

Determining Patterns in Neural Activity for Reaching Movements Using Nonnegative Matrix Factorization

Sung-Phil Kim

*Department of Electrical and Computer Engineering, University of Florida, Gainesville, FL 32611, USA
Email: phil@cnel.ufl.edu*

Yadunandana N. Rao

*Motorola Inc., FL, USA
Email: yadu@cnel.ufl.edu*

Deniz Erdogmus

*Department of Computer Science and Biomedical Engineering, Oregon Health & Science University,
Beaverton, OR 97006, USA
Email: derdogmus@ieee.org*

Justin C. Sanchez

*Department of Pediatrics, Division of Neurology, University of Florida, Gainesville, FL 32611, USA
Email: justin@cnel.ufl.edu*

Miguel A. L. Nicolelis

*Department of Neurobiology, Center for Neuroengineering, Duke University, Durham, NC 27710, USA
Emails: derdogmus@ieee.org; nicoleli@neuro.duke.edu*

Jose C. Principe

*Department of Electrical and Computer Engineering, University of Florida, Gainesville, FL 32611, USA
Email: principe@cnel.ufl.edu*

Received 31 January 2004; Revised 23 March 2005

We propose the use of nonnegative matrix factorization (NMF) as a model-independent methodology to analyze neural activity. We demonstrate that, using this technique, it is possible to identify local spatiotemporal patterns of neural activity in the form of sparse basis vectors. In addition, the sparseness of these bases can help infer correlations between cortical firing patterns and behavior. We demonstrate the utility of this approach using neural recordings collected in a brain-machine interface (BMI) setting. The results indicate that, using the NMF analysis, it is possible to improve the performance of BMI models through appropriate pruning of inputs.

Keywords and phrases: brain-machine interfaces, nonnegative matrix factorization, spatiotemporal patterns, neural firing activity.

1. INTRODUCTION

Brain-machine interfaces (BMIs) are an emerging field that aims at directly transferring the subject's intent of movement to an external machine. Our goal is to engineer devices that are able to interpret neural activity originating in the motor cortex and generate accurate predictions of hand position. In the BMI experimental paradigm, hundreds of microelectrodes are implanted in the premotor, motor, and

posterior parietal areas and the corresponding neural activity is recorded synchronously with behavior (hand reaching and grasping movements). Spike detection and sorting algorithms are used to determine the firing times of single neurons. Typically, the spike-time information is summarized into bin counts using short windows (100 milliseconds in this paper). A number of laboratories including our own have demonstrated that linear and nonlinear adaptive system identification approaches using the bin count input

can lead to BMIs that effectively predict the hand position and grasping force of primates for different movement tasks [1, 2, 3, 4, 5, 6, 7, 8]. The adaptive methods studied thus far include moving average models, time-delay neural networks (TDNNs), Kalman filter and extensions, recursive multilayer perceptrons (RMLPs), and mixture of linear experts gated by hidden Markov models (HMMs).

BMIs open up an important avenue to study the spatio-temporal organization of spike trains and their relationships with behavior. Recently, our laboratory has investigated the sensitivity of neurons and cortical areas based on their role in the mapping learned by the RMLP and the Wiener filter [7]. We examined how each neuron contributes to the output of the models, and found consistent relationships between cortical regions and segments of the hand trajectory in a reaching movement. This analysis indicated that, during each reaching action, specific neurons from the posterior parietal, the premotor dorsal, and the primary motor regions sequentially became dominant in controlling the output of the models. However, this approach relies on determining a suitable model, because it explicitly uses the learned model to infer the dependencies.

In this paper, we propose a model-independent methodology to study spatiotemporal patterns between neuronal spikes and behavior utilizing nonnegative matrix factorization (NMF) [9, 10]. In its original applications, NMF was mainly used to provide an alternative method for determining sparse representations of images to improve recognition performance [10, 11]. d'Avella and Tresch have also proposed an extension of NMF to extract time-varying muscle synergies for the analysis of behavior patterns of a frog [12]. The nonnegativity constraints in NMF result in the unsupervised selection of sparse bases that can be linearly combined (encoded) to reconstruct the original data. Our hypothesis is that NMF can similarly yield sparse bases for analyzing neural firing activity, because of the intrinsic nonnegativity of the bin counts and the sparseness of spike trains.

The application of NMF to extract local features of neural spike counts follows the method of obtaining sparse bases to describe the local features of face images. The basis vectors provided by NMF and their temporal encoding patterns are examined to determine how the activities of specific neurons localize to each segment of the reaching trajectory. We will show that the results from this model-independent analysis of the neuronal activity are consistent with the previous observations from the model-based analysis.

2. NONNEGATIVE MATRIX FACTORIZATION

NMF is a procedure to decompose a nonnegative data matrix into the product of two nonnegative matrices: bases and encoding coefficients. The nonnegativity constraint leads to a parts-based representation, since only additive, not subtractive, combinations of the bases are allowed. An $n \times m$ nonnegative data matrix \mathbf{X} , where each column is a sample vector, can be approximated by NMF as

$$\mathbf{X} = \mathbf{WH} + \mathbf{E}, \quad (1)$$

where \mathbf{E} is the error and \mathbf{W} and \mathbf{H} have dimensions $n \times r$ and $r \times m$, respectively. \mathbf{W} consists of a set of r basis vectors, while each column of \mathbf{H} contains the encoding coefficients for every basis for the corresponding sample. The number of bases is selected to satisfy $r(n + m) < nm$ so that the number of equations exceed that of the unknowns.

This factorization can be described in terms of columns as

$$\mathbf{x}_j \approx \mathbf{W}\mathbf{h}_j, \quad \text{for } j = 1, \dots, m, \quad (2)$$

where \mathbf{x}_j is the j th column of \mathbf{X} and \mathbf{h}_j is the j th column of \mathbf{H} . Thus, each sample vector is a linear combination of basis vectors in \mathbf{W} weighted by \mathbf{h}_j . The nonnegative constraints on \mathbf{W} and \mathbf{H} allow only additive combination of basis vectors to approximate \mathbf{x}_j . This constraint allows the visualization of the basis vectors as “part” of the original sample [10]. This is contrary to factorization by PCA, where negative basis vectors are allowed.

The decomposition of \mathbf{X} into \mathbf{W} and \mathbf{H} can be determined by optimizing an error function between the original data matrix and the decomposition. Two possible cost functions used in the literature are the Frobenius norm of the error matrix $\|\mathbf{X} - \mathbf{WH}\|_F^2$ and the Kullback-Leibler divergence $D_{KL}(\mathbf{X} \parallel \mathbf{WH})$. The nonnegativity constraint can be satisfied by using multiplicative update rules discussed in [10] to minimize these cost functions. In this paper, we will employ the Frobenius norm measure, for which the multiplicative update rules that converge to a local minimum are given below:

$$\begin{aligned} \mathbf{H}_{\mu j}(k+1) &= \mathbf{H}_{\mu j}(k) \frac{(\mathbf{W}^T \mathbf{X})_{\mu j}}{(\mathbf{W}^T \mathbf{WH})_{\mu j}}, \\ \mathbf{W}_{i\mu}(k+1) &= \mathbf{W}_{i\mu}(k) \frac{(\mathbf{XH}^T)_{i\mu}}{(\mathbf{WHH}^T)_{i\mu}}. \end{aligned} \quad (3)$$

\mathbf{A}_{ab} denotes the element of a matrix \mathbf{A} at a th row and b th column. It has been proven in [9] that the Frobenius norm cost function is nonincreasing under this update rule.

3. FACTORIZATION OF THE NEURONAL ACTIVITY MATRIX

We will now apply the multiplicative update rule in (2) to the neuronal bin-count matrix (created by real neural recordings of a behaving primate). The goal is to determine nonnegative sparse bases for the neural activity, from which we wish to deduce the local spatial structure of the neural population firing activity. These bases also point out common population firing patterns corresponding to the specific behavior. In addition, the resulting factorization yields a temporal encoding matrix that indicates how the instantaneous neural activity is optimally constructed from these localized representations. Since we are interested in the relationship between the neural activity and behavior, we would like to study the coupling between this temporal encoding pattern with the movement of the primate, as well as the contribution of the specific bases vectors, which represent neural populations.

TABLE 1: Distribution of neurons and cortical regions.

	Monkey-1				Monkey-2	
Regions	PP	M1(area 1)	PMd	M1(area 2)	M1	PMd
Neurons	1 ~ 33	34 ~ 54	55 ~ 81	82 ~ 104	1 ~ 37	38 ~ 54

3.1. Data preparation

Synchronous, multichannel neuronal spike trains were collected at Duke University using two female owl monkeys (*Aotus trivirgatus*): Belle (monkey-1) and Carmen (monkey-2).¹ Microwire electrodes were implanted in cortical regions where motor associations are known [1, 13]. During the neural recording process, up to sixty-four electrodes were implanted in posterior parietal (PP)-area 1, primary motor (M1)-area 2, area 4, and premotor dorsal (PMd)-area 3, each receiving sixteen electrodes. From each electrode, one to four neurons can be discriminated. The firing times of individual neurons were determined using spike detection and sorting algorithms [14] and were recorded while the primate performed a 3D reaching task that consists of a reach to food followed by eating. The primate's hand position was also recorded using multiple fiber optic sensors (with a shared time clock) and digitized with a 200 Hz sampling rate [1]. These sensors were contained in the plastic strip of which bending and twisting modified the transmission of the light through the sensors in order to record positions in 3D space more accurately. The neuronal firing times were binned in nonoverlapping windows of 100 milliseconds, representing the local firing rate for each neuron. In this recording session of approximately 20 minutes (12 000 bins), 104 neurons for monkey-1 and 54 neurons for monkey-2 could be discriminated (whose distribution to cortical regions is provided in Table 1 from [13]), and there were 71 reaching actions for monkey-1 and 65 for monkey-2, respectively. These reaching movements consist of three natural segments shown in Figure 1.

