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Session 1 - Systems Engineering and Intelligent Systems
Session 2 - Advances in Control Theory and Control Engineering
Session 3 - Optimisation and Management of Complex Systems and Networked Systems
Session 4 - Intelligent Vehicles and Mobile Systems
Session 5 - Robotics and Motion Systems

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Ch. Ament

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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A. Swerdlow / T. Machmer / K. Kroschel / A. Laubenheimer / S. Richter

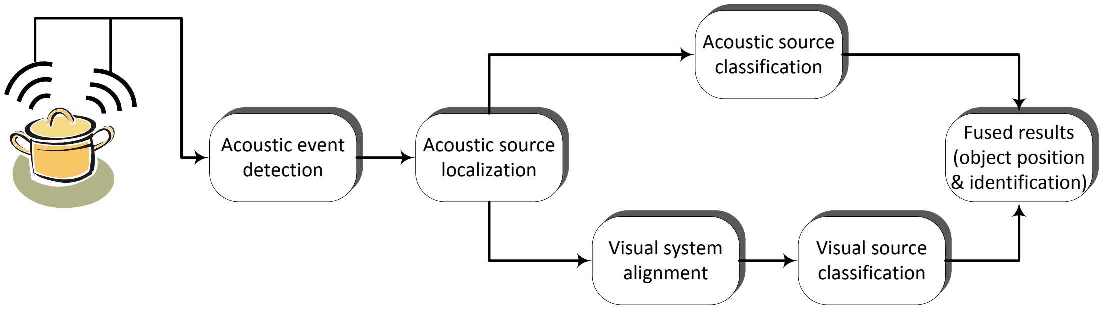
Opto-acoustical Scene Analysis for a Humanoid Robot

INTRODUCTION

The goal of the paper is to add the ability of a human to scan a scene acoustically and optically to a humanoid robot whose head is equipped with a visual system and a microphone array. The skill to scan and analyze a scene is an urgent precondition for a robot in order to cooperate with a human.

A typical peculiarity of the auditory system is that it senses its environment almost omnidirectional, whereas the visual system is only focused on a section of the environmental scene.

Figure 1: Block diagram of the opto-acoustical evaluation of the environment.



The human robot extracts the direction of acoustic events by the use of the acoustic sensory system. This is realized by a microphone array consisting of four microphones which are positioned at the ears, the forehead and the chin of the robot. Since the distance information which might be gained by analysis of the acoustic signals, is too imprecise, it is not used. Instead, the head is moved into the detected direction and the optical signal can be picked up by the visual system. Thus, by fusing acoustical and optical information, the coordinates of the event can be determined and the object identified by evaluating the acoustical and optical information. For exemplification, such an opto-acoustical evaluation of the environment is shown in Figure 1.

THE AUDIO SYSTEM

Acoustic Sound Source Localization

The technique of choice in most passive acoustic sound source localization systems using a microphone array is a two-step procedure. First, the time difference of arrival (TDOA) of sound signals in a pair of spatially separated microphones is estimated. Then the estimated TDOA is used in combination with the known microphone array geometry for the localization of the sound source in the environment. The most popular approach for determining the TDOAs is the Generalized Cross Correlation (GCC) method [1, 2], which was also used for this work.

Acoustic Sound Source Identification

In addition to the acoustic localization, the identification of localized persons and ambient sound sources is another major part of the acoustic scene analysis. The interaction between man and machine gains more and more importance. Typical applications are for instance the identification of speakers by humanoid robots or the identification of passengers within a car to adjust position and speaker specific properties.

We use the Mel Frequency Cepstral Coefficients (MFCC) as spectral features in combination with the Gaussian Mixture Model (GMM) to identify speakers [3, 4]. For the classification of ambient sound sources we present another approach. The sampled instationary signal $s(k)$ requires a short time spectral analysis based on segments of 16 ms each and an overlap by the factor 0.5, within which the signal is assumed to be stationary. Like speaker identification, these sources are usually instationary. In contrary to the speaker identification, data processing takes place in the time domain.

In order to be able to detect an acoustic event, the energy within a frame is calculated for each frame. The energy $en(\kappa)$ in the frame κ of length $L = 256$ is defined as $en(\kappa) = \frac{1}{L} \cdot \sum_{k=n_\kappa}^{n_\kappa+L-1} s^2(k)$.

