_{\theta,1}\mathbf{h}' + \frac{1}{K}\mathbf{C}^*\mathbf{v}_1 \\ &= \frac{1}{K}\mathbf{C}^*\mathbf{A}\mathbf{C}_x\mathbf{h}' + \frac{1}{K}\mathbf{C}^*\mathbf{v}_1, \end{aligned} \tag{74}$$

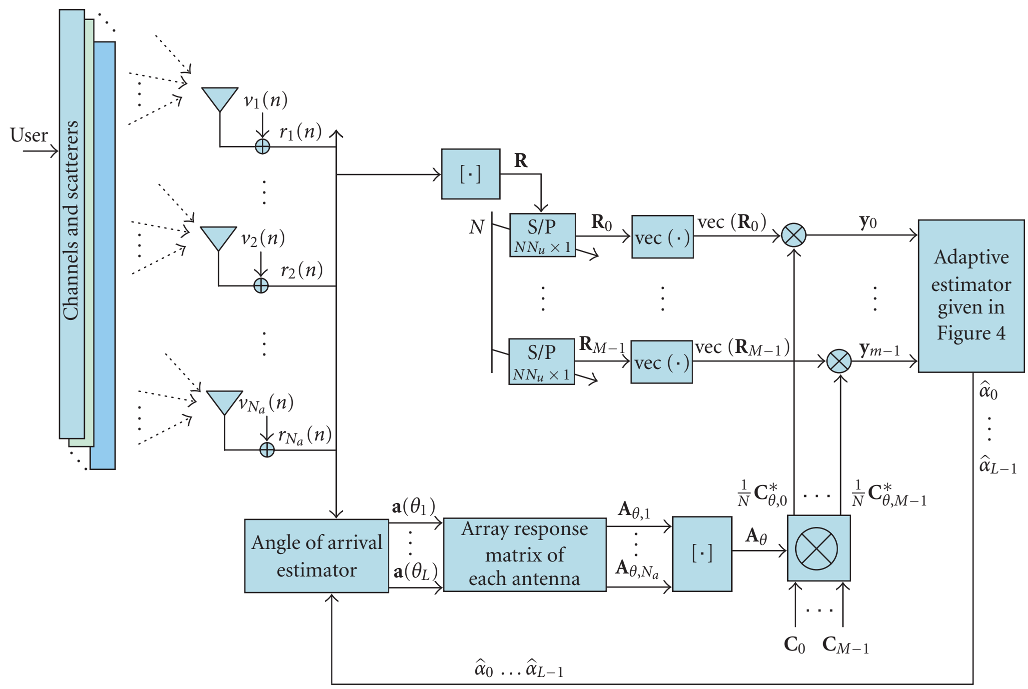


FIGURE 10: An adaptive multipath resolving scheme using an antenna array receiver.

where $\mathbf{h}$ is defined in (62) and $\mathbf{h}'$ is an $L \times 1$ vector that contains the first L elements of $\mathbf{h}$. Moreover, $\mathbf{v}_1$ and $\mathbf{y}_1$ are the first column of $\mathbf{V}$ and $\mathbf{Y}$, respectively. So $\mathbf{h}'$ can now be estimated using (74) in the same manner as $\mathbf{h}$ was estimated from $\mathbf{y}_m$ in (30) by using (49). Using $\mathbf{h}'$ to create $\mathbf{H}$, the least-squares estimate of $\mathbf{A}_\theta$ can be obtained as

$$\widehat{\mathbf{A}}_\theta = \widehat{\mathbf{Z}}\widehat{\mathbf{H}}^* \left(\widehat{\mathbf{H}}\widehat{\mathbf{H}}^*\right)^{-1}. \tag{75}$$

6.3. *Simulation results with antenna array*

The robustness of the proposed algorithm in resolving overlapping multipath components when the base station has an array of antennas is tested by computer simulations. In the simulations, a typical IS-95 signal is generated, pulse shaped, and transmitted through various multipath channels. The total power gain of the channel components is normalized to unity. We have considered 4 antennas at the base station and Figure 11 compares the simulation results when there are multiple antennas and single antenna at the base station. In this simulation, we have assumed 128 spreading sequences ($K = 128$), each chip is upsampled by order of 8 ($N_u = 8$), the upsampled receiving vector is partitioned into 8 subblocks ($M = 8$) and the adaptive filter step size is 0.7 ($\mu = 0.7$).

7. CONCLUSIONS

This paper develops two overlapping multipath resolving methods (adaptive and nonadaptive), and illustrates how the adaptive solution can be made robust to fast channel fading and data ill-conditioning by extracting and exploiting a priori information about the channel. The proposed techniques are further extended to the case with antenna arrays at the base station. Simulation results illustrate the performance of the techniques.

APPENDICES

A. PROOF OF (19)

To simplify $(1/K)\mathbf{C}^*\mathbf{A}\mathbf{C}_x$, we start with the given $\mathbf{A}$ in (6) and express it as

$$\begin{gathered}\mathbf{A} \triangleq \operatorname{Top}(\mathbf{p}),\\ \mathbf{p} \triangleq \operatorname{col}\left[p(0), p(1), \ldots, p(P-1)\right],\end{gathered} \tag{A.1}$$

where the notation $\operatorname{Top}(\mathbf{p})$ denotes the lower-triangular Toeplitz matrix determined by $\mathbf{p}$. Let

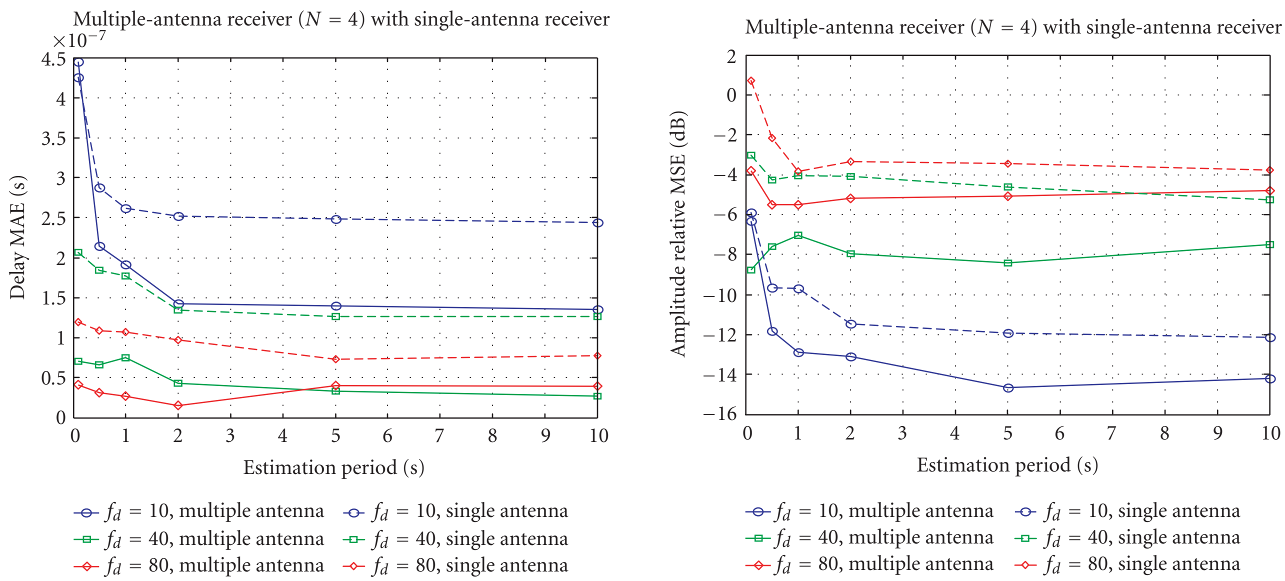
$$\begin{gathered}\mathbf{c}_i \triangleq i\text{th column of } \mathbf{C},\\ \mathbf{c}_{x,i} \triangleq i\text{th column of } \mathbf{C}_x,\end{gathered} \tag{A.2}$$

then

$$\mathbf{C}^*\mathbf{A}\mathbf{C}_x = \begin{bmatrix} \mathbf{c}_1^* \\ \hline \vdots \\ \hline \mathbf{c}_K^* \end{bmatrix} \operatorname{Top}(\mathbf{p})\left[\mathbf{c}_{x,1} \mid \cdots \mid \mathbf{c}_{x,L-1}\right]. \tag{A.3}$$

Now note that for any $m \times 1$ vector v and $n \times m$ Toeplitz matrix $\operatorname{Top}(w)$, where w is $l \times 1$ that $l < n$, we have

$$\operatorname{Top}(w)v = \operatorname{Top}(v)w, \tag{A.4}$$



(a) (b)