Based on the analysis of Wessberg et al. [1], the instantaneous movement is correlated with the current and the past neural data up to 1 second (10 bins). Therefore, for each time instant, we form a bin-count vector by concatenating 10 bins of firing counts (which correspond to 10-tap delay line in a linear filter) from every neuron. Hence, if $x_j(i)$ represents the i th bin of neuron j , where $i \in \{1, \dots, 12\,000\}$, a bin-count vector at time instance i is represented by $\mathbf{x}(i) = [x_1(i), x_1(i-1), \dots, x_1(i-9), x_2(i), \dots, x_n(i-9)]^T$, where n is the number of neurons. Since we are interested in determining repeated spatiotemporal firing patterns during the reaching movements, only the bin counts from time instances where the primate's arm is moving are considered. There is a possibility that in the selected training set some neurons never fire. The rows corresponding to these neurons must be removed from the bin-count matrix, since they tend to cause

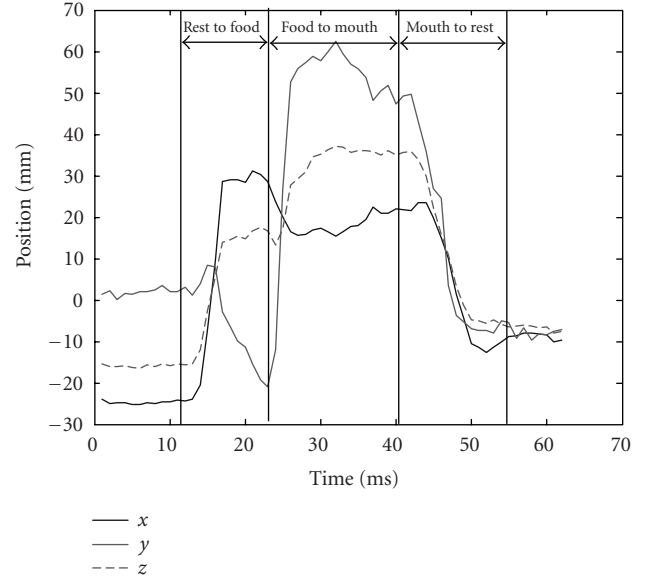


FIGURE 1: Segmentation of the reaching trajectories: reach from rest to food, reach from food to mouth, and reach from mouth to rest positions (taken from [7]).

instability in the NMF algorithm. In addition, to prevent the error criterion from focusing too much on neurons that simply fire frequently (although the temporal structure of their activity might not be significant for the task), the bin counts in each row (i.e., for each neuron) of the data matrix are normalized to have the unit length in its two norms. In general, if n neurons are considered for a total of m time instances, the data matrix \mathbf{X} has dimension $(10n) \times m$. Since the entries of the data matrix are bin counts, they are guaranteed to be nonnegative. Accounting for 71 or 65 movements, there are $m = 2143$ time instances for monkey-1 and $m = 2521$ for monkey-2.

3.2. Analysis of factorization process

In the application of NMF to a given neural firing matrix, there are several important issues that must be addressed: the selection of the number of bases, the uniqueness of the NMF solution, and understanding how NMF can find local structures of neural firing activity.

The problem of the choice of the number of bases can be addressed in the framework of model selection. A number of model selection techniques (e.g., the cross-validation) can be utilized for finding the optimal number of bases. In this paper, we choose to adopt a selection criterion that has been recently developed for clustering. The criterion is called the index I , which has been used to indicate the cluster

¹ All experimental procedures conformed to the National Academy Press Guide for the Care and Use of Laboratory Animals and were approved by the Duke University Animal Care and Use Committee.

validity [15]. This index has shown consistent performance of selecting the true number of clusters for various experimental settings. The index I is composed of three factors as

$$I(r) = \left(\frac{1}{r} \cdot \frac{E_1}{E_r} \cdot D_r \right)^p, \quad (4)$$

where E_r is the approximation error (Frobenius norm) for r bases, and D_r is the maximum Euclidean distance between bases such that

$$D_r = \max_{i,j=1}^r \|\mathbf{w}_i - \mathbf{w}_j\|. \quad (5)$$

The optimal r is the one that maximizes $I(r)$. We will utilize this index to determine the optimal r for NMF with $p = 1$.

Donoho and Stodden have shown that a unique solution of NMF is possible under certain conditions [16]. They have shown through a geometrical interpretation of NMF that if the data are not strictly positive, there can be only one set of nonnegative bases which spans the data in the positive orthant. With an articulated set of images obeying three rules (a generative model, linear independence of generators, and factorial sampling), they showed NMF identifies the generators or “parts” of images. If we consider our neuronal bin-count matrix, each row contains many zero entries (zero bin counts) even after removing nonfiring neurons since most neurons do not fire continuously once in every 100-millisecond window during the entire training set. Therefore, our neuronal data are not strictly positive. This implies that the existence of a unique set of nonnegative bases for the neuronal bin-count matrix is warranted. The question still remains if the NMF basis vectors can find the generative firing patterns for the neural population by meeting the three conditions mentioned above. Here, we discuss the neuronal bin-count data with respect to these conditions.

As stated previously, we have demonstrated through sensitivity analysis that the specific neuronal subsets from the PP, PMd, and M1 regions were sequentially involved in deriving the output of the predictive models during reaching movements [7]. Hence, the bin-count data for the reaching movement will contain increasing firing activity of the specific neuronal subset on local partitions of the trajectory. Due to binning, it is possible that more than one firing pattern is associated with a single data sample. This analysis leads to a generative model for the binned data in which data samples are generated by linear combination of the specific firing patterns with nonnegative coefficients. Also, these firing patterns will be linearly independent since the neuronal subset in each firing patterns tends to modulate firing rates only for the local part of trajectory. The third condition of factorial sampling can be approximately satisfied by the repetition of movements in which the variability of a particular firing pattern is observed during the entire data set. However, a more rigorous analysis is necessary to support the argument that the set of firing patterns is complete in factorial terms. Therefore, we expect that the NMF solutions may be slightly variable reflecting the ambiguity in the completeness of factorial

sampling. This might be overcome by collecting more data for reaching movements, and will be pursued in future studies.

3.3. Case studies

The NMF algorithm is applied to the described neuronal data matrix prepared using ten taps, $n = 91$ neurons for monkey-1 (after eliminating the neurons that do not fire through the entire training set) and $n = 52$ neurons for monkey-2. The NMF algorithm with 100 independent runs results in $r=5$ bases for both monkey-1 and monkey-2 datasets for which the index I is maximized. The means and the standard deviations of the normalized cost (Frobenius norm of error between approximation and the given data matrix divided by the Frobenius norm of the data only) for 100 runs are 0.8399 ± 0.001 for monkey-1 data and 0.7348 ± 0.002 for monkey-2 data. This implies that the algorithm approximately converges to the same solution with different initial conditions (although not sufficient).

In Figure 2, we show the resulting basis vectors (columns of \mathbf{W}) for the bin counts (presented in matrix form where columns are different neurons and rows are different delays), as well as their corresponding time-varying encoding coefficients (rows of \mathbf{H}) superimposed on the reaching trajectory coordinates of three consecutive movements. Based on the assumption that the neuronal bin-count data approximately satisfy the three conditions for the identification of the generators, the NMF basis vectors determine the sequence of spatiotemporal firing patterns representing the firing modulation of the specific neuronal subsets during the course of the reaching movement. Alternatively, we can say that NMF discovers these latent firing patterns of neural population by optimal linear approximation of the data with few bases [9]. For example, from the two basis vectors each corresponding to two primates in the left panel of Figure 2, we observe that firings of the neurons in group- b are followed by firings of the neurons in group- a (the bright activity denoted by b occurs earlier in time than the activity denoted by a , since increasing values in the vertical axis of each basis indicates going further back in time). Thus, NMF effectively determines and summarizes this sparse firing pattern that involves a group of neurons firing sequentially. Their relative average activity is also indicated by the relative magnitudes of the entries of this particular basis.

Using these time-synchronized neural activity and hand trajectory recordings, it is also possible to discover relationships between firing patterns and certain aspects of the movement. We can assess the repeatability of a certain firing pattern summarized by a basis vector by observing the time-varying activity of the corresponding encoding signal (the corresponding row of \mathbf{H}) in time. An increase in this coefficient corresponds to a larger emphasis to that basis in reconstructing the original neural activity data. In the right panel of Figure 2, we observe that all bases are activated regularly in time by their corresponding encoding signals (at different time instances and at different amplitudes). For example, the first basis for monkey-1 is periodically activated to the same amplitude, whereas the activation amplitude of

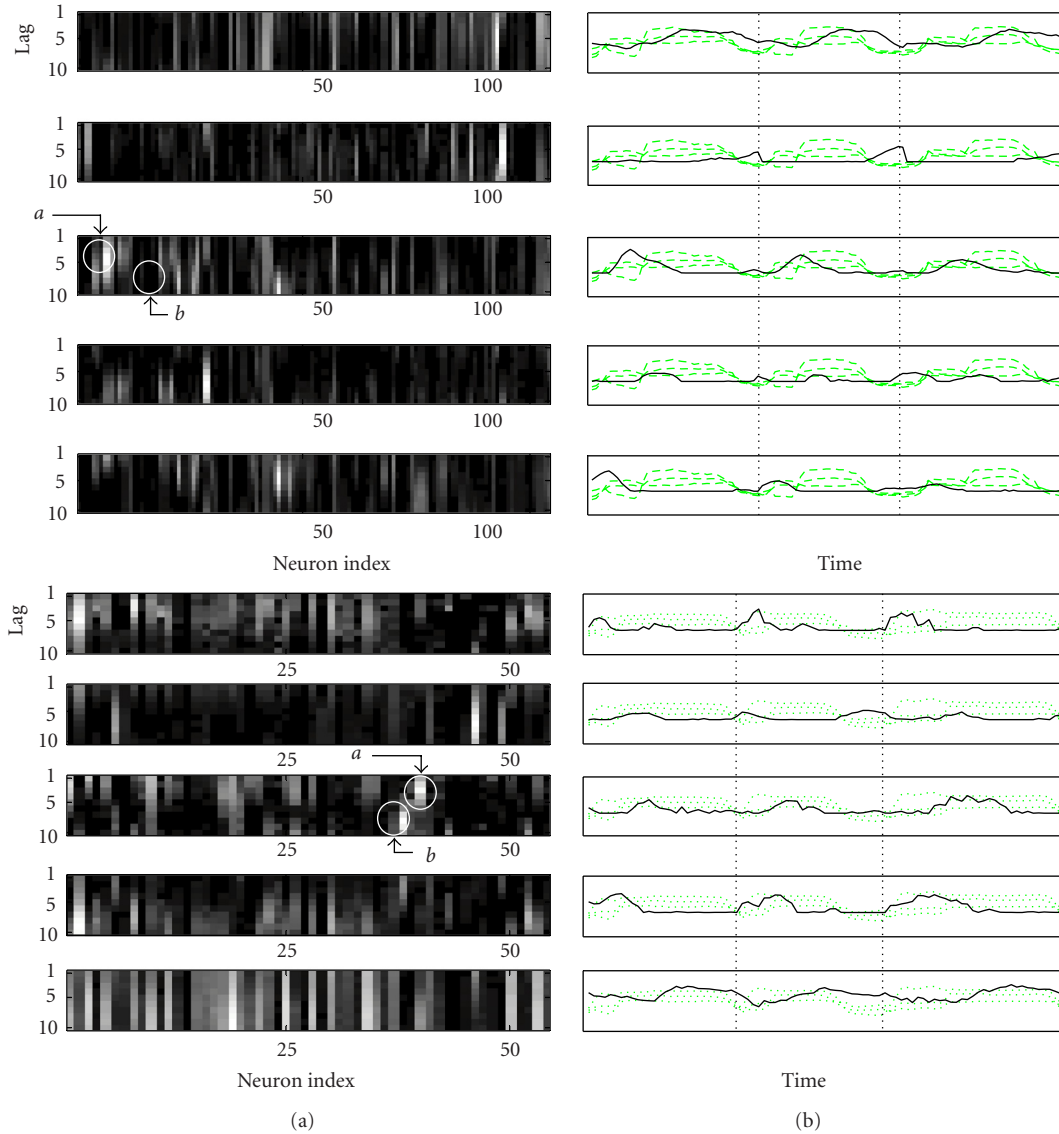


FIGURE 2: (a) The five bases for monkey-1 (top) and monkey-2 (bottom). (b) Their corresponding encoding signals (thick solid line) overlaid on the 3-dimensional coordinates of the reaching trajectory (dotted lines) for three consecutive representative reaching tasks (separated by the dashed lines). Note that the encoding signals are scaled to be in the same order of the magnitude of the reaching trajectory for the visual purpose.

the third basis varies in every movement, which might indicate a change in the role of the corresponding neuronal firing pattern in executing that particular movement. The periodic activation of encodings also indicates the bursting nature of the spatiotemporal repetitive patterns. Hence, the NMF bases tend to encode synchronous and bursting spatiotemporal patterns of neural firing activity.