For the classification of acoustic events, autoregressive (AR) models are used. The estimation of the detected sound class is done in the following way:

$$\hat{K}(\kappa) = \operatorname*{arg\,min}_{c=1,\ldots,N_K} \left[\min_{j=1,\ldots,P^{(c)}} \sum_{i=(\kappa-1)\cdot L}^{\kappa\cdot L-1} \left(s(k) - \sum_{\ell=1}^{M} p_{j,\ell}^{(c)} \cdot s(k-\ell) \right)^2 \right].$$

For each sound class $K^{(c)}$ with $c=1,\ldots,N_K$ to be recognized, one or more AR models $\mathbf{p}_j^{(c)}$ with $j=1,\ldots,P^{(c)}$ of order M are appointed. For every sound class $K^{(c)}$ and the associated prediction coefficients $\mathbf{p}_j^{(c)}$, the prediction error $e_j^{(c)}(k)$ for the sample $s(k)$ is determined. To be able to determine which model fits the currently handled frame κ at best, the energy of the prediction error signal is calculated for every sound class $K^{(c)}$ and the associated models $\mathbf{p}_j^{(c)}$ over the entire frame κ. Subsequently, the value of the prediction error of the model $\mathbf{p}_j^{(c)}$ and the sound class $K^{(c)}$ which represents the frame κ at best is calculated by finding the minimal prediction error. Finally, the frame κ is assigned to the estimated sound source class $\hat{K}$ by calculating the index of the class with the lowest prediction error.

THE VISUAL SYSTEM

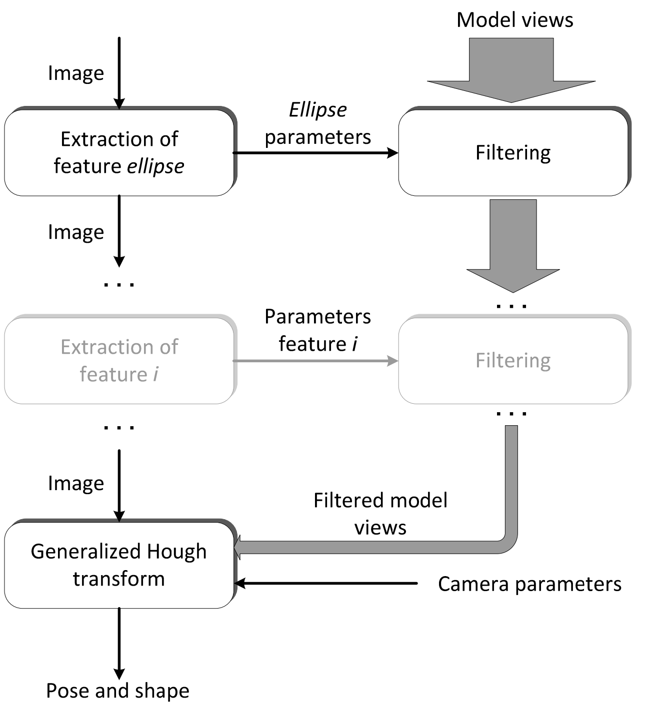
For pose and shape estimation, we have developed an appearance based method. Like [5] und [6], we use different model views to calculate the parameters of the object's pose. However, instead of using a 2-D-similarity transformation, we apply a chain of different filtering steps to obtain the best fitting model view.

The generation of virtual views of the objects, which are to be detected, is accomplished offline. Therefore CAD models are used. A virtual camera is placed on the surface of a sphere surrounding the CAD model of a given object. By changing radius r, azimuth and polar angels θ and ϕ, respectively, the model views are generated. By using deformable models, based on [7], we can not only detect static objects, but we are also able to deal with objects with different shapes. Figure 2 shows some example model views created for the object *jar* that we have used for our experiments.

Figure 2: Example model views for the object *jar.*

In order to provide an accurate object pose, an adequate large number of model views is required. To obtain the model view which fits best to the object in the camera image, several steps of filtering are applied to the set of model views. For this purpose features, for instance ellipses, edge segments or junctions are extracted in both the model view images and the camera image. By calculating a distance vector between these features in the model view images and the camera image, the most likely model views to fit the camera image's object are obtained and at each step the number of model views is reduced. Using efficient algorithms for feature extraction, the time needed for each step can be kept low.

Figure 3: Process of the optical pose and shape estimation.



The last step we apply is an extended form of the generalized Hough transform [8]. The model views passing all previous filters are processed and the one with the best fit to the camera image's object is obtained. Using this model view and its position in the camera image, which is provided by the generalized Hough transform, the final object pose can be calculated. Figure 3 illustrates the process of the optical pose and shape estimation.

EXPERIMENTAL SETUP AND SELECTED RESULTS

For data recording, omni-directional electret condenser microphones in combination with a colour camera (resolution 1392 x 1040 pixels) were used. Since in the project described in this paper a typical scene from a kitchen is sensed, real experiments were carried out in a test environment. For both, the acoustic and the optical analysis, we used jars with different shapes for our experiments. Additionally, each detection system was tested on further objects which are characteristic for a kitchen environment.

For the acoustic analysis, various kitchen appliances[1] in combination with two untrained sound sources[2] were used. The percentage of correct frame classifications and the required number of AR models of order 16 for each ambient sound source state are summarized in Table 1; the standard deviation is given in brackets.

