NEW MACHINE VISION APPLICATIONS IN GERMANY

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ABSTRACT

The availability of robust sensing devices, powerful image processing hardware and advanced system design has increased the use of computer vision methods considerably. Image analysis methods based on static 2D binary–, graylevel–, and color images have become standard sensors for various applications in the biomedical field, the printing industry, industrial automation, navigation, remote sensing, office automation, etc.

This paper reports about new machine vision applications in Germany resulting from the recent progress which has been made in this field. Since the complete spectrum of new machine vision applications cannot be covered we will limit ourselves to systems which are based on TV–like cameras and are primarily used for image analysis. The paper is structured by methodologies of image processing, like 3D Scene Analysis for Quality Control, Image Sequence and Motion Analysis, 3D Modelling, Knowledge Representation, and Human Interface techniques. The progress is illustrated by selected new applications which have recently been observed in this field in connection with products, prototypes, or concepts developed at research institutes and the industry in Germany.

1. INTRODUCTION

Research and development in machine vision is carried out in Germany in numerous institutions in the public and private sector. Especially the large companies of the electrical and optical industry who are suppliers of vision systems and the large users of vision components like the car industry and the machine industry support to a great extent research work in machine vision.

In the public sector there exists a number of research institutions with different designations and different financing models which do research and development in machine vision for various applications. They are partially supported by the federal government or by the states. Finally, research is conducted in the universities.

The universities and the public research institutes concentrate more on fundamental research, whereas the industry concentrates more on applied research. There are several initiatives to support know–how transfer and cooperations between the industry and the public research institutes.

The research is financed on one hand from private resources, mainly from the industry and on the other hand from public resources. A major role in public funding is played by European research programs like ESPRIT, RACE, PROMETHEUS, and others.

Since it is not possible to assess and review all activities which are related to machine vision, we have concentrated on new machine vision applications which are primarily based on an analysis of TV–like camera images. The analysis of other types of sensors, like NMR– and X–ray systems, ultrasound, IR, microwave, etc. will not be considered here. Further we have excluded those areas of image analysis which are not generally been accepted to belong to the field of machine vision like for instance telecommunications, archiving, document processing and photogrammetry.

The paper is structured by methodologies of image processing. The selection of the topics and the points of emphasis have been guided by our own research activities.

2. 3D SCENE ANALYSIS FOR QUALITY CONTROL

In industrial automation an increased request for computer vision systems can be observed. Most vision systems are used for quality monitoring which means sight inspection and completeness check. For the fully automated production the early recognition and removal of defective parts is indispensible on all production levels. For the detection of faulty materials, defective assemblies, manufacturing defects, and shipping damage, the inspection by vision systems is the only solution to achieve an economic automation. It guarantees an improved and documented quality, even if the number of different products and the work–pieces involved are increasing.

A second important component of fully automated production lines is the use of mechanical manipulators. They are mainly used for machine loading, welding, painting, and sealing. As of today mechanical manipulators have not been utilized extensively for assembly. With the increasing importance of medium and small batch production, manipulators have to become more and more flexible to be adaptable to changing tasks. While industrial robots with the requested flexibility are on the market, some of the complementary equipment, like the part feeding equipment which has to be designed in a task and part specific way, still requires a lot of engineering effort and often costs more than the robot. Here machine vision plays an important role in providing the required flexibility.

Most of the vision tasks in industrial automation use 2D vision systems. The inspection of complex surfaces, the action of mechanical manipulators in 3D space, requires a 3D scene analysis. Because of the requirements of industrial automation concerning environmental conditions, reliability, processing speed, cost effectiveness, etc. we observe that increasingly 3D sensors with controlled illumination and passive sensors using model based approaches are used for 3D scene analysis.

2.1 CONTROLLED ILLUMINATION

The principle of shape from shading can be used in connection with an appropriate illumination source to identify slopes of different ascent by the intensity of reflectance. The method permits a fast and reliable analysis of local 3D surface properties.

One area of application is the soldered joint and the assembly inspection of printed boards. Soldering errors like open soldered joints, solder bridges, balled soldered joints and solder meniscus faults can be recognized by this method. In addition mounting errors like missing components, wrongly placed components and twisted components can be detected. Using sequences of directed illumination from different directions, the existence of components like chips, Melfs, SOICs, Flatpacks, PLCCS, etc. and their orientation can be determined. The assessment of different error types requires a complex arrangement of illumination sources and cameras as is shown in Fig.1. Typical inspection times of such systems are 20 s for a single board of 360 x 400 mm containing approximately 40 components.

Structured illumination constitutes another common approach to assess 3D geometry by controlled illumination. The availability of robust projection devices, reliable optical components and the availability of special purpose processors for the data interpretation permits real time operations in an industrial environment and enables new applications of computer vision in industrial automation.