From the NMF decomposition, we observe certain associations between the activities of neurons from different cortical regions and different segments of the reaching trajectory. In particular, an analysis of the monkey-1 data based on Figure 2 indicates that neurons in PP and M1 (array 1) repeat similar firing patterns during the reach from rest to food. This assessment is based on the observation that bases three, four, and five, which involve firing activities from neurons

in these regions, are repeatedly activated by the increased amplitude of their respective encoding coefficients. Similarly, neurons in M1 (array 2) are repeatedly activated during the reach to and from the mouth (bases one and two). These observations are consistent with our previous analyses that were conducted through trained input-output models (such as the Wiener filter and RMLP) [7]. Table 2 compares the neurons, which were observed to have the highest sensitivity from trained models, and the neurons that have the largest magnitudes in each NMF basis. This comparison is based on monkey-1 dataset. We can see that neurons from NMF are a subset of neurons obtained from the sensitivity analysis. It is also worth stating that NMF basis provides more information than the model-based sensitivity analysis since it determines the synchronous spatiotemporal patterns while

TABLE 2: Comparison of important neurons (examined in the monkey-1 dataset).

Regions	PP	M1(area 1)	PMd	M1(area 2)
The high sensitive neurons through RMLP	4, 5, 7, 22, 26, 29	38, 45	None	93, 94
The largest-magnitude neurons in NMF bases	7, 29	45	None	93, 94

TABLE 3: Performance evaluation of the Wiener filter and the mixture of multiple models based on NMF.

	CC (x)	CC (y)	CC (z)	MSE (x)	MSE (y)	MSE (z)
Monkey-1						
Wiener filter	0.5772	0.6712	0.7574	0.4855	0.3468	0.2460
NMF mixture	0.7147	0.7078	0.8076	0.2711	0.2786	0.1627
Monkey-2						
Wiener filter	0.3737	0.4304	0.6192	0.3050	0.7405	0.2882
NMF mixture	0.4974	0.5041	0.6916	0.2354	0.5400	0.2112

the sensitivity analysis only determines individual important neurons. Finally, we would like to reiterate that the analysis presented here is solely based on the data, which means that this analysis does not need to train a specific model to investigate the neural population organization.

3.4. Modeling improvement for BMI using NMF

We will demonstrate a simple example showing the improved BMIs performance in predicting hand positions by utilizing NMF. We will compare the performance of two systems; the Wiener filter directly applied to the original spike count data and the mixture of multiple linear filters based on the NMF bases and encodings.

The straight Wiener filter is directly applied to the neural firing data to estimate the three coordinates of the primate's hand position. The Wiener filter has been a standard model for BMIs, and many other approaches have been compared with it [19]. With nine delays, the input dimensionality of the filter is 910 for monkey-1 or 510 for monkey-2 (discarding inactive (no firing) neural channels). Then we add a bias to each input vector to estimate the y-intercept. The weights of the filter are estimated by the Wiener-Hopf equation as

$$\mathbf{W} = \mathbf{R}^{-1}\mathbf{P}, \quad (6)$$

where \mathbf{R} is a 911×911 (or 511×511 for monkey-2) input correlation matrix, and \mathbf{P} is a 911×3 (or 511×3 for monkey-2) input-output cross-correlation matrix.

The mixture of multiple models employs the NMF encodings as mixing coefficients. An NMF basis is used as a window function for the corresponding local model. Therefore, each model sees a given input vector through a different window and uses the windowed input vector to produce the output. Then the NMF encodings are used to combine each model's output to produce the final estimate of the desired hand position vector. This can be described in the following equation:

$$\hat{d}_c(n) = \sum_{k=1}^K h_k(n) (\mathbf{z}_k(n)^T \mathbf{g}_{k,c} + b_{k,c}), \quad (7)$$

where $h_k(n)$ is an NMF encoding coefficient for the k th basis at n th column (i.e., time index), $\mathbf{g}_{k,c}$ is the weight vector of the k th model for the c th coordinate ($c \in [x, y, z]$), and $b_{k,c}$ is the y-intercept of the k th model for the c th coordinate. $\mathbf{z}_k(n)$ is the input vector windowed by the k th NMF basis. Its i th element is given by

$$z_{k,i}(n) = x_i(n) \cdot w_{k,i}. \quad (8)$$

Here, $x_i(n)$ is the normalized firing count of the neuron i at time instance n , and $w_{k,i}$ is the i th element of the k th NMF basis. $\mathbf{g}_{k,c}$ and $b_{k,c}$ can be estimated based on the MSE criterion by using of the stochastic gradient algorithm such as the normalized least mean square (NLMS). The weight update rule of the NLMS for each model is then given by

$$\begin{aligned} \mathbf{g}_{k,c}(n+1) &= \mathbf{g}_{k,c}(n) + \frac{\eta}{\beta + \|\mathbf{z}_k(n)\|^2} h_k(n) e_c(n) \mathbf{z}_k(n), \\ b_{k,c}(n+1) &= b_{k,c}(n) + \frac{\eta}{\beta + \|\mathbf{z}_k(n)\|^2} h_k(n) e_c(n), \end{aligned} \quad (9)$$

where η is the learning rate and β is the normalization factor. $e_c(n)$ is the error between the c th coordinate of the desired response and the model output.

In the experiment, we divided the data samples into 1771 training samples and 372 test samples for monkey-1 dataset and 1739 and 782, respectively, for monkey-2 dataset. The parameters are set as $\{\eta, \beta, K\} = \{0.01, 1, 5\}$. The entire training data set is presented 60 times sufficient enough for the weights to converge. The performance of the model is evaluated on the test set by two measures; the correlation coefficient (CC) between desired hand trajectory and the model output trajectory, and the mean squared error (MSE) normalized by the variance of the desired response. Table 3 presents the evaluation of the performance of two systems for both monkey-1 and monkey-2 datasets. It shows a significant improvement in generalization performance with the mixture of models based on NMF factorization.

Note that the general performance of models for the monkey-2 dataset is worse than that for the monkey-1

dataset. The reasons may come from many experimental variables. One of them may be the number of electrodes and the corresponding cortical areas, as we can see in Table 1 that only 32 electrodes were implanted in two areas for monkey-2, while 64 electrodes in four areas for monkey-1.

To quantify the performance difference between the Wiener filter and the mixture of multiple models, we can apply a statistical test based on the mean squared error (MSE) performance metric [17]. By modeling the performance difference in terms of the MSE using short-time windows as a normal random variable, one can apply the t-test to quantify significance. This t-test was applied to both modeling outputs for monkey-1 and monkey-2 with $\alpha = 0.01$ or $\alpha = 0.05$. For both datasets, the null hypothesis was rejected with both significance levels, resulting in the p -values of 0.0023 for monkey-1 and 0.0007 for monkey-2, respectively. Therefore, the statistical test of the performance difference demonstrates that the mixture of multiple models based on NMF improves the performance significantly compared to the standard Wiener filter.

3.5. Discussions

The results presented in the previous case study are a representative example of a broader set of NMF experiments performed on this recording. Selection of the number of taps and the number of bases (r) is dependent on the particular stimulus or behavior associated with the neural data. Although we have used a model selection method originally developed for clustering, and did not provide full justification that this index is suitable to NMF, the main motivation is to demonstrate that the problem of selecting the number of bases can be addressed in the context of model selection. This will be pursued in future research.

The number of patterns that can be distinctly represented by NMF is limited by the number of bases. A very small number of bases will lead to the combination of multiple patterns into a single nonsparse basis vector. At the other extreme, a very large number of bases will result in the splitting of a pattern into two or more bases, which have similar encoding coefficient signals in time. In these situations, the bases under consideration can be combined into one basis.

It is intriguing that the mixture of models based on NMF generalizes better than the Wiener filter despite the fact that the mixture contains much more model parameters. However, each model in the mixture receives the inputs processed by the sparse basis vector. Therefore, each model learns the mapping between only a particular subset of neurons and hand trajectories, and the effective number of parameters for each model is much less than the total number of input variables. Moreover, further overfitting is avoided by combining the outputs of local models by the sparse encodings of NMF.

4. CONCLUSIONS

Nonnegative matrix factorization is a novel and relatively new tool for analyzing the data structure when nonnegativity constraints are imposed. In BMIs the neural inputs are processed by grouping the firings into bin counts. Since the bin counts are always positive, we hypothesized that NMF

would be appropriate for analyzing the neural activity. The experimental results and the analysis presented in this paper showed that we could find repeated patterns in neuronal activity that occurred in synchrony with the reaching behavior and was automatically and efficiently represented in a set of sparse bases. The sparseness of the bases indicates that only a small number of neurons exhibit repeated firing patterns that are influential in reconstructing the original neural activity matrix.

As presented in [10], NMF provides local bases of the objects, while principal component analysis (PCA) provides global bases. In our preliminary experiments of PCA for the same data, we have observed that PCA only found the most frequently firing neurons, which may not be related to the behavior. Therefore, NMF can find local representation of the neural firing data, and this property of NMF can be more effective than PCA for BMIs where firing activities of different cortical areas are collected.

Lee and Seung have claimed in their paper that the statistical independence among the encodings of independent component analysis (ICA) forces the basis to be holistic [10]. And, if local parts of the neural activity occur together at the same time, the complicated dependencies between the encodings would not be captured by the ICA algorithm. However, we have observed that the NMF encodings seem to be uncorrelated over the entire movement. Hence, ICA with some nonnegative constraints (e. g., nonnegative ICA [18], the ICA model with nonnegative basis [19], and nonnegative sparse coding [20]) may yield interesting encodings of the neural firing activities. Further studies will present the comparison between NMF and these constrained ICA algorithms applied for BMIs.

While NMF is found to be a useful tool for analyzing neural data to find repeatable activity patterns, there are still several issues when using NMF for neural data analysis. Firstly, the method only detects patterns of activity, but it is known that the inactivity of a neuron could often indicate response to a stimulus or cause a behavior. An analysis based on NMF will fail to identify such neurons. Next, the nontationary characteristics of neural activities would make it difficult for NMF to find fixed spatiotemporal firing patterns. Since the neural ensemble function tends to change over neuronal space and time such that different spatio-temporal firing patterns may be involved for the same behavioral output, we may have to continuously adapt NMF factors to track those changes. This motivates us to consider a recursive algorithm of NMF, which will enable us to adapt NMF factors online. It will be covered in the future study.