Figure 11: Simulation results for the given channel in Figure 8 ($K = 128$, $N_u = 8$, $M = 8$ and $\mu = 0.7$).

where Top(v) is $n \times l$ Toeplitz. Then (A.3) can be written as

$$\mathbf{C}^*\mathbf{A}\mathbf{C}_x = \begin{bmatrix} \mathbf{c}_1^* \\ \hline \vdots \\ \hline \mathbf{c}_K^* \end{bmatrix} \left[\text{Top}\left(\mathbf{c}_{x,1}\right) \mid \cdots \mid \text{Top}\left(\mathbf{c}_{x,L-1}\right)\right]\mathbf{p}. \tag{A.5}$$

Due to the orthogonality property of the spreading sequences we have

$$R_c(\tau) = \sum_{j=0}^{K-1} c^*(j)c(j+\tau) = \begin{cases} K, & \tau = 0, \\ \rho \approx 0, & \tau \neq 0 \end{cases} \tag{A.6}$$

so that

$$\mathbf{c}_i^* \cdot \mathbf{c}_{x,l} \approx \begin{cases} K\displaystyle\sum_{j=0}^{K-1} x_l(j), & i = l, \\ 0, & i \neq l \end{cases} \tag{A.7}$$

and, therefore,

$$\begin{bmatrix} \mathbf{c}_1^* \\ \hline \vdots \\ \hline \mathbf{c}_K^* \end{bmatrix} \left[\text{Top}\left(\mathbf{c}_{x,l}\right)\right] = \text{Top}\left(\underbrace{\begin{bmatrix} 0 \\ \vdots \\ K\displaystyle\sum_{j=0}^{K-1} x_l(j) \\ 0 \\ \vdots \end{bmatrix}}_{\text{only the } l\text{th row is nonzero}}\right). \tag{A.8}$$

Substituting (A.8) into (A.5) gives

$$\begin{aligned} \mathbf{C}^*\mathbf{A}\mathbf{C}_x &= K\,\text{Top}(\mathbf{p})\,\text{diag}\left[\sum_{j=0}^{K-1} x_0(j), \ldots, \sum_{j=0}^{K-1} x_{L-1}(j)\right] \\ &= K\mathbf{A}_L\mathbf{X}_K, \end{aligned} \tag{A.9}$$

where

$$\begin{aligned} \mathbf{A}_L &\triangleq \text{Top}(\mathbf{p}), \\ \mathbf{X}_K &\triangleq \text{diag}\left[\sum_{j=0}^{K-1} x_0(j), \ldots, \sum_{j=0}^{K-1} x_{L-1}(j)\right]. \end{aligned} \tag{A.10}$$

B. NOISE PROPERTY

From (41), we have

$$\begin{aligned} v'(0) &= c(mN)v(0) + c(mN+1)v(1) \\ &\quad + \cdots + c((m+1)N-1)v(N-1), \\ v'(1) &= c(mN)v(1) + c(mN+1)v(2) \\ &\quad + \cdots + c((m+1)N-1)v(N) \\ &\vdots \end{aligned} \tag{B.1}$$

Then, when $i \neq j$,

$$\begin{aligned} &Ev'(i)v'^*(j) \\ &= E\left(\sum_{p=0}^{N-1}\sum_{q=0}^{N-1} c(mN+p)v(p+i)\left(c(mN+q)v(q+j)\right)^*\right) \end{aligned}$$

$$
\begin{aligned}
&= E\left(\sum_{\substack{p=0\\p+i=q+j}}^{N-1}\sum_{q=0}^{N-1} c(mN+p)v(p+i)\big(c(mN+q)v(q+j)\big)^*\right)\\
&\quad + E\left(\sum_{\substack{p=0\\p+i\neq q+j}}^{N-1}\sum_{q=0}^{N-1} c(mN+p)v(p+i)\big(c(mN+q)v(q+j)\big)^*\right)\\
&= \underbrace{\sigma_v^2\sum_{\substack{p=0\\p+i=q+j}}^{N-1}\sum_{q=0}^{N-1} c(mN+p)c(mN+q)^*}_{\sum_{p=0}^{N-1} c(mN+p)c^*(mN+p+i-j)\approx 0}\\
&\quad + \sum_{\substack{p=0\\p+i\neq q+j}}^{N-1}\sum_{q=0}^{N-1} c(mN+p)c(mN+q)^*\underbrace{E\big(v(p+i)v(q+j)^*\big)}_{=0}\\
&\approx 0.
\end{aligned}
\tag{B.2}
$$

It follows that $v'(i)$ and $v'(j)$ are uncorrelated for $i \neq j$.

C. EXTRACTING A PRIORI CHANNEL INFORMATION

In this appendix we explain how to extract useful a priori channel information from the received signal [26]. This information is used in Section 5 by the adaptive searcher for resolving overlapping multipath components.

(1) A power delay profile (PDP) is evaluated as follows:

$$
J_f(\tau) \triangleq \frac{1}{M}\sum_{m=0}^{M-1}\left|\frac{1}{N}\sum_{n=mNN_u}^{(m+1)NN_u-1} r(n)\mathbf{y}_m(n)\right|^2. \tag{C.1}
$$

(2) The *region of support* of the power delay profile, say R_f, is determined by comparing the PDP with a threshold λ_f. The region of support refers to the region of the delay (τ) that might contain significant multipath components:

$$
\tau \in R_f \quad \text{if } J_f(\tau) > \lambda_f. \tag{C.2}
$$

We restrict R_f to the first continuous region of delays. In other words, R_f starts from the earliest delay that is higher than the threshold until the value of τ at which the PDP falls below the threshold.

(3) The peak of the PDP is determined along with the delay that corresponds to the peak. Let τ_f denote the delay of the peak of $J_f(\tau)$:

$$
\tau_f \triangleq \arg\max_{\tau} J_f(\tau), \quad \tau \in R_f. \tag{C.3}
$$

Moreover, let m_f denote the value of the peak of $J_f(\tau)$:

$$
m_f \triangleq \max_{\tau} J_f(\tau), \quad \tau \in R_f. \tag{C.4}
$$

(4) The number of fading overlapping multipath components that exist in the region of support, R_f, is determined by using the multipath detection algorithm of [26]. Let the number of overlapping multipath components be denoted by O.

In summary, the following a priori information can be used in the multipath resolving stage.

(1) The delay of the ray to be resolved is confined to R_f.
(2) The number of fading overlapping multipath components that exist in R_f is equal to O.
(3) The maximum amplitude of any ray in this region is less than or equal to the square root of the maximum value of $J_f(\tau)$ after equalizing for the noise and fading biases that may arise in this value. This value is equal to $\sqrt{C_f(m_f - B_v)}$, where B_v and C_f are two noise and fading biases that can be calculated as described in (49)-(50).

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REFERENCES

[1] FCC Docket no. 94-102, "Revision of the commission's rules to ensure compatibility with enhanced 911 emergency calling," Tech. Rep. RM-8143, July 1996.

[2] J. J. Caffery and G. L. Stuber, "Overview of radiolocation in CDMA cellular systems," *IEEE Communications Magazine*, vol. 36, no. 4, pp. 38–45, 1998.

[3] J. O'Connor, B. Alexander, and E. Schorman, "CDMA infrastructure-based location finding for E911," in *Proceedings of 49th IEEE Vehicular Technology Conference (VTC '99)*, vol. 3, pp. 1973–1978, Houston, Tex, USA, May 1999.

[4] S. Fischer, H. Koorapaty, E. Larsson, and A. Kangas, "System performance evaluation of mobile positioning methods," in *Proceedings of 49th IEEE Vehicular Technology Conference (VTC '99)*, vol. 3, pp. 1962–1966, Houston, Tex, USA, May 1999.

[5] S. Tekinay, E. Chao, and R. Richton, "Performance benchmarking for wireless location systems," *IEEE Communications Magazine*, vol. 36, no. 4, pp. 72–76, 1998.

[6] J. J. Caffery and G. L. Stuber, "Radio location in urban CDMA microcells," in *Proceedings of 6th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC '95)*, vol. 2, pp. 858–862, Toronto, Ontario, Canada, September 1995.

[7] A. Ghosh and R. Love, "Mobile station location in a DS-CDMA system," in *Proceedings 48th IEEE Vehicular Technology Conference (VTC '98)*, vol. 1, pp. 254–258, Ottawa, Ontario, Canada, May 1998.

[8] C. Drane, M. Macnaughtan, and C. Scott, "Positioning GSM telephones," *IEEE Communications Magazine*, vol. 36, no. 4, pp. 46–54, 1998.