The line–scan–method can be used for edge following under extreme conditions like high temperatures, for instance to direct a precision welding robot with high accuracy.

The projection of gratings and the analysis based on line fringe techniques or moire'–techniques enables the recording of 3D coordinates with very high resolution. The measuring range for TV–camera based systems goes from a few microns up to a few metres at a lateral resolution of up to 1000 x 1000 pixels. The analysis by means of phase shift techniques or fringe analysis allows the acquisition of 3D measuring data in an online mode. Application fields are form and form fidelity tests, surface inspection, 3D contouring, deformation, and vibration analysis. The advantage compared to classic interferometric sytems are the simple and rugged type of construction and easy handling. Examples for application are postoperative control measurements in surgery or dent analysis on car surfaces [1].

Another method for the fast acquisition of depth maps is the coded light approach. A sequence of stripe patterns is projected, where the bit pattern over time for neighbouring stripes corresponds to Gray code encoding. Since each stripe is uniquely identified by its code the depth map can be calculated very fast and efficiently by using triangulation techniques. A map of 512 x 512 pixels at 8 Bit depth resolution can be recorded in two seconds. One area of application is the use as 3D sensing device in robot cells [2].

2.2 UNCONTROLLED ILLUMINATION

The recognition of 3D objects and the determination of their position and orientation in 3D space have a key function in industrial automation processes. The solution of this problem by using for minimization of the processing effort just one monocular image is only possible, when the objects under investigation are known beforehand and when a relevant description of the object, i.e. a model, is made available to the image analysis system. The usual approach is that characteristic primitives of the object are extracted from the image and are compared in their properties and spatial relations to the equivalent primitives of the model description. One problem is to select characteristic primitives which can be recognized reliably and efficiently in an image, independently of the natural fluctuations of the illumination source, small changes of the camera position, and changes in the reflective properties of the object surface. Usually edge type primitives are used, like straight edges, circular edges or the edges of vertices. The second problem is to find a fast and efficient method for the comparison between the structural description of the model and the structural description extracted from the image which is robust enough to tolerate misclassifications of primitives and missing primitives due to partial occlusion. Several systems of this type have been reported [3],[4]. Heuser [4] describes a system which works in 3D, where the structural comparison between image data and model uses the relaxation principle. Fig.KEIN MERKER shows an example of a typical scene, where one of the objects found is overlaid by the 3D model which has been used for the scene analysis. The computation time for recognizing the object and calculating the 6 spatial translation and rotation parameters for this example was less then 20 s on a 68030 processor.

The application of this principle of model based image analysis is still in an experimental stage. It is usually used with restrictions concerning the degree of freedom in spatial position and orientation in order to reduce the processing time further. Applications are found in the recognition of partially ordered workpieces for the loading and unloading of boxes or palettes, support for the flexible control in automated assembly processes, check for correctness and completeness of parts, size measurements of planks in wood processing, etc.

3. IMAGE SEQUENCE AND MOTION ANALYSIS

For the assessment of dynamic processes it is necessary to process image sequences. The computational effort to process for instance 25 images per second of a standard video camera in real– time is significant. Therefore the application of computer vision methods to image sequence analysis is very often connected with the use of special purpose hardware or with the use of parallel computer architectures. Applications frequently deal with the observation and description of time varying scenes or the motion compensated assessment of particular objects.

An example is the on–line evaluation of experiments in pharmaceutical laboratories. The development of medication for the treatment of thrombosis requires in vivo observations of the formation of thrombi in animal experiments. The analysis of sequences is performed in **two steps**. In a **first** initializing **step** the scene has to be **segmented** into tissue, blood vessel and thrombus, where the thrombus is found growing from the inside of the vessel wall into the blood stream. In a second step the thrombus is tracked over the time while the motion of the vessel wall is compensated. Fig.KEIN MERKER shows one frame of the sequence, where the relevant parts of the scene, like the vessel and the thrombus are marked.

The observed objects and the observing camera respective are not still but are moving in a real world scene. Frequently a **motion analysis** is used **in connection with the sequence analysis to compensate f**or the **motion** between the object or scene under investigation and the observation platform before further analyses are applied. There exists a wealth of literature on the problem of 2D– and 3D–motion estimation from image sequences. One example is a survey from Aggarwal [5]. There are various applications for the use of motion analysis in connection with image sequence analysis. Frequently there is the request to read text on moving objects, where the text becomes deteriorated by adverse illumination effects, motion blur, noise, perspective distortions, etc.. In these cases the signal to noise ratio of the text image to be interpreted can be considerably improved by tracking the object and averaging the relevant part containing the text. In Fig.KEIN MERKER we show the improvement of the quality of imprinted text on a metal surface, where 6 images have been taken over time. **Applications** are the reading of **license plates on cars** for the determination of admission permits to parking lots, restricted areas, etc., or the identification of cars on highways for automated traffic measurements and highway control, and the **automated reading of traffic signs** from the driving car [6].