In our application of NMF, we demonstrated that the NMF learning algorithm resulted in similar Frobenius norm of the error matrix for 100 runs obtained with different initial conditions. However, this does not necessarily mean that the resulted factors are similar with small variance. Therefore, we need to quantify the similarity of the NMF results with different initializations. An alternative is to employ other methods to obtain the global solution such as genetic or simulated annealing algorithms. This will be presented in a follow-up report.

ACKNOWLEDGMENTS

The authors would like to thank Johan Wessberg for collecting the data used in this paper. This work was supported by the DARPA project no. N66001-02-C-8022.

REFERENCES

- [1] J. Wessberg, C. R. Stambaugh, J. D. Kralik, et al., "Real-time prediction of hand trajectory by ensembles of cortical neurons in primates," *Nature*, vol. 408, no. 6810, pp. 361–365, 2000.
- [2] D. W. Moran and A. B. Schwartz, "Motor cortical activity during drawing movements: population representation during spiral tracing," *Journal of Neurophysiology*, vol. 82, no. 5, pp. 2693–2704, 1999.
- [3] J. K. Chapin, K. A. Moxon, R. S. Markowitz, and M. A. L. Nicolelis, "Real-time control of a robot arm using simultaneously recorded neurons in the motor cortex," *Nature Neuroscience*, vol. 2, no. 7, pp. 664–670, 1999.
- [4] M. D. Serruya, N. G. Hatsopoulos, L. Paninski, M. R. Fellows, and J. P. Donoghue, "Brain-machine interface: instant neural control of a movement signal," *Nature*, vol. 416, no. 6877, pp. 141–142, 2002.
- [5] J. C. Sanchez, S.-P. Kim, D. Erdogmus, et al., "Input-output mapping performance of linear and nonlinear models for estimating hand trajectories from cortical neuronal firing patterns," in *Proc. 12th IEEE International Workshop on Neural Networks for Signal Processing*, pp. 139–148, Martigny, Switzerland, September 2002.
- [6] S. Darmanjian, S.-P. Kim, M. C. Nechyba, et al., "Bimodal brain-machine interface for motor control of robotic prosthetic," in *Proc. IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS '03)*, vol. 4, pp. 3612–3617, Las Vegas, Nev, USA, October 2003.
- [7] J. C. Sanchez, D. Erdogmus, Y. N. Rao, et al., "Interpreting neural activity through linear and nonlinear models for brain machine interfaces," in *Proc. 25th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, vol. 3, pp. 2160–2163, Cancun, Mexico, September 2003.
- [8] J. M. Carmena, M. A. Lebedev, R. E. Crist, et al., "Learning to control a brain-machine interface for reaching and grasping by primates," *PLoS Biology*, vol. 1, no. 2, pp. 1–16, 2003.
- [9] D. D. Lee and H. S. Seung, "Algorithms for non-negative matrix factorization," in *Advances in Neural Information Processing Systems 13*, T. K. Leen, T. G. Dietterich, and V. Tresp, Eds., pp. 556–562, MIT Press, Cambridge, Mass, USA, 2001.
- [10] D. D. Lee and H. S. Seung, "Learning the parts of objects by non-negative matrix factorization," *Nature*, vol. 401, no. 6755, pp. 788–791, 1999.
- [11] D. Guillamet, M. Bressan, and J. Vitrià, "A weighted non-negative matrix factorization for local representations," in *Proc. IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR '01)*, vol. 1, pp. 942–947, Kauai, Hawaii, USA, December 2001.
- [12] A. d'Avella and M. C. Tresch, "Modularity in the motor system: decomposition of muscle patterns as combinations of time-varying synergies," in *Advances in Neural Information Processing Systems 14*, T. G. Dietterich, S. Becker, and Z. Ghahramani, Eds., pp. 629–632, MIT Press, Cambridge, Mass, USA, 2002.
- [13] J. C. Sanchez, *From cortical neural spike trains to behavior: modeling and analysis*, Ph.D. dissertation, Department of Biomedical Engineering, University of Florida, Gainesville, Fla, USA, 2004.
- [14] M. A. L. Nicolelis, A. A. Ghazanfar, B. M. Faggin, S. Votaw, and L. M. Oliveira, "Reconstructing the engram: simultaneous, multisite, many single neuron recordings," *Neuron*, vol. 18, no. 4, pp. 529–537, 1997.
- [15] U. Maulik and S. Bandyopadhyay, "Performance evaluation of some clustering algorithms and validity indices," *IEEE Trans. Pattern Anal. Machine Intell.*, vol. 24, no. 12, pp. 1650–1654, 2002.
- [16] D. Donoho and V. Stodden, "When does non-negative matrix factorization give a correct decomposition into parts?" in *Advances in Neural Information Processing Systems 16*, S. Thrun, L. K. Saul, and B. Schölkopf, Eds., pp. 1141–1148, MIT Press, Cambridge, Mass, USA, 2004.
- [17] S.-P. Kim, J. C. Sanchez, Y. N. Rao, et al., "A Comparison of optimal MIMO linear and nonlinear models for brain-machine interfaces," submitted to *Neural Computation*, 2004.
- [18] M. Plumbley, "Conditions for nonnegative independent component analysis," *IEEE Signal Processing Lett.*, vol. 9, no. 6, pp. 177–180, 2002.
- [19] L. Parra, C. Spence, P. Sajda, A. Ziehe, and K.-R. Müller, "Unmixing hyperspectral data," in *Advances in Neural Information Processing Systems 12*, S. A. Solla, T. K. Leen, and K.-R. Müller, Eds., pp. 942–948, MIT Press, Cambridge, Mass, USA, 2000.
- [20] P. O. Hoyer, "Non-negative sparse coding," in *Proc. 12th IEEE International Workshop on Neural Networks for Signal Processing*, pp. 557–565, Martigny, Switzerland, September 2002.

Sung-Phil Kim was born in Seoul, South Korea. He received a B.S. degree from the Department of Nuclear Engineering, Seoul National University, Seoul, South Korea, in 1994. In 1998, he entered the Department of Electrical and Computer Engineering, University of Florida, in pursuit of Master of Science degree. He joined the Computational NeuroEngineering Laboratory as a Research Assistant in 2000. He also received an M.S. degree in December 2000 from the Department of Electrical and Computer Engineering, University of Florida. From 2001, he continued to pursue a Ph.D. degree in the Department of Electrical and Computer Engineering, University of Florida under supervision of Dr. Jose C. Principe. In the Computational NeuroEngineering Laboratory, he has investigated the decoding models and the analytical methods for brain-machine interfaces.



Yadunandana N. Rao was born in Mysore, India. He received his B.E. degree in electronics and communication engineering from the University of Mysore, India, in August 1997, and the M.S. and Ph.D. degrees in electrical and computer engineering from the University of Florida, Gainesville, Fla, in 2000 and 2004, respectively. From May 2000 to January 2001, he worked as a Design Engineer at GE Medical Systems, Wis. Currently he is a Senior Engineer at Motorola, Fla. His research interests include adaptive signal processing theory, algorithms and analysis, neural networks for signal processing, and biomedical applications.



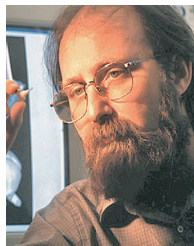
Deniz Erdogmus received his B.S. degrees in electrical engineering and mathematics in 1997, and his M.S. degree in electrical engineering, with emphasis on systems and control, in 1999, all from the Middle East Technical University, Turkey. He received his Ph.D. degree in electrical engineering from the University of Florida, Gainesville, in 2002. Since 1999, he has been with the Computational NeuroEngineering Laboratory, University of Florida, working with Jose Principe. His current research interests include information-theoretic aspects of adaptive signal processing and machine learning, as well as their applications to problems in communications, biomedical signal processing, and controls. He is the recipient of the IEEE SPS 2003 Young Author Award, and is a Member of IEEE, Tau Beta Pi, and Eta Kappa Nu.



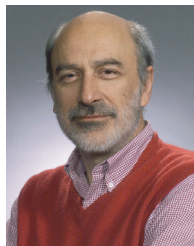
Justin C. Sanchez received a B.S. degree with highest honors in engineering science along with a minor in biomechanics from the University of Florida in 2000. From 1998 to 2000, he spent three years as a Research Assistant in the Department of Anesthesiology, University of Florida. In 2000, he joined the Department of Biomedical Engineering and Computational NeuroEngineering Laboratory, the University of Florida. In the spring of 2004, he completed both his M.E. and Ph.D. degrees in biomedical signal processing working on the development of modeling and analysis tools for brain-machine interfaces. He is currently a Research Assistant Professor in the Department of Pediatrics, Division of Neurology, the University of Florida. His neural engineering electrophysiology laboratory is currently developing neuroprosthetics for use in the research and clinical settings.



Miguel A. L. Nicolelis was born in Sao Paulo, Brazil, in 1961. He received his M.D. and Ph.D. degrees from the University of Sao Paulo, Brazil, in 1984 and 1988, respectively. After postdoctoral work at Hahnemann University, Philadelphia, he joined Duke University, where he now codirects the Center for Neuroengineering and is a Professor of neurobiology, biomedical engineering, and psychological and brain sciences. His laboratory is interested in understanding the general computational principles underlying the dynamic interactions between populations of cortical and subcortical neurons involved in motor control and tactile perception.



Jose C. Principe is a Distinguished Professor of electrical and computer engineering and biomedical engineering at the University of Florida where he teaches advanced signal processing, machine learning, and artificial neural networks (ANNs) modeling. He is a BellSouth Professor and the Founder and Director of the University of Florida Computational NeuroEngineering Laboratory (CNEL). His primary area of interest is processing of time-varying signals with adaptive neural models. The CNEL has been studying signal and pattern recognition principles based on information-theoretic criteria (entropy and mutual



information). He is an IEEE Fellow. He is a Member of the AD-COM of the IEEE Signal Processing Society, a Member of the Board of Governors of the International Neural Network Society, and the Editor-in-Chief of the IEEE Transactions on Biomedical Engineering. He is a Member of the Advisory Board of the University of Florida Brain Institute. He has more than 90 publications in refereed journals, 10 book chapters, and 200 conference papers. He directed 35 Ph.D. dissertations and 45 Master theses. He recently wrote an interactive electronic book entitled *Neural and Adaptive Systems: Fundamentals Through Simulation* published by John Wiley and Sons.

Special Issue on

Search and Retrieval of 3D Content and Associated Knowledge Extraction and Propagation

Call for Papers

With the general availability of 3D digitizers, scanners, and the technology innovation in 3D graphics and computational equipment, large collections of 3D graphical models can be readily built up for different applications (e.g., in CAD/CAM, games design, computer animations, manufacturing and molecular biology). For such large databases, the method whereby 3D models are sought merits careful consideration. The simple and efficient query-by-content approach has, up to now, been almost universally adopted in the literature. Any such method, however, must first deal with the proper positioning of the 3D models. The two prevalent-in-the-literature methods for the solution to this problem seek either

- Pose Normalization: Models are first placed into a canonical coordinate frame (normalizing for translation, scaling, and rotation). Then, the best measure of similarity is found by comparing the extracted feature vectors, or
- Descriptor Invariance: Models are described in a transformation invariant manner, so that any transformation of a model will be described in the same way, and the best measure of similarity is obtained at any transformation.

