06311 Executive Summary

Sensor Data and Information Fusion in Computer Vision and Medicine
— Dagstuhl Seminar —

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1 More Than the Sum of Its Parts

Today many technical systems are equipped with multiple sensors and information sources, like cameras, ultrasound sensors or web data bases. It is no problem to generate an exorbitantly large amount of data, but it is mostly unsolved how to take advantage of the expectation that the collected data provide more information than the sum of its parts. The design and analysis of algorithms for sensor data and information acquisition and fusion as well as the usage in a differentiated application field was the major focus of the Seminar held in the International Conference and Research Center (IBFI), Schloss Dagstuhl. 24 researchers, practitioners, and application experts from different areas met to summarize the current state-of-the-art technology in data and information fusion, to discuss current research problems in fusion, and to envision future demands of this challenging research field. The considered application scenarios for data and information fusion were in the fields of computer vision and medicine.

2 Applications of Sensor Data and Information Fusion

2.1 Computer Vision

The research field of computer vision deals with the problem of designing algorithms and building systems that gain information from images or multi-dimensional data. Typical examples are the tracking objects, the estimation of 3–D structure and motion, the recognition of objects or the analysis of complex scenes. In the seminar we studied two major tasks of fusion:

1. Strategies for the acquisition of images and data to solve individual computer vision tasks in an optimal manner, and

2. Efficient algorithms for image data and information fusion to solve computer vision and robotics problems reliably.

The fusion of statistical information extracted from images is applied to object tracking, multiple views and viewpoint planning to support active object recognition with robots. Multimodal sensor data allow for the implementation of an attention system for robots and advanced driver assistance systems rely on sensor data fusion.

Driver assistance systems, for instance, provide options like lane departure warning adaptive cruise control units. Multiple sensors are required to collect all the data to perceive the environment around the car. The fusion algorithms for this specific application underlay important constraints: It has to guarantee the demanded high degree of reliabilty and to fulfill the strong cost requirements of the automobile industry.

2.2   Medicine

Medical imaging is an emerging field which has experienced recently a tremendous reduction of innovation cycles. Progress and advances in medical imaging have an immediate impact on commericial products and clinical practice. Today various imaging modalities with completely different capabilites are available for diagnosis, intervention, surgery, or monitoring. Each modality like X-ray, computerized tomography, magnetic resonance imaging or ultrasound has its own advantage. In multi-modal image registration, images of different modalities are transformed into a single coordinate system such that an overlay fading of the images is possible. Physicians get simultaneous access to the patient's image data and no mental combination of various information sources is required anymore. Today industry provides combined, i.e. hybrid systems like SPECT/CT–, PET/CT–, or PET/MR–scanners to allow for the registration of functional and morphologic images. Software-based image registration is still considered unsolved and is an important basic research task in the field of medical image processing. The mathematical modeling and judgment of non-rigid deformations, the definition of proper similarity measures between images acquired by different modalities, the treatment of different image dimensions and the incorporation of prior knowledge are considered to be the major scientific challenges.

3   Methods

Image registration and data fusion can be considered as an optimization task: a proper objective function is defined, and the the fusion task is solved by the optimization of the objective function. This includes both classification and regression problems.

In image registration, for instance, the objective function is defined through distances of assigned image intensities or matched point features. Within the

optimization process the transformation parameters are estimated that minimize the objective function. The registration problem based on point correspondences can be considered as a mixed integer optimization problem. Intensity based image registration requires the optimization of an objective function that measures the similarity of intensities of assigned image grid points. Commonly variational approaches are used as well as gradient descent methods. In the seminar it was also shown that the variational formulation can be interpreted in the context of optimal control of partial differential equations. Other contributions have demonstrated that registration can be done in an unified framework with image pre-processing like intensity correction, image enhancement, and segmentation. Prior knowledge for image registration can be generated by hybrid scanners or manually registered data sets. By the incorporation of specific statistically motivated regularization terms, the objective function can take account for priors. The diagnosis of incomplete multimodal image data makes use of priors, too. In the seminar novel statistical learning methods for the analysis incomplete data as well as for the acquisition of priors were discussed.

Statistical approaches contribute to advances in decision making and classification in the presence of multiple information sources. The Bayesian theory of designing multiple expert systems provides a formalism for the treatment of sensor data fusion in pattern recognition and opens up new dimensions in classification theory. This technology can be applied to standard pattern recognition problems as well as applications like driver assistance, object tracking or robot attention control.

4 Conclusions

Computer vision problems are traditionally motivated by robotics and surveillance applications. Most medical image analysis problems come from the application fields medicine and biology. Though no less important, the information fusion problems posed by the robotics community tend to be more related to basic research than those arising from medicine. As they are typically dynamic in nature, must work quickly, and must effectively deal with rapidly changing and unknown environments. By comparison, the majority of information fusion problems in medicine and biology are static and operate under more controlled conditions. Not surprisingly, techniques to perform information fusion have evolved differently in these communities with minor to no overlap.

In an inspiring environment the seminar brought together members of both communities and initialized scientific discussions that yield hope for the huge potential of synergies.