[9] N. J. Thomas and D. G. M. Cruickshank, "A passive mobile location system for UMTS," in *Proceedings of IEE Colloquium on*

UMTS Terminals and Software Radio, pp. 10/1–10/6, Glasgow, UK, April 1999.

[10] S. Sakagami, S. Aoyama, K. Kuboi, S. Shirota, and A. Akeyama, "Vehicle position estimates by multibeam antennas in multipath environments," *IEEE Transactions on Vehicular Technology*, vol. 41, no. 1, pp. 63–68, 1992.

[11] J. M. Zagami, S. A. Parl, J. J. Bussgang, and K. D. Melillo, "Providing universal location services using a wireless E911 location network," *IEEE Communications Magazine*, vol. 36, no. 4, pp. 66–71, 1998.

[12] T. S. Rappaport, J. H. Reed, and B. D. Woerner, "Position location using wireless communications on highways of the future," *IEEE Communications Magazine*, vol. 34, no. 10, pp. 33–41, 1996.

[13] L. A. Stilp, "Carrier and end-user applications for wireless location systems," in *Wireless Technologies and Services for Cellular and Personal Communication Services*, vol. 2602 of *Proceedings of the SPIE*, pp. 119–126, Philadelphia, Pa, USA, October 1995.

[14] I. J. Paton, E. W. Crompton, J. G. Gardiner, and J. M. Noras, "Terminal self-location in mobile radio systems," in *Proceedings of 6th International Conference on Mobile Radio and Personal Communications*, vol. 1, pp. 203–207, Coventry, UK, December 1991.

[15] A. Giordano, M. Chan, and H. Habal, "A novel location-based service and architecture," in *Proceedings of 6th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC '95)*, vol. 2, pp. 853–857, Toronto, Ontario, Canada, September 1995.

[16] N. R. Yousef, A. H. Sayed, and N. Khajehnouri, "Detection of fading overlapping multipath components," to appear in *Signal Processing*.

[17] A. H. Sayed, A. Tarighat, and N. Khajehnouri, "Network-based wireless location: challenges faced in developing techniques for accurate wireless location information," *IEEE Signal Processing Magazine*, vol. 22, no. 4, pp. 24–40, 2005.

[18] J. J. Caffery and G. L. Stuber, "Vehicle location and tracking for IVHS in CDMA microcells," in *Proceedings of 5th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC '94)*, vol. 4, pp. 1227–1231, The Hague, The Netherlands, September 1994.

[19] Z. Kostic, I. M. Sezan, and E. L. Titlebaum, "Estimation of the parameters of a multipath channel using set-theoretic deconvolution," *IEEE Transactions on Communications*, vol. 40, no. 6, pp. 1006–1011, 1992.

[20] T. G. Manickam and R. J. Vaccaro, "A non-iterative deconvolution method for estimating multipath channel responses," in *Proceedings of IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP '93)*, vol. 1, pp. 333–336, Minneapolis, Minn, USA, April 1993.

[21] T. S. Rappaport, *Wireless Communications: Principles & Practice*, Prentice-Hall, Upper Saddle River, NJ, USA, 1996.

[22] S. Glisic and B. Vucetic, *Spread Spectrum CDMA Systems for Wireless Communications*, Artech House, Boston, Mass, USA, 1997.

[23] N. R. Yousef and A. H. Sayed, "A new adaptive estimation algorithm for wireless location finding systems," in *Proceedings of 33rd Asilomar Conference on Signals, Systems, and Computers (ACSSC '99)*, vol. 1, pp. 491–495, Pacific Grove, Calif, USA, October 1999.

[24] N. R. Yousef and A. H. Sayed, "Adaptive multipath resolving for wireless location systems," in *Proceedings of 35th Asilomar Conference on Signals, Systems and Computers (ACSSC '01)*, vol. 2, pp. 1507–1511, Pacific Grove, Calif, USA, November 2001.

[25] A. Jakobsson, A. L. Swindlehurst, and P. Stoica, "Subspace-based estimation of time delays and Doppler shifts," *IEEE Transactions on Signal Processing*, vol. 46, no. 9, pp. 2472–2483, 1998.

[26] N. R. Yousef and A. H. Sayed, "Detection of fading overlapping multipath components for mobile-positioning systems," in *Proceedings of IEEE International Conference on Communications (ICC '01)*, vol. 10, pp. 3102–3106, Helsinki, Finland, June 2001.

[27] N. R. Yousef and A. H. Sayed, "Robust multipath resolving in fading conditions for mobile-positioning systems," in *Proceedings of 17th National Radio Science Conference (NRSC '00)*, vol. 1, no. C19, pp. 1–8, Minufiya, Egypt, February 2000.

Nabil R. Yousef received the B.S. and M.S. degrees in electrical engineering from Ain-Shams University, Cairo, Egypt, in 1994 and 1997, respectively, and the Ph.D. degree in electrical engineering from the University of California, Los Angeles, in 2001. He was a Staff Scientist at the Broadband Systems Group (2001–2005), Broadcom Corporation, Irvine, Calif. His work at Broadcom involved developing highly integrated systems for cable modems, cable modem termination systems, wireless broadband receivers, and DTV receivers. He is currently the Director of Systems Engineering at Newport Media Inc., Lake Forest, Calif. He is involved in developing highly integrated receivers for mobile TV standards such as DVB-H, T-DMB, ISDB-T and MedisFlo. His research interests include adaptive filtering, equalization, OFDM and CDMA systems, wireless communications, and wireless positioning. He has over 30 issued and pending US patents. He is the recipient of a 1999 Best Student Paper Award at an international meeting for work on adaptive filtering, and of the 1999 NOKIA Fellowship Award. He received many awards for his innovations from Motorola, Broadcom, and Newport Media Inc.

Ali H. Sayed is Professor and Chairman of electrical engineering at the University of California, Los Angeles. He is also the Principal Investigator of the UCLA Adaptive Systems Laboratory (www.ee.ucla.edu/asl). He has over 250 journal and conference publications, he is the author of the textbook *Fundamentals of Adaptive Filtering* (Wiley, New York, 2003), and is coauthor of the research monograph *Indefinite Quadratic Estimation and Control* (SIAM, Philadelphia, PA, 1999) and of the graduate-level textbook *Linear Estimation* (Prentice-Hall, Englewood, Cliffs, NJ, 2000). He is also coeditor of the volume *Fast Reliable Algorithms for Matrices with Structure* (SIAM, Philadelphia, pa, 1999). He has contributed several articles to engineering and mathematical encyclopedias and handbooks and has served on the program committees of several international meetings. His research interests span several areas, including adaptive and statistical signal processing, filtering and estimation theories, signal processing for communications, interplays between signal processing and control methodologies, system theory, and fast algorithms for large-scale problems.

He received the 1996 IEEE Donald G. Fink Award, 2002 Best Paper Award from the IEEE Signal Processing Society, 2003 Kuwait Prize in Basic Science, 2005 Frederick E. Terman Award, and is coauthor of two Best Student Paper Awards at international meetings (1999, 2001). He is a Member of the editorial board of the IEEE Signal Processing Magazine. He has also served twice as Associate Editor of the IEEE Transactions on Signal Processing, and as Editor-in-Chief of the same journal during 2003–2005. He is serving as Editor-in-Chief of the EURASIP Journal on Applied Signal Processing and as General Chairman of ICASSP 2008.

Nima Khajehnouri received the B.Sc. degree in electrical engineering from Sharif University of Technology, Tehran, Iran, in 2001, and the M.S. degree in electrical engineering from the University of California, Los Angeles (UCLA) in 2002 with emphasis on signal processing. Since 2003, he has been pursuing the Ph.D. degree in electrical engineering at UCLA. His research focuses on signal processing techniques for communication systems, including multiuser MIMO communications, relay networks, and signal processing for sensor networks.

Special Issue on Human-Activity Analysis in Multimedia Data

Call for Papers

Many important applications of multimedia revolve around the detection of humans and the interpretation of human behavior, for example, surveillance and intrusion detection, automatic analysis of sports videos, broadcasts, movies, ambient assisted living applications, video conferencing applications, and so forth. Success in this task requires the integration of various data modalities including video, audio, and associated text, and a host of methods from the field of machine learning. Additionally, the computational efficiency of the resulting algorithms is critical since the amount of data to be processed in videos is typically large and real-time systems are required for practical implementations.

Recently, there have been several special issues on the human detection and human-activity analysis in video. The emphasis has been on the use of video data only. This special issue is concerned with contributions that rely on the use of multimedia information, that is, audio, video, and, if available, the associated text information.