The existing 3D retrieval systems allow the user to perform queries by example. The queried 3D model is then processed, low-level geometrical features are extracted, and similar objects are retrieved from a local database. A shortcoming of the methods that have been proposed so far regarding the 3D object retrieval, is that neither is the semantic information (high-level features) attached to the (low-level) geometric features of the 3D content, nor are the personalization options taken into account, which would significantly improve the retrieved results. Moreover, few systems exist so far to take into account *annotation* and *relevance feedback* techniques, which are very popular among the corresponding content-based image retrieval systems (CBIR).

Most existing CBIR systems using knowledge either annotate all the objects in the database (full annotation) or

annotate a subset of the database manually selected (partial annotation). As the database becomes larger, full annotation is increasingly difficult because of the manual effort needed. Partial annotation is relatively affordable and trims down the heavy manual labor. Once the database is partially annotated, traditional image analysis methods are used to derive semantics of the objects not yet annotated. However, it is not clear “how much” annotation is sufficient for a specific database and what the best subset of objects to annotate is. In other words how the knowledge *will be propagated*. Such techniques have not been presented so far regarding the 3D case.

Relevance feedback was first proposed as an interactive tool in text-based retrieval. Since then it has been proven to be a powerful tool and has become a major focus of research in the area of content-based search and retrieval. In the traditional computer centric approaches, which have been proposed so far, the “best” representations and weights are fixed and they cannot effectively model high-level concepts and user’s perception subjectivity. In order to overcome these limitations of the computer centric approach, techniques based on *relevant feedback*, in which the human and computer interact to refine high-level queries to representations based on low-level features, should be developed.

The aim of this special issue is to focus on recent developments in this expanding research area. The special issue will focus on novel approaches in 3D object retrieval, transforms and methods for efficient geometric feature extraction, annotation and relevance feedback techniques, knowledge propagation (e.g., using Bayesian networks), and their combinations so as to produce a single, powerful, and dominant solution.

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

- 3D content-based search and retrieval methods (volume/surface-based)
- Partial matching of 3D objects
- Rotation invariant feature extraction methods for 3D objects

- Graph-based and topology-based methods
- 3D data and knowledge representation
- Semantic and knowledge propagation over heterogeneous metadata types
- Annotation and relevance feedback techniques for 3D objects

Authors should follow the EURASIP JASP manuscript format described 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.mstracking.com/asp/>, according to the following timetable:

Manuscript Due	February 1, 2006
Acceptance Notification	June 1, 2006
Final Manuscript Due	September 1, 2006
Publication Date	4th Quarter, 2006

GUEST EDITORS:

Petros Daras, Informatics and Telematics Institute, Centre for Research and Technology Hellas, 57001 Thessaloniki, Greece; daras@iti.gr

Ming Ouhyoung, National Taiwan University, Taipei 106, Taiwan; ming@csie.ntu.edu.tw

Tsuhan Chen, Carnegie Mellon University, Pittsburgh, PA 15213, USA; tsuhan@cmu.edu

Special Issue on Robust Speech Recognition

Call for Papers

Robustness can be defined as the ability of a system to maintain performance or degrade gracefully when exposed to conditions not well represented in the data used to develop the system. In automatic speech recognition (ASR), systems must be robust to many forms of signal degradation, including speaker characteristics (e.g., dialect and accent), ambient environment (e.g., cellular telephony), transmission channel (e.g., voice over IP), and language (e.g., new words, dialect switching). Robust ASR systems, which have been under development for the past 35 years, have made great progress over the years closing the gap between performance on pristine research tasks and noisy operational data.

However, in recent years, demand is emerging for a new class of systems that tolerate extreme and unpredictable variations in operating conditions. For example, in a cellular telephony environment, there are many nonstationary forms of noise (e.g., multiple speakers) and significant variations in microphone type, position, and placement. Harsh ambient conditions typical in automotive and mobile applications pose similar challenges. Development of systems in a language or dialect for which there is limited or no training data in a target language has become a critical issue for a new generation of voice mining applications. The existence of multiple conditions in a single stream, a situation common to broadcast news applications, and that often involves unpredictable changes in speaker, topic, dialect, or language, is another form of robustness that has gained attention in recent years.

Statistical methods have dominated the field since the early 1980s. Such systems tend to excel at learning the characteristics of large databases that represent good models of the operational conditions and do not generalize well to new environments.

This special issue will focus on recent developments in this key research area. Topics of interest include (but are not limited to):

- Channel and microphone normalization
- Stationary and nonstationary noise modeling, compensation, and/or rejection
- Localization and separation of sound sources (including speaker segregation)

- Signal processing and feature extraction for applications involving hands-free microphones
- Noise robust speech modeling
- Adaptive training techniques
- Rapid adaptation and learning
- Integration of confidence scoring, metadata, and other alternative information sources
- Audio-visual fusion
- Assessment relative to human performance
- Machine learning algorithms for robustness
- Transmission robustness
- Pronunciation modeling

Authors should follow the EURASIP JASP manuscript format described 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.mstracking.com/asp/>, according to the following timetable:

Manuscript Due	February 1, 2006
Acceptance Notification	June 1, 2006
Final Manuscript Due	September 1, 2006
Publication Date	4th Quarter, 2006

GUEST EDITORS:

Herve Bourlard, IDIAP Research Institute, Swiss Federal Institute of Technology at Lausanne (EPFL), 1920 Martigny, Switzerland; herve.bourlard@idiap.ch

Mark Gales, Department of Engineering, University of Cambridge, Cambridge CB2 1PZ, UK; mjfg@eng.cam.ac.uk

Maurizio Omologo, ITC-IRST, 38050 Trento, Italy; omologo@itc.it

S. Parthasarathy, AT&T Labs - Research, NJ 07748, USA; sps@research.att.com

Joe Picone, Department of Electrical and Computer Engineering, Mississippi State University, MS 39762-9571, USA; picone@cavs.msstate.edu

Special Issue on Signal Processing Technologies for Ambient Intelligence in Home-Care Applications

Call for Papers

The possibility of allowing elderly people with different kinds of disabilities to conduct a normal life at home and achieve a more effective inclusion in the society is attracting more and more interest from both industrial and governmental bodies (hospitals, healthcare institutions, and social institutions). Ambient intelligence technologies, supported by adequate networks of sensors and actuators, as well as by suitable processing and communication technologies, could enable such an ambitious objective.

Recent researches demonstrated the possibility of providing constant monitoring of environmental and biomedical parameters, and the possibility to autonomously originate alarms, provide primary healthcare services, activate emergency calls, and rescue operations through distributed assistance infrastructures. Nevertheless, several technological challenges are still connected with these applications, ranging from the development of enabling technologies (hardware and software), to the standardization of interfaces, the development of intuitive and ergonomic human-machine interfaces, and the integration of complex systems in a highly multidisciplinary environment.

The objective of this special issue is to collect the most significant contributions and visions coming from both academic and applied research bodies working in this stimulating research field. This is a highly interdisciplinary field comprising many areas, such as signal processing, image processing, computer vision, sensor fusion, machine learning, pattern recognition, biomedical signal processing, multimedia, human-computer interfaces, and networking.

The focus will be primarily on the presentation of original and unpublished works dealing with ambient intelligence and domotic technologies that can enable the provision of advanced homecare services.

This special issue will focus on recent developments in this key research area. Topics of interest include (but are not limited to):

- Video-based monitoring of domestic environments and users
- Continuous versus event-driven monitoring
- Distributed information processing

- Data fusion techniques for event association and automatic alarm generation
- Modeling, detection, and learning of user habits for automatic detection of anomalous behaviors
- Integration of biomedical and behavioral data
- Posture and gait recognition and classification
- Interactive multimedia communications for remote assistance
- Content-based encoding of medical and behavioral data
- Networking support for remote healthcare
- Intelligent/natural man-machine interaction, personalization, and user acceptance

Authors should follow the EURASIP JASP manuscript format described at <http://www.hindawi.com/journals/asp/>. Prospective authors should submit an electronic copy of their complete manuscripts through the EURASIP JASP manuscript tracking system at <http://www.mstracking.com/asp/>, according to the following timetable:

Manuscript Due	March 1, 2006
Acceptance Notification	July 1, 2006
Final Manuscript Due	October 1, 2006
Publication Date	1st Quarter, 2007

GUEST EDITORS:

Francesco G. B. De Natale, Department of Information and Communication Technology, University of Trento, Via Sommarive 14, 38050 Trento, Italy; denatale@ing.unitn.it

Aggelos K. Katsaggelos, Department of Electrical and Computer Engineering, Northwestern University, 2145 Sheridan Road, Evanston, IL 60208-3118, USA; aggk@ece.northwestern.edu

Oscar Mayora, Create-Net Association, Via Solteri 38, 38100 Trento, Italy; oscar.mayora@create-net.it

Ying Wu, Department of Electrical and Computer Engineering, Northwestern University, 2145 Sheridan Road, Evanston, IL 60208-3118, USA; yingwu@ece.northwestern.edu

Special Issue on Spatial Sound and Virtual Acoustics

Call for Papers

Spatial sound reproduction has become widespread in the form of multichannel audio, particularly through home theater systems. Reproduction systems from binaural (by headphones) to hundreds of loudspeaker channels (such as wave field synthesis) are entering practical use. The application potential of spatial sound is much wider than multichannel sound, however, and research in the field is active. Spatial sound covers for example the capturing, analysis, coding, synthesis, reproduction, and perception of spatial aspects in audio and acoustics.

In addition to the topics mentioned above, research in virtual acoustics broadens the field. Virtual acoustics includes techniques and methods to create realistic percepts of sound sources and acoustic environments that do not exist naturally but are rendered by advanced reproduction systems using loudspeakers or headphones. Augmented acoustic and audio environments contain both real and virtual acoustic components.

Spatial sound and virtual acoustics are among the major research and application areas in audio signal processing. Topics of active study range from new basic research ideas to improvement of existing applications. Understanding of spatial sound perception by humans is also an important area, in fact a prerequisite to advanced forms of spatial sound and virtual acoustics technology.

This special issue will focus on recent developments in this key research area. Topics of interest include (but are not limited to):

- Multichannel reproduction
- Wave field synthesis
- Binaural reproduction
- Format conversion and enhancement of spatial sound
- Spatial sound recording
- Analysis, synthesis, and coding of spatial sound
- Spatial sound perception and auditory modeling
- Simulation and modeling of room acoustics
- Auralization techniques
- Beamforming and sound source localization
- Acoustic and auditory scene analysis
- Augmented reality audio

- Virtual acoustics (sound environments and sources)
- Intelligent audio environments
- Loudspeaker-room interaction and equalization
- Applications

Authors should follow the EURASIP JASP manuscript format described 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.mstracking.com/asp/>, according to the following timetable:

Manuscript Due	May 1, 2006
Acceptance Notification	September 1, 2006
Final Manuscript Due	December 1, 2006
Publication Date	1st Quarter, 2007

GUEST EDITORS:

Ville Pulkki, Helsinki University of Technology, Espoo, Finland; ville@acoustics.hut.fi

Christof Faller, EPFL, Lausanne, Switzerland; christof.faller@epfl.ch

Aki Hirma, Philips Research Labs, Eindhoven, The Netherlands; aki.hirma@philips.com

Tapio Lokki, Helsinki University of Technology, Espoo, Finland; ktlokki@cc.hut.fi

Werner de Bruijn, Philips Research Labs, Eindhoven, The Netherlands; werner.de.bruijn@philips.com

Special Issue on Advances in Electrocardiogram Signal Processing and Analysis

Call for Papers

Since its invention in the 19th century when it was little more than a scientific curiosity, the electrocardiogram (ECG) has developed into one of the most important and widely used quantitative diagnostic tools in medicine. It is essential for the identification of disorders of the cardiac rhythm, extremely useful for the diagnosis and management of heart abnormalities such as myocardial infarction (heart attack), and offers helpful clues to the presence of generalised disorders that affect the rest of the body, such as electrolyte disturbances and drug intoxication.