---

[1] **KC(P)**: kitchen clock (programming), **KC(E)**: kitchen clock (expiration), **CG(A)**: coffee grinder (activity), **T(D)**: toaster (down), **T(U)**: toaster (up), **TP(R)**: telephone (ringing), **J(B)**: jar (boiling)

[2] **US(S)**: untrained source (speech), **US(KN)**: untrained source (knocking noise)

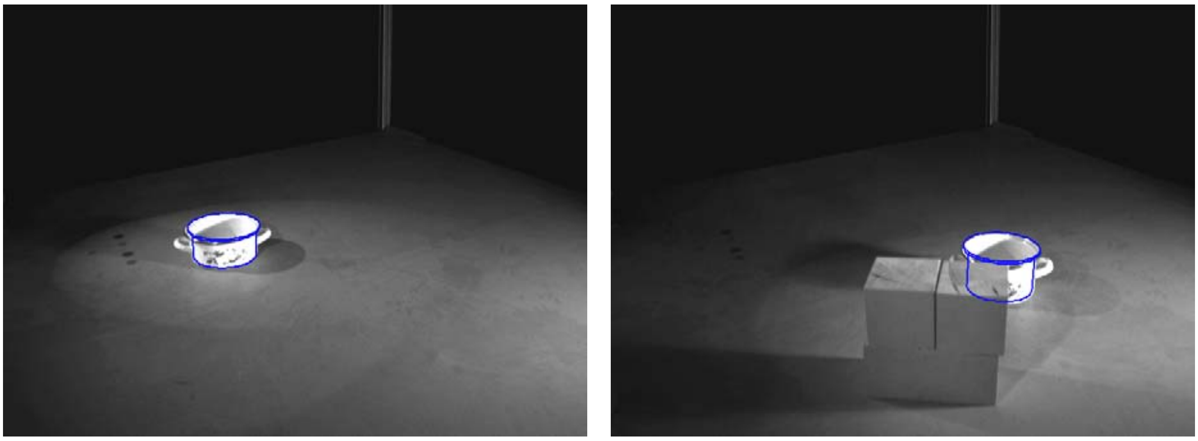
Table 1: Percentage results of the frame based classification with AR models of order 16 for kitchen appliances.

Sound class\AR model	KC(P)	KC(E)	CG(A)	T(D)	T(U)	T(R)	J(B)
KC(P)	**98.10 (1.95)**	1.90 (1.95)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
KC(E)	1.15 (0.26)	**98.85 (0.26)**	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
CG(A)	1.31 (0.41)	0.00 (0.00)	**80.24 (2.33)**	12.99 (1.68)	4.99 (1.17)	0.48 (0.30)	0.00 (0.00)
T(D)	1.03 (0.09)	0.00 (0.00)	2.53 (1.10)	**84.55 (3.37)**	11.84 (3.42)	0.04 (0.09)	0.00 (0.00)
T(U)	1.07 (0.01)	0.00 (0.00)	0.40 (0.50)	11.52 (3.01)	**87.01 (3.14)**	0.00 (0.00)	0.00 (0.00)
TP(R)	1.03 (0.09)	0.00 (0.00)	1.50 (0.36)	0.32 (0.33)	0.12 (0.18)	**97.03 (0.52)**	0.00 (0.00)
J(B)	0.99 (0.00)	0.00 (0.00)	0.95 (0.66)	8.12 (2.20)	1.43 (0.55)	0.00 (0.00)	**88.51 (1.93)**
US(S)	3.33 (0.77)	0.00 (0.00)	81.03 (3.90)	4.00 (1.53)	3.09 (0.82)	8.16 (3.32)	0.40 (0.34)
US(KN)	1.07 (0.18)	0.08 (0.11)	36.87 (6.30)	44.24 (5.52)	11.64 (1.40)	6.10 (1.69)	0.00 (0.00)
Average number of needed AR models	**5.12**	**5.68**	**16.36**	**17.48**	**17.40**	**15.20**	**20.04**

As can be seen, the classification with AR models is a multiple detection issue. This is the reason why also untrained sound sources (speech, knocking noise) are always classified. To avoid this deficiency, frames can be aggregated into blocks of defined size. A trade-off has to be made between a high percentage of correct classification results and a high number of estimates which is crucial for the continuous real-time classification. The entire acoustic event within the actual block matches the sound source class, which prevails in this block. This approach increases the detection rate to nearly 100%. Additionally, blocks can be labelled as invalid (rejected) in case that less than a defined percentage of frames within one block classify the same sound class.

For the optical analysis, we used several kitchen objects like cups, bowls, dishes, and the above-mentioned jars. Figure 4 shows two different-sized jars. By means of the calculated pose and shape parameters, a CAD model of the jar is projected into the respective camera image. As one can see, the presented method is able to detect even partially occluded objects.

Figure 4: Results of the optical pose and shape detection.



CONCLUSION

Fusing the acoustical and optical long-term information leads to what we call an opto-acoustical map which can be provided to the humanoid robot and therewith enhances the robots environment analysis capabilities, even under bad illumination conditions and in acoustically challenging environments.

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