Papers on the following and related topics are solicited:

- Video characterization, classification, and semantic annotation using both audio and video, and text (if available).
- Video indexing and retrieval using multimedia information.
- Segmentation of broadcast and sport videos based on audio and video.
- Detection of speaker turns and speaker clustering in broadcast video.
- Separation of speech and music/jingles in broadcast videos by taking advantage of multimedia information.
- Video conferencing applications taking advantage of both audio and video.
- Human mood detection, and classification of interactivity in duplexed multimedia signals as in conversations.
- Human computer interaction, ubiquitous computing using multimedia.
- Intelligent audio-video surveillance and other security-related applications.

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GUEST EDITORS:

A. Enis Cetin, Department of Electrical and Electronics Engineering, Bilkent University, Ankara 06800, Turkey; cetin@ee.bilkent.edu.tr

Eric Pauwels, Signals and Images Research Group, Centre for Mathematics and Computer Science (CWI), 1098 SJ Amsterdam, The Netherlands; eric.pauwels@cwi.nl

Ovidio Salvetti, Institute of Information Science and Technologies (ISTI), Italian National Research Council (CNR), 56124 Pisa, Italy; ovidio.salvetti@isti.cnr.it

Special Issue on

Signal Processing for Location Estimation and Tracking in Wireless Environments

Call for Papers

In recent years, the proliferation of mobile computing devices and wireless technologies has fostered a growing interest in location-aware systems and services. The availability of location information on objects and human beings is critical in many military and civilian applications such as emergency call services, tracking of valuable assets, monitoring individuals with special needs in assisted living facilities, location-assisted gaming (e.g., Geocaching), etc.

Existing positioning systems can be categorized based on whether they are intended for indoor or outdoor applications. Within both of these application areas, there are two major categories of position estimation techniques, as discussed below.

- *Geometric techniques*–Position is estimated by exploiting time of arrival (TOA), time difference of arrival (TDOA), angle of arrival (AOA) or other information derived from the relationship between the geometry of an array of receivers and the modeled propagation characteristics of the transmitted signal.
- *Mapping approaches*–Position is estimated based on comparison of local measurements to a "map" of expected distribution of the measured values. For example, in a wireless LAN application, received signal strength (RSS) might be observed either at the location of the client or at a remote reference point. Mapping approaches are also known as location fingerprinting.

Although geometric approaches have the potential to achieve higher precision than mapping approaches, they generally require direct-path signal reception or accurate environmental information at the receiver and often perform poorly in complex multipath environments. On the other hand, estimation accuracy of mapping approaches is limited by both the accuracy of the reference map and the accuracy of observed measurements. Furthermore, frequent and extensive site-survey measurements are often needed to accommodate the time varying nature of wireless channels, structural changes in the environment, and upgrades of wireless infrastructure.

In addition to snapshots of AOA, TOA, TDOA or RSS measurements, motion models or prior knowledge of structural constraints can often be used to enhance location estimation accuracy for mobile objects by "tracking" location estimates over time. Trackers that integrate such information into the computation of location estimates are generally implemented using techniques such as Kalman filters, particle filters, Markov chain Monte Carlo methods, etc.

The purpose of the proposed special issue is to present a comprehensive picture of both the current state of the art and emerging technologies in signal processing for location estimation and tracking in wireless environments. Papers are solicited on all related aspects from the point of view of both theory and practice. Submitted articles must be previously unpublished and not concurrently submitted for publication on other journals.

Topics of interest include (but are not limited to):

- Received signal strength (RSS), angle-of-arrival (AOA), and time-based location estimation
- Ultrawideband (UWB) location estimation
- Bayesian location estimation and tracking
- Pattern recognition and learning theory approaches to location estimation
- Applications of expectation-maximization (EM) and Markov chain Monte Carlo (MCMC) techniques
- Applications of electromagnetic propagation modeling to location estimation
- Mitigation of errors due to non-line-of-sight propagation
- System design and configuration
- Performance evaluation, performance bounds, and statistical analysis

- Computational complexity and distributed computation
- Distributed location estimation
- Synchronization issues
- Testbed implementation, real-world deployment, and measurement

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GUEST EDITORS:

Richard J. Barton, Department of Electrical and Computer Engineering, University of Houston, Houston, TX 77204, USA; rbarton@uh.edu

Rong Zheng, Department of Computer Science, University of Houston, Houston, TX 77204, USA; rzheng@cs.uh.edu

Sinan Gezici, Mitsubishi Electric Research Labs, Cambridge, MA 02139, USA; gezici@ieee.org

Venugopal V. Veeravalli, Department of Electrical and Computer Engineering, University of Illinois, Urbana, IL 61801, USA; vvv@uiuc.edu

Special Issue on Track Before Detect Algorithms

Call for Papers

Seamless detection and tracking schemes are able to integrate unthresholded (or below target detection threshold) multiple sensor responses over time to detect and track targets in low signal-to-noise ratio (SNR) and high clutter scenarios. These schemes, also called "track-before-detect (TBD)" algorithms are especially suitable for tracking weak targets that would only very rarely cross a standard detection threshold as applied at the sensor level.

Thresholding sensor responses result in a loss of information. Keeping this information allows some TBD approaches to deal with the classical data association problem effectively in high clutter and low SNR situations. For example, in detection scenarios with simultaneous activation/illumination from different signal sources this feature allows the application of triangulation techniques, where in the case of contact tracking approaches essential information about weak targets would often be lost because these targets did not produce signals that cross the normal detection threshold. Extending this example to a multi-sensor network scenario, a TBD algorithm that can use unthresholded (or below threshold) data has the potential to show improved performance compared to an algorithm that relies on thresholded data. In low SNR situations, this can substantially increase performance particularly in the case of a dense multi-target scenario.

Naturally, TBD algorithms consume high computational processing power: An efficient realization and coding of the TBD scheme is mandatory.

Another issue that arises when using the TBD scheme is the quality of the sensor model: Practical experience with thresholded data shows that a coarser modelling of the likelihood function might be sufficient and often leads to robust algorithms. How much have these sensor models to be improved in order to allow the TBD algorithms to exploit the information provided with the unthresholded data?

TBD algorithms that are well known to the tracking community are the likelihood ratio detection and tracking (LRDT), maximum likelihood probabilistic data association (MLPDA), maximum likelihood probabilistic multihypothesis tracking (MLPMHT), Houghtransform based methods and dynamic programming techniques; also related are the probability hypothesis density (PHD), the histogram probabilistic multi- hypothesis tracking (H-PMHT) algorithms, and, of course, various particle filter approaches. Some of these algorithms are capable of tracking extended targets and performing signal estimation in multi-sensor measurements.

The aim of this special issue is to focus on recent developments in this expanding research area. The special issue will focus on one hand on the development and comparison of algorithmic approaches, and on the other hand on their currently ever-widening range of applications such as in active or passive surveillance scenarios (e.g. for object tracking and classification with image and video based sensors, or scenarios involving chemical, electromagnetic and acoustic sensors). Special interest lies in multi-sensor data fusion and/or multi-target tracking applications.

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Yvo Boers, Surface Radar, Thales Nederland B.V. Haaksbergerstraat 49, 7554 PA Hengelo, The Netherlands; yvo.boers@nl.thalesgroup.com

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Wolfgang Koch, FGAN-FKIE, Neuenahrer Strasse 20, D53343 Wachtberg, Germany; w.koch@fgan.de

Tod Luginbuhl, Naval Undersea Warfare Center, 1176 Howell Street, Newport, RI 02841-1708, USA; t.e.luginbuhl@ieee.org

Lawrence D. Stone, Metron Inc., 11911 Freedom Drive, Suite 800, Reston, VA 20190, USA; stone@metsci.com

Roy L. Streit, Metron Inc., 11911 Freedom Drive, Suite 800, Reston, VA 20190, USA; streit@metsci.com

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Special Issue on

Advanced Signal Processing and Pattern Recognition Methods for Biometrics

Call for Papers

Biometric identification has established itself as a very important research area primarily due to the pronounced need for more reliable and secure authentication architectures in several civilian and commercial applications. The recent integration of biometrics in large-scale authentication systems such as border control operations has further underscored the importance of conducting systematic research in biometrics. Despite the tremendous progress made over the past few years, biometric systems still have to reckon with a number of problems, which illustrate the importance of developing new biometric processing algorithms as well as the consideration of novel data acquisition techniques. Undoubtedly, the simultaneous use of several biometrics would improve the accuracy of an identification system. For example the use of palmprints can boost the performance of hand geometry systems. Therefore, the development of biometric fusion schemes is an important area of study. Topics related to the correlation between biometric traits, diversity measures for comparing multiple algorithms, incorporation of multiple quality measures, and so forth need to be studied in more detail in the context of multibiometrics systems. Issues related to the individuality of traits and the scalability of biometric systems also require further research. The possibility of using biometric information to generate cryptographic keys is also an emerging area of study. Thus, there is a definite need for advanced signal processing, computer vision, and pattern recognition techniques to bring the current biometric systems to maturity and allow for their large-scale deployment.