Recording and analysis of the ECG now involves a considerable amount of signal processing for S/N enhancement, beat detection, automated classification, and compression. These involve a whole variety of innovative signal processing methods, including adaptive techniques, time-frequency and time-scale procedures, artificial neural networks and fuzzy logic, higher-order statistics and nonlinear schemes, fractals, hierarchical trees, Bayesian approaches, and parametric models, amongst others.

This special issue will review the current status of ECG signal processing and analysis, with particular regard to recent innovations. It will report major achievements of academic and commercial research institutions and individuals, and provide an insight into future developments within this exciting and challenging area.

This special issue will focus on recent developments in this key research area. Topics of interest include (but are not limited to):

- Beat (QRS complex) detection
- ECG compression
- Denoising of ECG signals
- Morphological studies and classification
- ECG modeling techniques
- Expert systems and automated diagnosis
- QT interval measurement and heart-rate variability
- Arrhythmia and ischemia detection and analysis
- Interaction between cardiovascular signals (ECG, blood pressure, respiration, etc.)

- Intracardiac ECG analysis (implantable cardiovascular devices, and pacemakers)
- ECGs and sleep apnoea
- Real-time processing and instrumentation
- ECG telemedicine and e-medicine
- Fetal ECG detection and analysis
- Computational tools and databases for ECG education and research

Authors should follow the EURASIP JASP manuscript format described at <http://www.hindawi.com/journals/asp/>. Prospective authors should submit an electronic copy of their complete manuscripts through the EURASIP JASP manuscript tracking system at <http://www.mstracking.com/asp/>, according to the following timetable:

Manuscript Due	May 1, 2006
Acceptance Notification	September 1, 2006
Final Manuscript Due	December 1, 2006
Publication Date	1st Quarter, 2007

GUEST EDITORS:

William Sandham, Scotsig, Glasgow G12 9pf, UK;
w.sandham@scotsig.co.uk

David Hamilton, Department of Electronic and Electrical Engineering, University of Strathclyde, Glasgow G1 1XW, UK; d.hamilton@eee.strath.ac.uk

Pablo Laguna Lasaosa, Departamento de Ingeniería Electrónica y Comunicaciones, Universidad de Zaragoza, 50015 Zaragoza, Spain; laguna@unizar.es

Maurice Cohen, University of California, San Francisco, USA; mcohen@fresno.ucsf.edu

Special Issue on Emerging Signal Processing Techniques for Power Quality Applications

Call for Papers

Recently, end users and utility companies are increasingly concerned with perturbations originated from electrical power quality variations. Investigations are being carried out to completely characterize not only the old traditional type of problems, but also new ones that have arisen as a result of massive use of nonlinear loads and electronics-based equipment in residences, commercial centers, and industrial plants. These nonlinear load effects are aggravated by massive power system interconnections, increasing number of different power sources, and climatic changes.

In order to improve the capability of equipments applied to monitoring the power quality of transmission and distribution power lines, power systems have been facing new analysis and synthesis paradigms, mostly supported by signal processing techniques. The analysis and synthesis of emerging power quality and power system problems led to new research frontiers for the signal processing community, focused on the development and combination of computational intelligence, source coding, pattern recognition, multirate systems, statistical estimation, adaptive signal processing, and other digital processing techniques, implemented in either DSP-based, PC-based, or FPGA-based solutions.

The goal of this proposal is to introduce powerful and efficient real-time or almost-real-time signal processing tools for dealing with the emerging power quality problems. These techniques take into account power-line signals and complementary information, such as climatic changes.

This special issue will focus on recent developments in this key research area. Topics of interest include (but are not limited to):

- Detection of transients
- Classification of multiple events
- Identification of isolated and multiple disturbance sources
- Compression of voltage and current data signals
- Location of disturbance sources
- Prediction of transmission and distribution systems failures
- Demand forecasting

- Parameters estimation for fundamental, harmonics, and interharmonics

Digital signal processing techniques applied to power quality applications are a very attractive and stimulating area of research. Its results will provide, in the near future, new standards for the decentralized and real-time monitoring of transmission and distribution systems, allowing to closely follow and predict power system performance. As a result, the power systems will be more easily planned, expanded, controlled, managed, and supervised.

Authors should follow the EURASIP JASP manuscript format described at <http://www.hindawi.com/journals/asp/>. Prospective authors should submit an electronic copy of their complete manuscripts through the EURASIP JASP manuscript tracking system at <http://www.mstracking.com/asp/>, according to the following timetable:

Manuscript Due	May 1, 2006
Acceptance Notification	September 1, 2006
Final Manuscript Due	December 1, 2006
Publication Date	2nd Quarter, 2007

GUEST EDITORS:

Moisés Vidal Ribeiro, Department of Electrical Circuit, Federal University of Juiz de Fora, CEP 36036-330, Juiz de Fora, Brazil; mrbeiro@ieee.org

Jacques Szczupack, Department of Electrical Engineering, Pontifical Catholic University of Rio de Janeiro, CEP 22453-900, Rio de Janeiro, Brazil; jacques@ele.puc-rio.br

M. Reza Iravani, The Edward S. Rogers SR., Department of Electrical and Computer Engineering, University of Toronto, Toronto, ON, Canada M5S 3G4; iravani@ecf.utoronto.ca



Irene Yu-Hua Gu, Department of Signals and Systems,
Chalmers University of Technology, SE-412 96, Gothenburg,
Sweden; irenegu@s2.chalmers.se

Pradipta Kishore Dash, C. V. Raman, College of
Engineering Bhubaneswar, Khurda-752054, Orissa, India;
pkdash_india@yahoo.com

Alexander Mamishev, Department of Electrical
Engineering, University of Washington, WA 98195-2500,
Seattle, USA; mamishev@ee.washington.edu

Special Issue on Super-resolution Enhancement of Digital Video

Call for Papers

When designing a system for image acquisition, there is generally a desire for high spatial resolution and a wide field-of-view. To achieve this, a camera system must typically employ small f-number optics. This produces an image with very high spatial-frequency bandwidth at the focal plane. To avoid aliasing caused by undersampling, the corresponding focal plane array (FPA) must be sufficiently dense. However, cost and fabrication complexities may make this impractical. More fundamentally, smaller detectors capture fewer photons, which can lead to potentially severe noise levels in the acquired imagery. Considering these factors, one may choose to accept a certain level of undersampling or to sacrifice some optical resolution and/or field-of-view.

In image super-resolution (SR), postprocessing is used to obtain images with resolutions that go beyond the conventional limits of the uncompensated imaging system. In some systems, the primary limiting factor is the optical resolution of the image in the focal plane as defined by the cut-off frequency of the optics. We use the term "optical SR" to refer to SR methods that aim to create an image with valid spatial-frequency content that goes beyond the cut-off frequency of the optics. Such techniques typically must rely on extensive a priori information. In other image acquisition systems, the limiting factor may be the density of the FPA, subsequent postprocessing requirements, or transmission bitrate constraints that require data compression. We refer to the process of overcoming the limitations of the FPA in order to obtain the full resolution afforded by the selected optics as "detector SR." Note that some methods may seek to perform both optical and detector SR.

Detector SR algorithms generally process a set of low-resolution aliased frames from a video sequence to produce a high-resolution frame. When subpixel relative motion is present between the objects in the scene and the detector array, a unique set of scene samples are acquired for each frame. This provides the mechanism for effectively increasing the spatial sampling rate of the imaging system without reducing the physical size of the detectors.

With increasing interest in surveillance and the proliferation of digital imaging and video, SR has become a rapidly growing field. Recent advances in SR include innovative algorithms, generalized methods, real-time implementations,

and novel applications. The purpose of this special issue is to present leading research and development in the area of super-resolution for digital video. Topics of interest for this special issue include but are not limited to:

- Detector and optical SR algorithms for video
- Real-time or near-real-time SR implementations
- Innovative color SR processing
- Novel SR applications such as improved object detection, recognition, and tracking
- Super-resolution from compressed video
- Subpixel image registration and optical flow

Authors should follow the EURASIP JASP manuscript format described 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.mstracking.com/asp/>, according to the following timetable:

Manuscript Due	September 1, 2006
Acceptance Notification	February 1, 2007
Final Manuscript Due	April 15, 2007
Publication Date	3rd Quarter, 2007

GUEST EDITORS:

Russell C. Hardie, Department of Electrical and Computer Engineering, University of Dayton, 300 College Park, Dayton, OH 45469-0026, USA; rhardie@udayton.edu

Richard R. Schultz, Department of Electrical Engineering, University of North Dakota, Upson II Room 160, P.O. Box 7165, Grand Forks, ND 58202-7165, USA; RichardSchultz@mail.und.nodak.edu

Kenneth E. Barner, Department of Electrical and Computer Engineering, University of Delaware, 140 Evans Hall, Newark, DE 19716-3130, USA; barner@ee.udel.edu

Special Issue on

Advanced Signal Processing and Computational Intelligence Techniques for Power Line Communications

Call for Papers

In recent years, increased demand for fast Internet access and new multimedia services, the development of new and feasible signal processing techniques associated with faster and low-cost digital signal processors, as well as the deregulation of the telecommunications market have placed major emphasis on the value of investigating hostile media, such as powerline (PL) channels for high-rate data transmissions.

Nowadays, some companies are offering powerline communications (PLC) modems with mean and peak bit-rates around 100 Mbps and 200 Mbps, respectively. However, advanced broadband powerline communications (BPLC) modems will surpass this performance. For accomplishing it, some special schemes or solutions for coping with the following issues should be addressed: (i) considerable differences between powerline network topologies; (ii) hostile properties of PL channels, such as attenuation proportional to high frequencies and long distances, high-power impulse noise occurrences, time-varying behavior, and strong inter-symbol interference (ISI) effects; (iv) electromagnetic compatibility with other well-established communication systems working in the same spectrum, (v) climatic conditions in different parts of the world; (vii) reliability and QoS guarantee for video and voice transmissions; and (vi) different demands and needs from developed, developing, and poor countries.

These issues can lead to exciting research frontiers with very promising results if signal processing, digital communication, and computational intelligence techniques are effectively and efficiently combined.

The goal of this special issue is to introduce signal processing, digital communication, and computational intelligence tools either individually or in combined form for advancing reliable and powerful future generations of powerline communication solutions that can be suited with for applications in developed, developing, and poor countries.