This special issue aims to focus on emerging biometric technologies and comprehensively cover their system, processing, and application aspects. Submitted articles must not have been previously published and must not be currently submitted for publication elsewhere. Topics of interest include, but are not limited to, the following:

- Fusion of biometrics
- Analysis of facial/iris/palm/fingerprint/hand images
- Unobtrusive capturing and extraction of biometric information from images/video
- Biometric identification systems based on face/iris/palm/fingerprint/voice/gait/signature
- Emerging biometrics: ear, teeth, ground reaction force, ECG, retina, skin, DNA
- Biometric systems based on 3D information
- User-specific parameterization
- Biometric individuality
- Biometric cryptosystems
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- Sensor interoperability
- Performance evaluation and statistical analysis

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Nikolaos V. Boulgouris, Department of Electronic Engineering, Division of Engineering, King's College London, London WC2R 2LS, UK; nikolaos.boulgouris@kcl.ac.uk

Juwei Lu, EPSON Edge, EPSON Canada Ltd., Toronto, Ontario M1W 3Z5, Canada; juwei@ieee.org

Konstantinos N. Plataniotis, The Edward S. Rogers Sr. Department of Electrical and Computer Engineering, University of Toronto, Toronto, Ontario, Canada, M5S 3G4; kostas@dsp.utoronto.ca

Arun Ross, Lane Department of Computer Science & Electrical Engineering, West Virginia University, Morgantown WV, 26506, USA; arun.ross@mail.wvu.edu

Special Issue on Signal Processing for Data Converters

Call for Papers

Data converters (ADCs and DACs) ultimately limit the performance of today's communication systems. New concepts for high-speed, high-resolution, and power-aware converters are therefore required, which also lead to an increased demand for high-speed and high-resolution sampling systems in the measurement industry. Present converter technologies operate on their limits, since the downscaling of IC technologies to deep submicron technologies makes their design increasingly difficult. Fortunately, downscaling of IC technologies allows for using additional chip area for digital signal processing algorithms with hardly any additional costs. Therefore, one can use more elaborate signal processing algorithms to improve the conversion quality, to realize new converter architectures and technologies, or to relax the requirements on the analog design. Pipelined ADCs constitute just one example of converter technology where signal processing algorithms are already extensively used. However, time-interleaved converters and their generalizations, including hybrid filter bank-based converters and parallel sigma-delta-based converters, are the next candidates for digitally enhanced converter technologies, where advanced signal processing is essential. Accurate models constitute one foundation of digital corrected data converters. Generating and verifying such models is a complex and time-consuming process that demands high-performance instrumentation in conjunction with sophisticated software defined measurements.

The aim of this special issue is to bring forward recent developments on signal processing methods for data converters. It includes design, analysis, and implementation of enhancement algorithms as well as signal processing aspects of new converter topologies and sampling strategies. Further, it includes design, analysis, and implementation of software defined measurements for characterization and modeling of data converters.

Topics of interest include (but are not limited to):

- Analysis, design, and implementation of digital algorithms for data converters
- Analysis and modeling of novel converter topologies and their signal processing aspects
- Digital calibration of data converters
- Error identification and correction in time-interleaved ADCs and their generalizations
- Signal processing for application-specific data converters (communication systems, measurement systems, etc.)
- New sampling strategies
- Sampling theory for data converters
- Signal processing algorithms for data converter testing
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Christian Vogel, Signal Processing and Speech Communication Laboratory, Graz University of Technology, 8010 Graz, Austria; vogel@tugraz.at

Håkan Johansson, Department of Electrical Engineering, Linköping University, 581 83 Linköping, Sweden; hakanj@isy.liu.se

Boris Murmann, Department of Electrical Engineering, Stanford University, Stanford, CA 94305-4070, USA; murmann@stanford.edu

EURASIP JOURNAL ON ADVANCES IN SIGNAL PROCESSING

Special Issue on Distributed Space-Time Systems

Call for Papers

Diversity is a powerful technique to mitigate channel fading and to improve robustness to cochannel interference in a wireless network. Space-time wireless systems traditionally use multiple colocated antennas at the transmitter and receiver along with appropriate signal design (also known as space-time coding) to realize spatial diversity in the link. Typically this diversity can augment any frequency and time diversity available to the receiver. Multiple antennas also offer the ability to use spatial multiplexing to dramatically increase the data rate.

A recent development in this area aims at dispensing with the need for colocated antennas. Popularly known as the cooperative diversity technique, this uses the antennas at multiple user terminals in a network in the form of a virtual antenna array to realize spatial diversity in a distributed fashion. Such techniques create new challenges in the design of wireless systems.

The purpose of this call for papers is to address some of these challenges such as new protocols for cooperative diversity, cross-layer design, cooperative multiplexing, space-time coding for distributed antennas, cooperative channel estimation and equalization, selecting the right users for participating in a cooperative network, modulation specific issues like OFDMA and CDMA, and distributed space-time processing for sensor networks.

Papers on the following and related topics are solicited for this special issue:

- New protocols for cooperative diversity systems
- Cross-layer protocol design
- Signal design for distributed space-time systems
- Cooperative channel estimation and equalization
- Cooperative MIMO systems
- Distributed space-time processing for sensor networks
- Power allocation in distributed space-time systems
- Fast algorithms and efficient architectures for virtual MIMO receivers
- Energy efficient relay network architectures

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Ranjan K. Mallik, Department of Electrical Engineering, Indian Institute of Technology - Delhi, Hauz Khas, New Delhi 110016, India; rkmallik@ee.iitd.ernet.in

Arogyaswami J. Paulraj, Department of Electrical Engineering, Stanford University, 232 Packard, 350 Serra Mall, Stanford, CA 94305, USA; apaulraj@stanford.edu

Mrityunjoy Chakraborty, Department of Electronics and Electrical Communication Engineering, Indian Institute of Technology - Kharagpur, Kharagpur 721302, West Bengal, India; mrityun@ece.iitkgp.ernet.in

Keith Q. T. Zhang, Department of Electronic Engineering, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong; eekzhang@cityu.edu.hk

George K. Karagiannidis, Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki, 54 124 Thessaloniki, Greece; geokarag@auth.gr

Special Issue on

Cooperative Localization in Wireless Ad Hoc and Sensor Networks

Call for Papers

One of the major requirements for most applications based on wireless ad hoc and sensor networks is accurate node localization. In fact, sensed data without position information is often less useful.

Due to several factors (e.g., cost, size, power), only a small fraction of nodes obtain the position information of the anchor nodes. In this case, a node has to estimate its position without a direct interaction with anchor nodes and a cooperation between nodes is needed in a multihop fashion. In some applications, none of the nodes are aware of their absolute position (anchor-free) and only relative coordinates are estimated instead.

Most works reported in the literature have studied cooperative localization with the emphasis on algorithms. However, very few works give emphasis on the localization as estimation or on the investigation of fundamental performance limits as well as on experimental activities. In particular, the fundamental performance limits of multihop and anchor-free positioning in the presence of unreliable measurements are not yet well established. The knowledge of such limits can also help in the design and comparison of new low-complexity and distributed localization algorithms. Thus, measurement campaigns in the context of cooperative localization to validate the algorithms as well as to derive statistical models are very valuable.

The goal of this special issue is to bring together contributions from signal processing, communications and related communities, with particular focus on signal processing, new algorithm design methodologies, and fundamental limitations of cooperative localization systems. Papers on the following and related topics are solicited:

- anchor-based and anchor-free distributed and cooperative localization algorithms that can cope with unreliable range measurements
- derivation of fundamental limits in multihop and anchor-free localization scenarios
- new localization algorithms design methodologies based, for example, on statistical inference and factor graphs
- low-complexity and energy-efficient distributed localization algorithms
- distributed ranging and time synchronization techniques
- measurement campaigns and statistical channel modeling
- algorithm convergence issues
- UWB systems
- localization through multiple-antenna systems
- experimental results

Authors should follow the EURASIP JASP manuscript format at http://www.hindawi.com/journals/asp/. Prospective authors should submit an electronic copy of their complete manuscript through the EURASIP JASP Manuscript Tracking System at http://www.hindawi.com/mts/, according to the following timetable:

Manuscript Due	August 1, 2007
Acceptance Notification	December 1, 2007
Final Manuscript Due	March 1, 2008
Publication Date	2nd Quarter 2008

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Davide Dardari, WiLAB, Department of Electronics, Computer Science and Systems (DEIS), University of Bologna at Cesena, Italy; ddardari@ieee.org

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Lorenzo Mucchi, Department of Electronics and Telecommunications, University of Florence, 50121 Florence, Italy; mucchi@lenst.det.unifi.it

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Special Issue on Multimedia over Wireless Networks

Call for Papers

Scope

In recent years there has been a tremendous increase in demand for multimedia delivered over wireless networks. The design and capabilities of the mobile devices and the services being offered reflect the increase in multimedia usage in the wireless setting. Applications that are in the process of becoming essential to users include video telephony, gaming, or TV broadcasting. This trend creates great opportunities for identifying new wireless multimedia applications, and for developing advanced systems and algorithms to support these applications. Given the nature of the channel and of the mobile devices, issues such as scalability, error resiliency, and energy efficiency are of great importance in applications involving multimedia transmission over wireless networks.

The papers in this issue will focus on state-of-the-art research on all aspects of wireless multimedia communications. Papers showing significant contributions are solicited on topics including but are not limited to:

- Error resilience and error concealment algorithms
- Rate control for wireless multimedia coding
- Scalable coding and transmission
- Joint source-channel coding
- Joint optimization of power consumption and rate-distortion performance
- Wireless multimedia traffic modeling
- Wireless multimedia streaming
- Wireless multimedia coding
- QoS for wireless multimedia applications
- Distributed multimedia coding

Authors should follow the EURASIP Journal on Wireless Communications and Networking manuscript format described at http://www.hindawi.com/journals/wcn/. Prospective authors should submit an electronic copy of their complete manuscript through the EURASIP Journal on Wireless Communications and Networking's Manuscript Tracking System at http://www.hindawi.com/mts/, according to the following timetable:

Manuscript Due	March 1, 2007
Acceptance Notification	July 1, 2007
Final Manuscript Due	October 1, 2007
Publication Date	4th Quarter, 2007

GUEST EDITORS:

Dan Lelescu, R&D lab, Imaging Division, Micron Technology, Inc., 2125 O'Nel Drive, San Jose, CA 9513, USA; danlelescu@yahoo.com

Peter Schelkens, Deptartment of Electronics and Information Processing (ETRO), Vrije Universiteit Brussel (VUB), Pleinlaan 2, 1050 Brussel, Belgium; Peter.Schelkens@vub.ac.be

Kameswara Rao Namuduri, Deptartment of Electrical and Computer Engineering, Wichita State University, 1845 Fairmount, Wichita, 67260 KS, USA; kamesh.namuduri@wichita.edu

EURASIP JOURNAL ON IMAGE AND VIDEO PROCESSING

Special Issue on Anthropocentric Video Analysis: Tools and Applications

Call for Papers

Humans are a basic entity in most videos. Lately, there has been increased interest in devising automated video analysis algorithms that aim to extract, efficiently describe, and organize information regarding the state or state transition of individuals (identity, emotional state, activity, position and pose, etc), interactions between individuals (dialogue, gestures, engagement into collaborative or competitive activities like sports), physical characteristics of humans (anthropometric characteristics, 3D head/body models), and so forth. Such information can be utilized in a multitude of important applications that include, but are not limited to:

- Human computer interaction, ubiquitous computing
- Video characterization, classification, and semantic annotation
- Video indexing and retrieval
- Temporal video segmentation (shot and scene boundary detection) and summarization
- Intelligent video surveillance, access control, and other security related applications

High quality and original contributions on the following (nonexhaustive) list of topics related to anthropocentric video analysis and its applications are solicited:

- Detection and tracking of humans or human body parts
- Action recognition and human behavior analysis
- Emotional state recognition
- Anthropocentric video characterization, semantic annotation, indexing, retrieval, temporal segmentation and summarization
- Efficient description schemes for anthropocentric video information
- Dialogue detection, LiP activity detection, visual speech recognition
- Hand gesture recognition
- 3D modeling of humans
- Person verification and recognition

Authors should follow the EURASIP JIVP manuscript format at http://www.hindawi.com/journals/ivp/. Prospective authors should submit an electronic copy of their complete manuscripts through the EURASIP JIVP manuscript tracking system at http://www.hindawi.com/mts/, according to the following timetable:

Manuscript Due	February 1, 2007
Acceptance Notification	June 1, 2007
Final Manuscript Due	September 1, 2007
Publication Date	4th Quarter, 2007

GUEST EDITORS:

Nikos Nikolaidis, Department of Informatics, Aristotle University of Thessaloniki, Greece; nikolaid@aiia.csd.auth.gr

Maja Pantic, Department of Computing, Imperial College London, UK; m.pantic@imperial.ac.uk

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IEEE ICME 2007 Call for Papers
2007 International Conference on Multimedia & Expo (ICME)

July 2-5, 2007
Beijing International Convention Center, Beijing, China

Sponsored by: Circuits and Systems Society, Communications Society, Computer Society, and Signal Processing Society.

IEEE International Conference on Multimedia & Expo is a major annual international conference with the objective of bringing together researchers, developers, and practitioners from academia and industry working in all areas of multimedia. ICME serves as a forum for the dissemination of state-of-the-art research, development, and implementations of multimedia systems, technologies and applications. ICME is co-sponsored by four IEEE societies including the Circuits and Systems Society, the Communications Society, the Computer Society, and the Signal Processing Society. The conference will feature world-class plenary speakers, exhibits, special sessions, tutorials, and paper presentations.

Prospective authors are invited to submit a four-page paper in double-column format including authors' names, affiliations, and a short abstract. Only electronic submissions will be accepted. Topics include but are not limited to:

- Audio, image, video processing
- Virtual reality and 3-D imaging
- Signal processing for media integration
- Multimedia communications and networking
- Multimedia security and content protection
- Multimedia human-machine interface and interaction
- Multimedia databases
- Multimedia computing systems and appliances
- Hardware and software for multimedia systems
- Multimedia standards and related issues
- Multimedia applications
- Multimedia and social media on the Internet

A number of awards will be presented to the Best Papers and Best Student Papers at the conference. Participation for special sessions and tutorial proposals are encouraged.

SCHEDULE

- Special Session Proposals Due: **December 1, 2006**
- Tutorial Proposals Due: **December 1, 2006**
- Regular Paper Submissions Due: **January 5, 2007**
- Notification of Acceptance: **March 19, 2007**
- Camera-Ready Papers Due: **April 16, 2007**

Check the conference website http://www.icme2007.org for updates.

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3DTV CONFERENCE 2007

THE TRUE VISION - CAPTURE, TRANSMISSION AND DISPLAY OF 3D VIDEO

May 7-9, 2007, KICC Conference Center, Kos Island, Greece

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First Call For Papers

Creating exact 3D moving images as ghost-like replicas of 3D objects has been an ultimate goal in video science. Capturing 3D scenery, processing the captured data for transmission, and displaying the result for 3D viewing are the main functional components. These components encompass a wide range of disciplines: imaging and computer graphics, signal processing, telecommunications, electronics, optics and physics are needed.

The objective of the **3DTV-Conference** is to bring together researchers and developers from academia and industry with diverse experience and activity in distinct, yet complementary, areas so that full scale 3D video capabilities are seemlessly integrated.

Topics of Interest

3D Capture and Processing
- 3D time-varying scene capture technology
- Multi-camera recording
- 3D photography algorithms
- Synchronization and calibration of camera arrays
- 3D view registration
- Multi-view geometry and calibration
- Holographic camera techniques
- 3D motion analysis and tracking
- Surface modeling for 3-D scenes
- Multi-view image and 3D data processing

3D Transmission
- Systems, architecture and transmission aspects of 3D
- 3D streaming
- Error-related issues and handling of 3d video
- Hologram compression
- Multi-view video coding
- 3D mesh compression
- Multiple description coding for 3D
- Signal processing for diffraction and holographic 3DTV

3D Visualization
- 3D mesh representation
- Texture and point representation
- Object-based representation and segmentation
- Volume representation
- 3D motion animation
- Dense stereo and 3D reconstruction
- Stereoscopic display techniques
- Holographic display technology
- Reduced parallax systems and integral imaging
- Underlying optics and VLSI technology
- Projection and display technology for 3D videos
- Human factors

3D Applications
- 3D imaging in virtual heritage and virtual archaeology
- 3D Teleimmersion and remote collaboration
- Augmented reality and virtual environments
- 3D television, cinema, games and entertainment
- Medical and biomedical applications
- 3D Content-based retrieval and recognition
- 3D Watermarking

Paper Submission

Prospective contributors are invited to submit full papers electronically using the on-line submission interface, following the instructions available at http://www.3dtv-con.org. Papers should be in Adobe PDF format, written in English, with no more than four pages including figures, using a font size of 11. Conference proceedings will be published online by the IEEE.