Topics of interest include (but are not limited to)

- Multicarrier, spread spectrum, and single carrier techniques
- Channel modeling

- Channel coding and equalization techniques
- Multiuser detection and multiple access techniques
- Synchronization techniques
- Impulse noise cancellation techniques
- FPGA, ASIC, and DSP implementation issues of PLC modems
- Error resilience, error concealment, and Joint source-channel design methods for video transmission through PL channels

Authors should follow the EURASIP JASP manuscript format described at the journal site <http://asp.hindawi.com/>. Prospective authors should submit an electronic copy of their complete manuscripts through the EURASIP JASP manuscript tracking system at <http://www.mstracking.com/asp/>, according to the following timetable:

Manuscript Due	October 1, 2006
Acceptance Notification	January 1, 2007
Final Manuscript Due	April 1, 2007
Publication Date	3rd Quarter, 2007

GUEST EDITORS:

Moisés Vidal Ribeiro, Federal University of Juiz de Fora, Brazil; mrubeiro@ieee.org

Lutz Lampe, University of British Columbia, Canada; lampe@ece.ubc.ca

Sanjit K. Mitra, University of California, Santa Barbara, USA; mitra@ece.ucsb.edu

Klaus Dostert, University of Karlsruhe, Germany; klaus.dostert@etec.uni-karlsruhe.de

Halid Hrasnica, Dresden University of Technology, Germany hrasnica@ifn.et.tu-dresden.de

Special Issue on

Video Adaptation for Heterogeneous Environments

Call for Papers

The explosive growth of compressed video streams and repositories accessible worldwide, the recent addition of new video-related standards such as H.264/AVC, MPEG-7, and MPEG-21, and the ever-increasing prevalence of heterogeneous, video-enabled terminals such as computer, TV, mobile phones, and personal digital assistants have escalated the need for efficient and effective techniques for adapting compressed videos to better suit the different capabilities, constraints, and requirements of various transmission networks, applications, and end users. For instance, Universal Multimedia Access (UMA) advocates the provision and adaptation of the same multimedia content for different networks, terminals, and user preferences.

Video adaptation is an emerging field that offers a rich body of knowledge and techniques for handling the huge variation of resource constraints (e.g., bandwidth, display capability, processing speed, and power consumption) and the large diversity of user tasks in pervasive media applications. Considerable amounts of research and development activities in industry and academia have been devoted to answering the many challenges in making better use of video content across systems and applications of various kinds.

Video adaptation may apply to individual or multiple video streams and may call for different means depending on the objectives and requirements of adaptation. Transcoding, transmoding (cross-modality transcoding), scalable content representation, content abstraction and summarization are popular means for video adaptation. In addition, video content analysis and understanding, including low-level feature analysis and high-level semantics understanding, play an important role in video adaptation as essential video content can be better preserved.

The aim of this special issue is to present state-of-the-art developments in this flourishing and important research field. Contributions in theoretical study, architecture design, performance analysis, complexity reduction, and real-world applications are all welcome.

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

- Heterogeneous video transcoding
- Scalable video coding
- Dynamic bitstream switching for video adaptation

- Signal, structural, and semantic-level video adaptation
- Content analysis and understanding for video adaptation
- Video summarization and abstraction
- Copyright protection for video adaptation
- Crossmedia techniques for video adaptation
- Testing, field trials, and applications of video adaptation services
- International standard activities for video adaptation

Authors should follow the EURASIP JASP manuscript format described 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.mstracking.com/asp/>, according to the following timetable:

Manuscript Due	September 1, 2006
Acceptance Notification	January 1, 2007
Final Manuscript Due	April 1, 2007
Publication Date	3rd Quarter 2007

GUEST EDITORS:

Chia-Wen Lin, Department of Computer Science and Information Engineering, National Chung Cheng University, Chiayi 621, Taiwan; cwlin@cs.ccu.edu.tw

Yap-Peng Tan, School of Electrical and Electronic Engineering, Nanyang Technological University, Nanyang Avenue, Singapore 639798, Singapore; eyptan@ntu.edu.sg

Ming-Ting Sun, Department of Electrical Engineering, University of Washington, Seattle, WA 98195, USA ; sun@ee.washington.edu

Alex Kot, School of Electrical and Electronic Engineering, Nanyang Technological University, Nanyang Avenue, Singapore 639798, Singapore; eackot@ntu.edu.sg



Anthony Vetro, Mitsubishi Electric Research Laboratories,
201 Broadway, 8th Floor, Cambridge, MA 02138, USA;
avetro@merl.com

Special Issue on

Transforming Signal Processing Applications into Parallel Implementations

Call for Papers

There is an increasing need to develop efficient “system-level” models, methods, and tools to support designers to quickly transform signal processing application specification to heterogeneous hardware and software architectures such as arrays of DSPs, heterogeneous platforms involving microprocessors, DSPs and FPGAs, and other evolving multiprocessor SoC architectures. Typically, the design process involves aspects of application and architecture modeling as well as transformations to translate the application models to architecture models for subsequent performance analysis and design space exploration. Accurate predictions are indispensable because next generation signal processing applications, for example, audio, video, and array signal processing impose high throughput, real-time and energy constraints that can no longer be served by a single DSP.

There are a number of key issues in transforming application models into parallel implementations that are not addressed in current approaches. These are engineering the application specification, transforming application specification, or representation of the architecture specification as well as communication models such as data transfer and synchronization primitives in both models.

The purpose of this call for papers is to address approaches that include application transformations in the performance, analysis, and design space exploration efforts when taking signal processing applications to concurrent and parallel implementations. The Guest Editors are soliciting contributions in joint application and architecture space exploration that outperform the current architecture-only design space exploration methods and tools.

Topics of interest for this special issue include but are not limited to:

- modeling applications in terms of (abstract) control-dataflow graph, dataflow graph, and process network models of computation (MoC)
- transforming application models or algorithmic engineering
- transforming application MoCs to architecture MoCs
- joint application and architecture space exploration

- joint application and architecture performance analysis
- extending the concept of algorithmic engineering to architecture engineering
- design cases and applications mapped on multiprocessor, homogeneous, or heterogeneous SOCs, showing joint optimization of application and architecture

Authors should follow the EURASIP JASP manuscript format described 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.mstracking.com/asp/>, according to the following timetable:

Manuscript Due	September 1, 2006
Acceptance Notification	January 1, 2007
Final Manuscript Due	April 1, 2007
Publication Date	3rd Quarter 2007

GUEST EDITORS:

F. Depretre, Leiden Embedded Research Center, Leiden University, Niels Bohrweg 1, 2333 CA Leiden, The Netherlands; edd@liacs.nl

Roger Woods, School of Electrical and Electronic Engineering, Queens University of Belfast, Ashby Building, Stranmillis Road, Belfast, BT9 5AH, UK; r.woods@qub.ac.uk

Ingrid Verbauwhede, Katholieke Universiteit Leuven, ESAT-COSIC, Kasteelpark Arenberg 10, 3001 Leuven, Belgium; Ingrid.verbauwhede@esat.kuleuven.be

Erwin de Kock, Philips Research, High Tech Campus 31, 5656 AE Eindhoven, The Netherlands; erwin.de.kock@philips.com



NEWS RELEASE

Nominations Invited for the Institute of Acoustics 2006 A B Wood Medal

The Institute of Acoustics, the UK's leading professional body for those working in acoustics, noise and vibration, is inviting nominations for its prestigious A B Wood Medal for the year 2006.

The A B Wood Medal and prize is presented to an individual, usually under the age of 35, for distinguished contributions to the application of underwater acoustics. The award is made annually, in even numbered years to a person from Europe and in odd numbered years to someone from the USA/Canada. The 2005 Medal was awarded to Dr A Thode from the USA for his innovative, interdisciplinary research in ocean and marine mammal acoustics.

Nominations should consist of the candidate's CV, clearly identifying peer reviewed publications, and a letter of endorsement from the nominator identifying the contribution the candidate has made to underwater acoustics. In addition, there should be a further reference from a person involved in underwater acoustics and not closely associated with the candidate. Nominees should be citizens of a European Union country for the 2006 Medal. Nominations should be marked confidential and addressed to the President of the Institute of Acoustics at 77A St Peter's Street, St. Albans, Herts, AL1 3BN. The deadline for receipt of nominations is **15 October 2005**.

Dr Tony Jones, President of the Institute of Acoustics, comments, "A B Wood was a modest man who took delight in helping his younger colleagues. It is therefore appropriate that this prestigious award should be designed to recognise the contributions of young acousticians."

Further information and an nomination form
can be found on the Institute's website at
www.ioa.org.uk.

A B Wood

Albert Beaumont Wood was born in Yorkshire in 1890 and graduated from Manchester University in 1912. He became one of the first two research scientists at the Admiralty to

work on antisubmarine defence. He designed the first directional hydrophone and was well known for the many contributions he made to the science of underwater acoustics and for the help he gave to younger colleagues. The medal was instituted after his death by his many friends on both sides of the Atlantic and was administered by the Institute of Physics until the formation of the Institute of Acoustics in 1974.

PRESS CONTACT

Judy Edrich

Publicity & Information Manager, Institute of Acoustics
Tel: 01727 848195; E-mail: judy.edrich@ioa.org.uk

EDITORS NOTES

The Institute of Acoustics is the UK's professional body for those working in acoustics, noise and vibration. It was formed in 1974 from the amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society (a daughter society of the Institution of Mechanical Engineers). The Institute of Acoustics is a nominated body of the Engineering Council, offering registration at Chartered and Incorporated Engineer levels.

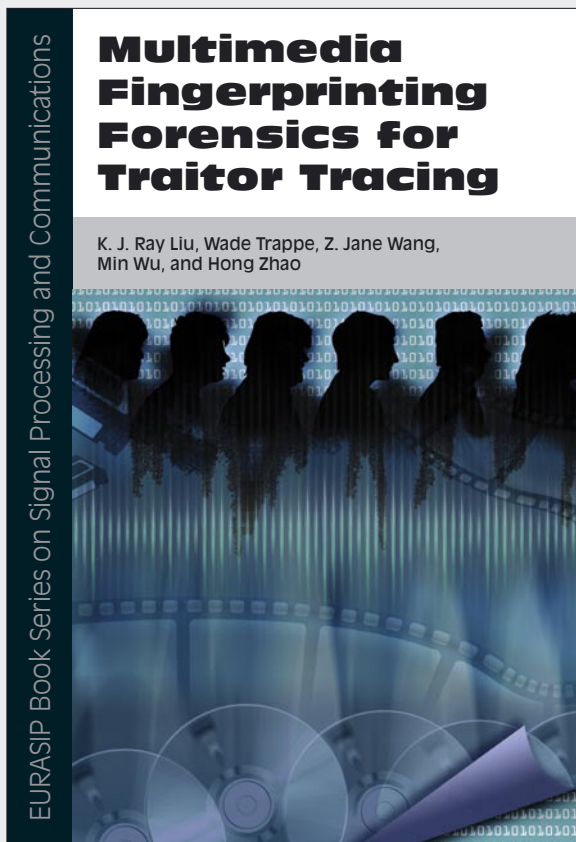
The Institute has some 2500 members from a rich diversity of backgrounds, with engineers, scientists, educators, lawyers, occupational hygienists, architects and environmental health officers among their number. This multidisciplinary culture provides a productive environment for cross-fertilisation of ideas and initiatives. The range of interests of members within the world of acoustics is equally wide, embracing such aspects as aerodynamics, architectural acoustics, building acoustics, electroacoustics, engineering dynamics, noise and vibration, hearing, speech, underwater acoustics, together with a variety of environmental aspects. The lively nature of the Institute is demonstrated by the breadth of its learned society programmes.