Important Dates

1 December 2006	Special sessions and tutorials proposals
15 December 2006	Regular Paper submission
9 February 2007	Notification of acceptance
2 March 2007	Submission of camera-ready papers

3DTV NoE
ITI-CERTH
Information Society Technologies
Institute of Electrical and Electronics Engineers
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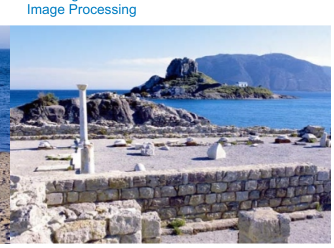
MPEG-IF





5th International Symposium on

Image and Signal Processing and Analysis ISPA 2007

September 27-29, 2007, Istanbul, Turkey

http://www.isispa.org

Call for Papers

The 5th International Symposium on Image and Signal Processing and Analysis (ISPA 2007) will take place in Istanbul, Turkey, from September 27-29, 2007. The scientific program of the symposium consists of invited lectures, regular papers, and posters. The aim of the symposium is to foster interaction of researchers and exchange of new ideas. Prospective authors are invited to submit their manuscripts reporting original work, as well as proposals for special sessions.

Co-Operations and Co-Sponsorships

- European Association for Signal Processing (EURASIP)
- IEEE Region 8*

Symposium Topics

A. Image and Video Processing
B. Image and Video Analysis
C. Image Formation and Reproduction
D. Signal Processing
E. Signal Analysis
F. Applications

For a detailed list of subtopics please visit ISPA 2007 web site.

Important Dates

Submission of full paper: February 15, 2007
Notification of acceptance/rejection: April 15, 2007
Submission of camera-ready papers and registration: May 15, 2007

Symposium Venue

Located in the center of the Old World, Istanbul is one of the world's great cities famous for its historical monuments and scenic beauties. It is the only city in the world which spreads over two continents: it lies at a point where Asia and Europe are separated by a narrow strait - the Bosphorus. Istanbul has been the cradle for many civilizations for over 2500 years and has a very rich history. It has been the capital of three great empires, the Roman, Byzantine and Ottoman empires, and for more than 1,600 years over 120 emperors and sultans ruled the world from here. Istanbul is the heart of Turkey with respect to entertainment, culture, education, shopping, imports and exports, tourism and the arts. The symposium will be organized in the congress center of the Bogazici University.

Paper Submission Procedure

Papers including title, author list and affiliations, figures, results, and references should not exceed six A4 pages. Detailed instructions for electronic submission are available on the ISPA web site. All papers will be subject to a peer-review process with at least two reviewers. All accepted papers will be published in the symposium proceedings in book form and on CD-ROM, which will be available through IEEE Publications Center and in IEEExplore digital library.

Call for Special Session Proposals

Prospective organizers of special sessions are invited to send proposals to Special Session Co-Chairs, according to instructions provided on the ISPA web site. The aim of a special session is to provide an overview of the state-of-the-art and current research directions in specific fields of image and signal processing and analysis.

Best Student Paper Award

Best Student Paper Award in the amount of 300 EUR will be given to a student author. The student's name must appear first on the paper and the paper must be presented at the symposium to be eligible for the award.

* request pending

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maria.petrou@imperial.ac.uk
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Special Sessions Co-Chairs
Bulent Sankur
bulent.sankur@boun.edu.tr
Bogazici University, Turkey

Robert Bregovic
bregovic@cs.tut.fi
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Publicity Chair
Enis Cetin
cetin@bilkent.edu.tr
Bilkent University, Turkey

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Aysın Ertuzun
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ertuz@boun.edu.tr
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Marko Subasic
marko.subasic@fer.hr
University of Zagreb, Croatia

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Gulbin Akgun
gulbin@sabanciuniv.edu
Sabancı University, Turkey

Information Tech. Chair
Vjekoslav Levacic
vjekoslav.levacic@fer.hr
University of Zagreb, Croatia

Symposium Secretariat
Gulbin Akgun
Sabanci University, Faculty of Engineering and Natural Sciences
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Fax: 216 483 9550
secretariat@isispa.org

ISSPA 2007

International Symposium on Signal Processing and its Applications

in conjunction **with the International Conference on Information Sciences, Signal Processing and their Applications**

12 – 15 February 2007, Millennium Hotel, Sharjah, U.A.E.

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Call For Participation

ISSPA 2007 marks the 20th anniversary of launching the first ISSPA in 1987 in Brisbane, Australia. Since its inception, ISSPA has provided, through a series of 8 symposia, a high quality forum for engineers and scientists engaged in research and development of Signal and Image Processing theory and applications. Effective 2007, ISSPA will extend its scope to add the new track of information sciences. Hence, the intention that the previous full name of ISSPA is replaced after 2007 by the following new full name:
International Conference on Information Sciences, Signal Processing and their Applications. ISSPA is an IEEE indexed conference.

ISSPA 2007 is organized by the University of Sharjah, College of Engineering, Etisalat University College and the American University of Sharjah.

The regular technical program will run for three days along with an exhibition of signal processing and information sciences products. In addition, tutorial sessions will be held on the first day of the symposium. Presentations will be given in the following topics:

1. Filter Design Theory and Methods
2. Multirate Filtering & Wavelets
3. Adaptive Signal Processing
4. Time-Frequency/Time-Scale Analysis
5. Statistical Signal & Array Processing
6. Radar & Sonar Processing
7. Speech Processing & Recognition
8. Fractals and Chaos Signal Processing
9. Signal Processing in Communications
10. Signal processing in Networking
11. Multimedia Signal Processing
12. Nonlinear signal processing
13. Biomedical Signal and Image Processing
14. Image and Video Processing
15. Image Segmentation and Scene Analysis
16. VLSI for Signal and Image Processing
17. Cryptology, Steganography, and Digital Watermarking
18. Image indexing & retrieval
19. Soft Computing & Pattern Recognition
20. Natural Language Processing
21. Signal Processing for Bioinformatics
22. Signal Processing for Geoinformatics
23. Biometric Systems and Security
24. Machine Vision
25. Data visualization
26. Data mining
27. Sensor Networks and Sensor Fusion
28. Signal Processing and Information Sciences Education
29. Others
30. Special Sessions

Prospective authors were invited to submit ***full length*** *(four pages) papers* ***via the conference website*** *for presentation in any of the areas listed above (showing area in submission). Submission of proposals for student session, tutorials and sessions on special topics were sent to the conference secretary. All articles submitted to ISSPA 2007 are* ***peer-reviewed*** *using a* ***blind review process*** *by at least two independent reviewers.*

For more details see

www.isspa2007.org/

Important Deadlines:

Full Paper Submission:
October 14, 2006
Tutorials/Special Sessions Submission:
October 14, 2006
Notification of Acceptance:
December 3, 2006
Final Accepted Paper Submission:
December 19, 2006

Conference Secretary

A-K. Hamid
University of Sharjah, UAE
Tel : +971 6 5050932
Fax :+971 6 5050872
E-mail: akhamid@sharjah.ac.ae

IEEE

EURASIP

15th European Signal Processing Conference

EUSIPCO 2007

September 3-7, 2007, Poznań, Poland

Just in the centre of Europe!

EURASIP

European Association for Signal, Speech and Image Processing

CALL FOR PAPERS

The 2007 European Signal Processing Conference (EUSIPCO-2007) is the fifteenth in a series of conferences promoted by EURASIP, the European Association for Signal, Speech, and Image Processing. The conference will be organized by Poznań University of Technology, Faculty of Electronics and Telecommunications Chair of Multimedia Telecommunications and Microelectronics and PTETiS Society in Conference Center at Poznań International Fair.

As usual, EUSIPCO-2007 areas of interest will cover all aspects of signal processing theory and applications as listed below. Proposals for special sessions and tutorials are strongly encouraged. Accepted papers will be published in the proceedings of EUSIPCO-2007. Acceptance will be based on quality, relevance and originality.

The conference topics include:

- Audio and Electroacoustics
- Design and Implementation of Signal Processing Systems
- DSP Applications and Embedded Systems
- Emerging Technologies in Signal Processing
- Signal Processing for Communications
- Image and Multidimensional Signal Processing
- Medical Imaging
- Image and Video Analysis
- Multimedia Signal Processing
- Speech Processing and Coding
- Image, Video and Audio Compression
- Nonlinear Signal Processing
- Sensor Array and Multichannel Processing
- Signal Detection and Estimation
- Signal Processing Applications (Biology, Geophysics, Seismic, Radar, Sonar, Remote Sensing, Astronomy, Bio-informatics, Positioning, etc.)
- Signal Processing Algorithms and their Implementations in Communication Systems
- Hardware Solutions for Signal Processing
- Education on Signal Processing

Submission

Procedures to submit a paper, proposals for sessions/tutorials, can be found at www.eusipco2007.org. Submitted papers must be final, full papers, no more than five pages long all inclusive and strictly conforming to the format specified on the EUSIPCO web site.

Best Student Paper Awards

Student authors who appear as first authors in a paper may enter the student paper contest.

Important Dates (updated)

Proposals for Special Sessions and Tutorials:	December 11, 2006
Electronic submission of Full papers (4 pages A4):	February 5, 2007
Notification of Acceptance:	May 11, 2007
Submission of Camera-Ready Papers and Registration:	June 10, 2007

www.eusipco2007.org

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mbartkow@et.put.poznan.pl
Poznań University of Technology, Poland

Special Sessions
Maciej Niedźwiecki
maciekn@eti.pg.gda.pl
Gdańsk University of Technology, Poland

Tutorials
Tomasz Zieliński
tzielin@uci.agh.edu.pl
AGH University of Science and Technology, Poland

Local Arrangements
Sławomir Maćkowiak
smack@et.put.poznan.pl
Poznań University of Technology, Poland

Overseas Liason
Andrzej Cichocki
cia@brain.riken.jp
Brain Science Institute RIKEN, Japan

Wen Gao
wgao@pku.edu.cn
Peking University, China

Yo-Sung Ho
hoyo@gist.ac.kr
Gwangju Institute of Science and Technology, Korea

Janusz Konrad
jkonrad@bu.edu
Boston University, USA

Masayuki Tanimoto
tanimoto@nuee.nagoya-u.ac.jp
Nagoya University, Japan

Scientific Secretariat
office@eusipco2007.org
Poznań University of Technology
Chair of Multimedia Telecommunications and Microelectronics
Polanka 3, 60-965 Poznań
POLAND

POLITECHNIKA POZNAŃSKA

PTETiS

About EURASIP:

The European Association for Signal, Speech and Image Processing (www.eurasip.org) was founded on 1 September 1978 to: "improve communication between groups and individuals that work within the multidisciplinary, fast growing field of Signal Processing in Europe and elsewhere, and to exchange and disseminate information in the field all over the world." The association exists to promote the efforts of researchers by providing a learned and professional platform for dissemination and discussion of all aspects of signal processing. EURASIP is a non profit organization which is governed by its Administrative Committee (AdCom).

EURASIP Areas of Interest:

- Continuous and discrete time signal theory
- Applications of signal processing
- Systems and technology
- Speech communication
- Image processing and communication.

EURASIP sponsors and co-sponsors a number of conferences within Europe and the rest of the world each year. The main event is EUSIPCO (European Signal Processing Conference), which is now recognized as one of the premier signal processing conferences, attracting delegates and papers from all over the world. The venues of consecutive conferences are: Lausanne, Switzerland (1980); Erlangen, Germany (1983); Hague, the Netherlands (1986); Grenoble, France (1988); Barcelona, Spain (1990); Brussels, Belgium (1992); Edinburgh, UK (1994); Trieste, Italy (1996); Rhodes, Greece (1998); Tampere, Finland (2000); Toulouse, France (2002); Vienna, Austria (2004); Antalya, Turkey (2005); Florence, Italy (2006).
The 2007 event will be held in Poznań, Poland.

About Poznań

Poznań, a capital of Wielkopolska province, is the fifth biggest city in Poland with population of 580 000. It is halfway between Berlin and Warsaw and it is older than each one of them. Poznań is easily accessible, since it is located in central Europe and it is easy to get there both from Western and Eastern part of the continent and also the rest of the world.
Poznań-Ławica International Airport is situated only 6 km from the conference venue. There are a lot of direct flights to many of European cities. The conference site is in the city centre, in a walking distance from the main railway station, as well as a variety of hotels of various standards.
Poznań is a dynamic economic, academic, scientifical and cultural centre. Thanks to its excellent economic performance and International Fair the city is often called the economic capital of Poland. It is an excellent place for organizing conferences because it is also a centre of academic life. There are 22 universities and other institutions of higher education with over 120 000 students. Among the universities there is Poznań University of Technology one of the biggest and most recognized technical universities in Poland. Thanks to such a considerable number of students the city has got a creative and unforgettable atmosphere. An abundance of monuments and interesting places from all époques creates pleasant surroundings for social meetings after conference sessions.

www.eusipco2007.org

IEEE

Fifth International Workshop on

Content-Based Multimedia Indexing, CBMI-2007

June 25-27, 2007
Bordeaux, France

EURASIP

CBMI 2007 CALL FOR PAPERS

Following the four successful previous events of CBMI (Toulouse 1999, Brescia 2001, Rennes 2003 and Riga 2005), the LABRI / *University of Bordeaux* will organize the next CBMI event. CBMI'07 aims at bringing together the various communities involved in the different aspects of Content-Based Multimedia Indexing. The scientific program of CBMI'07 will include the presentation of invited plenary talks, special sessions as well as regular sessions with contributed research papers.

Authors are encouraged to submit extended papers to the Special Issue of Signal Processing: Image Communication journal, EURASIP on CBMI. Topics of interest for submissions include, but are not limited to:

- Multimedia indexing and retrieval (image, audio, video, text)
- Multimedia content extraction
- Matching and similarity search
- Construction of high level indices
- Multi-modal and cross-modal indexing
- Content-based search techniques
- Multimedia data mining
- Presentation tools
- Meta-data compression and transformation
- Handling of very large scale multimedia database
- Organisation, summarisation and browsing of multimedia documents
- Applications
- Evaluation and metrics

PAPER SUBMISSION

Prospective authors are invited to submit full papers of not more than eight (8) pages including results, figures and references. Papers will be accepted only by electronic submission through the conference web site: http://cbmi07.labri.fr/. Style files (Latex and Word) are provided for the convenience of the authors.

Submission of full paper (to be received by):	**January 25, 2007**
Notification of acceptance:	**March 10, 2007**
Submission of camera-ready papers:	**April 10, 2007**

WORKSHOP VENUE

CBMI'07 will be held in Bordeaux (France) on June 25-27, 2007

For further information: http://cbmi07.labri.fr/

MUSCLE
Multimedia Understanding through Semantics, Computation and Learning

CNRS
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

COST 292
Semantic Multimodal Analysis of Digital Media

INRIA

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University of Bordeaux/LABRI
jenny.benois@labri.fr

Technical Program Chair
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Centrum voor Wiskunde en Informatica
Eric.Pauwels@cwi.nl

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15th International Conference on Digital Signal Processing

July 1-4, 2007
Cardiff
Wales, UK

Call for Papers

The 15th International Conference on Digital Signal Processing (DSP 2007), the most longstanding conference in the area of DSP, organised in cooperation with the IEEE, will be held in Cardiff the capital of Wales, UK, July 1-4, 2007. DSP 2007 belongs to a series of events which had its genesis in London in 1968 and continued to Florence, Nicosia, Lemessos, and Santorini. The last meeting took place overlooking the cauldron in the bay of Fira, Santorini, in 2002. This now tranquil location was once the scene of a massive eruption which led directly to the extinction of one of Europe's oldest civilisations, the Minoans; in 2007 delegates will be brought right up to date in an area of rebirth, Cardiff Bay, the heart of Europe's youngest capital. The conference will contain a number of Special sessions organised by internationally recognised experts. The programme will also include presentations of new results in lecture and poster sessions, together with plenary sessions delivered by eminent scientists. Accepted papers will appear in IEEE Xplore.

Special Sessions

TBA

Indicative Topics of Interest

Adaptive signal processing
Array processing, radar and sonar
Biomedical signal and image processing
Bioinformatics and genomic signal processing
Blind equalization
Blind source separation
Collaborative networking
Computer vision and pattern recognition
Data fusion
Design and implementation of signal processing systems
Detection and estimation theory
Distributed Signal Processing
Image and multidimensional signal processing
Information forensics and security
Joint source-channel coding
Machine learning for signal processing
Multimedia signal processing
Multimudal signal processing
Multivariate statistical analysis
Musical signal processing
Nonlinear signal processing
Progressive data transmission
Sensor array and multichannel systems
Speech and language processing
Time-frequency and time-scale analysis

Expected dates (to be confirmed):

Electronic paper submission	February 19, 2007
Acceptance notification	April 2, 2007
Camera-ready papers	April 9, 2007
Conference	July 1-4, 2007

www.cardiff.ac.uk/dsp2007/

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