For more information please visit our site at
www.ioa.org.uk.

EURASIP Book Series on SP&C, Volume 4, ISBN 977-5945-18-6

MULTIMEDIA FINGERPRINTING FORENSICS FOR TRAITOR TRACING

Edited by: K. J. Ray Liu, Wade Trappe, Z. Jane Wang, Min Wu, and Hong Zhao



The popularity of multimedia content has led to the widespread distribution and consumption of digital multimedia data. As a result of the relative ease with which individuals may now alter and repackage digital content, ensuring that media content is employed by authorized users for its intended purpose is becoming an issue of eminent importance to both governmental security and commercial applications. Digital fingerprinting is a class of multimedia forensic technologies to track and identify entities involved in the illegal manipulation and unauthorized usage of multimedia content, thereby protecting the sensitive nature of multimedia data as well as its commercial value after the content has been delivered to a recipient.

“Multimedia Fingerprinting Forensics for Traitor Tracing” covers the essential aspects of research in this emerging technology, and explains the latest development in this field. It describes the framework of multimedia fingerprinting, discusses the challenges that may be faced when enforcing usage policies, and investigates the design of fingerprints that cope with new families of multiuser attacks that may be mounted against media fingerprints. The discussion provided in the book highlights challenging problems as well as future trends in this research field, providing readers with a broader view of the evolution of the young field of multimedia forensics.

Topics and features:

Comprehensive coverage of digital watermarking and fingerprinting in multimedia forensics for a number of media types; Detailed discussion on challenges in multimedia fingerprinting and analysis of effective multiuser collusion attacks on digital fingerprinting; Thorough

investigation of fingerprint design and performance analysis for addressing different application concerns arising in multimedia fingerprinting; Well-organized explanation of problems and solutions, such as order-statistics-based nonlinear collusion attacks, efficient detection and identification of colluders, group-oriented fingerprint design, and anticollusion codes for multimedia fingerprinting.

For more information and online orders, please visit <http://www.hindawi.com/books/spc/volume-4/>
For any inquiries on how to order this title, please contact books.orders@hindawi.com

The EURASIP Book Series on Signal Processing and Communications publishes monographs, edited volumes, and textbooks on Signal Processing and Communications. For more information about the series, please visit <http://hindawi.com/books/spc/about.html>



11th International Congress of Human Genetics

August 6-10, 2006
Brisbane Australia



International Federation of
Human Genetics Societies

Register now @ www.ichg2006.com

genzyme
Therapeutics

gsk
GlaxoSmithKline


genetic technologies

**Queensland
Events**

LifeScientist

Congress Secretariat:

ICHG 2006 Congress Secretariat
c/- ICMS Pty Ltd,
PO Box 3496, South Brisbane Queensland 4101, Australia
Phone: +61 7 3844 1138 Fax: +61 7 3844 0909
Email: ichg2006@icms.com.au

www.ichg2006.com





CALL FOR PAPERS

8th ACM Multimedia Security Workshop

September 26–27, 2006



**ACM Multimedia and Security
Workshop**
September 26–27, 2006

Organizing Committee

General Chair

Sviatoslav Voloshynovskiy

University of Geneva, Switzerland

Local Arrangement Chair and Treasurer

Oleksiy Koval

University of Geneva, Switzerland

Program Chairs

Jana Dittmann

*Otto-von-Guericke University Magdeburg,
Germany*

Jessica Fridrich

SUNY Binghamton, USA

ACM SIGMM Chair

Ramesh Jain

Georgia Tech, USA

Program Committee

Mauro Barni

Ahmet M. Eskicioglu

Teddy Furon

Mariam Haroutunian

Ton Kalker

Stefan Katzenbeisser

Deepa Kundur

Inald Lagendijk

Heung-Kyo Lee

Nasir Memon

M. Kivanc Mihcak

Pierre Moulin

Fernando Perez-Gonzalez

Thierry Pun

Claus Viehauer

Min Wu

Time Schedule

Submissions start: February 1

Submissions end: April 20

Authors notified: July 20

Camera ready by: August 10

Workshop: September 26–27, 2006

The objective of this 8th ACM Multimedia and Security Workshop is to identify the key issues to be addressed by future research in the areas of media manipulation recognition, media data authentication, and detection of hidden communication channels. We expect the workshop to help motivate this research and to establish fruitful relationships with the key actors from academia, industry, and government in the US and European and Asian countries. It will consist of invited papers, full papers, short papers, and possibly a rump or a panel session. This event continues a successful series of workshops started in 1998.

OBJECTIVES

- Discussion of emerging technologies in digital multi-media authentication, identification, fingerprinting, and steganalysis
- Identification of key research problems with the biggest impact on specified deficiencies in the field of secure multimedia distribution
- Formulation of target applications of identified technologies (in both the commercial and military sectors)
- Discussion of legal issues connected to multimedia security, digital watermarking, and steganography

SCOPE AND PAPERS

Papers should address theoretical and practical issues of multimedia watermarking and steganography. We will consider both theoretical papers dealing with fundamental issues and application oriented contributions (software and hardware demos are highly encouraged). Topics include but are not limited to:

- Robust watermarking of multimedia
- Authentication of multimedia
- Informational-theoretical aspects of data hiding
- Steganography and steganalysis
- Forensic analysis of digital multimedia
- Practical systems with aspects of data hiding
- Watermarking quality evaluation and benchmarks
- New applications, security issues, and legal aspects
- Data hiding applications in biometrics: document security and person authentication

In particular, the call for papers includes request for full papers with high degree of innovations as well as short papers with interesting improvements of existing art or new ideas and research directions. Full papers should be 6–12 pages long, short papers 4–6 pages long (ACM format <http://www.acm.org/sigmm/>). Accepted papers will be published in ACM workshop proceedings.

Submission Deadline April 20, 2006

Authors are invited to submit, by email, full papers or short papers by indicating the type of the paper (full/short) in electronic format (PDF or PostScript) to <https://msrcmt.research.microsoft.com/ACM2006>. Create a new user account, login, and follow the submission instructions.

4th International Workshop on

Adaptive Multimedia Retrieval

4th International Workshop on Adaptive Multimedia Retrieval
July 27-28, 2006 - University of Geneva, Switzerland



<http://vipr.unige.ch/amr2006>

The workshop focuses especially on researchers that are working on feature extraction techniques for multimedia, computer linguistic approaches, (dynamic) data analysis methods, and visualization methods as well as user interface design. Therefore, contributions to the workshop should focus on, but are not limited to:

- Multimedia retrieval systems (for text, image, audio, video and mixed-media)
- Theoretical foundations of multimedia retrieval and mining
- Intelligent multimedia data modelling, indexing and structure extraction
- Adaptive Hypermedia and web based systems
- Metadata for multimedia retrieval
- Multimedia and multi-modal mining
- Semantic content analysis for multimedia
- Semantic web and ontologies
- Adaptive query languages
- Similarity measures (especially user adaptive measures)
- User and preference modelling (including feedback models)
- Methods for adaptive data visualization and user interfaces

General Chair:

- **Stéphane Marchand-Maillet**
University of Geneva

Program Chairs:

- **Eric Bruno**
University of Geneva
- **Andreas Nürnberger**
University of Magdeburg
- **Marcin Detyniecki**
LIP6, CNRS Paris

Local Chair:

- **Nicolas Moënné-Loccoz**
University of Geneva

Deadline for paper submission:

Notification of acceptance/rejection:
Deadline for final paper submission:
Workshop starts:

March 17, 2006

May 19, 2006
June 2, 2006
July 27, 2006

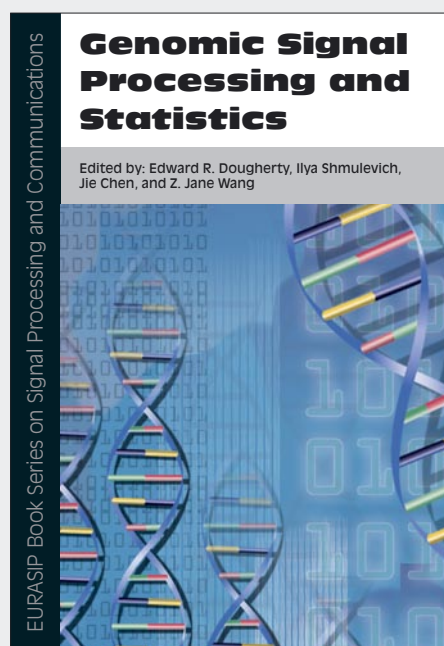
Submissions should be formatted according to **Springer LNCS style**.
Papers should have about 10 pages but must not exceed **15 pages**.

Support:



GENOMIC SIGNAL PROCESSING AND STATISTICS

Edited by: Edward R. Dougherty, Ilya Shmulevich, Jie Chen, and Z. Jane Wang



Recent advances in genomic studies have stimulated synergetic research and development in many cross-disciplinary areas. Genomic data, especially the recent large-scale microarray gene expression data, represents enormous challenges for signal processing and statistics in processing these vast data to reveal the complex biological functionality. This perspective naturally leads to a new field, genomic signal processing (GSP), which studies the processing of genomic signals by integrating the theory of signal processing and statistics. Written by an international, interdisciplinary team of authors, this invaluable edited volume is accessible to students just entering this emergent field, and to researchers, both in academia and industry, in the fields of molecular biology, engineering, statistics, and signal processing. The book provides tutorial-level overviews and addresses the specific needs of genomic signal processing students and researchers as a reference book.

The book aims to address current genomic challenges by exploiting potential synergies between genomics, signal processing, and statistics, with special emphasis on signal processing and statistical tools for structural and functional understanding of genomic data. The book is partitioned into three parts. In part I, a brief history of genomic research and a background introduction from both biological and signal-processing/statistical perspectives are provided so that readers can easily follow the material presented in the rest of the book. In part II, overviews of state-of-the-art techniques are provided. We start with a chapter on sequence analysis, and follow with chapters on feature selection, clustering, and classification of microarray data. The next three chapters discuss the modeling, analysis, and simulation of biological regulatory networks, especially gene regulatory networks based on Boolean and Bayesian approaches. The next two chapters treat visualization and compression of gene data, and supercomputer implementation of genomic signal processing systems. Part II concludes with two chapters on systems biology and medical implications of genomic research. Finally, part III discusses the future trends in genomic signal processing and statistics research.

For more information and online orders please visit: <http://www.hindawi.com/books/spc/volume-2/>
For any inquiries on how to order this title please contact books.orders@hindawi.com

The EURASIP Book Series on Signal Processing and Communications publishes monographs, edited volumes, and textbooks on Signal Processing and Communications. For more information about the series please visit: <http://hindawi.com/books/spc/about.html>