In industrial automation motion detection and motion compensation, i.e. image registration, is widely used in all instances, where a **quality assessment** is made on the basis of a **point to point comparison** between the tested object and a prototype, like multicolor–print check on cigarette packets, screen prints, etc.

A number of applications for image sequence analysis in time varying 3D scenes is investigated in connection with the European research program PROMETHEUS for the improvement of the road traffic of the future. One partial goal of the overall project is to obtain increased driving safety and comfort via environment sensing, interpretation, and intervention. An autonomous test vehicle **VITA** (VIsion Technology Application) has been equipped with sensors, electronically controlled actors for braking, acceleration and steering, processing systems and a copilot computer in order to demonstrate the feasibility and to assess the potentials of computer vision technology[7]. The visual sensors employ **two B/W CCD vide**o cameras **with different focal length**, one for the observation in the near field with small focal length and one for the observaton in the mid– and far field with large focal length. The envisioned system functions are (a) lane keeping, (b) obstacle detection, (c) stop & go driving and (d) lane change support, and (e) intersection control.

The prerequisite for any autonomous driving on a street is the **lane keeping capability**. The 4D problem of observing a time variant 3D scene is treated very efficiently as a control problem, i.e. no efforts have been made to extract explicitly the underlying 3D structure of the scene. The expectations about the dynamical behaviour of the vehicle and relevant objects in the surrounding is modelled by a state space system. On the basis of the relevant features of the surrounding like lane markings or obstacle edges the position of the vehicle position is obtained by recursive estimation techniques. This information is used to guide the vehicle in lateral direction. Figure KEIN MERKER shows a frame of the sequence and indicates that eight areas of interest are used to track the lane markings. The superiority of this approach, at least for well structured scenes like roads, has been demonstrated repeatedly during the last years by driving a 5 ton test vehicle at a speed close to 100km/h on a freeway and up to 60 km/h on an unmarked two–lane country road.

A survey of the previous work is given in [8]. The method has been extended to be used for obstacle detection [9]. If a candidate for an **obstacle** satifies the shape and location criteria the object is tracked and the relative position and speed are determined. The information is used to stop the car or to perform a lane change. A **stop & go function** is used to track the vehicle ahead and to maintain a safe distance. The **vehicle ahead** is automatically recognized by some symmetry measure [10]. The distance to the vehicle and its speed are measured. In the intersection control function the type and the distance of intersections are recognized. The system is based on the fitting of edge information against various versions of internal intersection models.

4. 3D MODELLING

There is an increasing request for obtaining computer graphic models of natural scenes in order to create realistic visual sensations by producing computer animations and three dimensional montage pictures. Applications are

- in the movie and TV industry, for film production, synthetic studio environments,
- in future communication systems and virtual reality applications [11],
- in advertising, instruction and education,
- for the visualization part of various training simulators, like flight– and driving simulators,
- for planning purposes in landscape and city planning, architecture, etc.

Though considerable progress has been made in the past years in computer graphics and 3D visualization techniques it is still not possible to produce with reasonable effort natural looking landscapes, persons, animals, etc.. A solution to the problem is expected from the integration of computer graphics with the analysis of natural scenes by machine vision techniques.

The machine vision approach to 3D modelling is to choose an appropriate parametric description of the 4D scene and to estimate the parameters from a set of spatial and temporal image sequences. Various problems are connected with this task. First, the scene has to be understood, i.e. to be explained by a set of independently moving 3D objects. For each object an appropriate model description has to be chosen. On one hand appropriateness is determined by the type of object, since a human head requires a different parametric description than a car, a tree, a sea surface, or a curtain waving in the wind. On the other hand the use of the model becomes important for the appropriate choice. The adequate model for a house is different, when it is used for viewing from a far distance, for producing the sights from a walk around the house or for a simulated walk into the house. The treatment of many of these problems requires till today human interaction. Automated modelling becomes only feasible, when restrictions about the type of scene and various properties in the scene can be made. Problems in modelling which are still subject to ongoing research are image segmentation, object recognition, motion detection and motion compensation, surface interpolation, treatment of flexible objects, entering of prior knowledge about the objects in the scene and the relations between them, etc.

Some principles which have evolved lately are texture mapping and modelling through analysis by synthesis. Texture mapping [12] exploits the fact that humans can perceive shape only coarsly. Therefore, naturally looking objects can be obtained by using a coarse 3D object shape and modelling the fine structure like the hairs on a human head, the grass on a ground, etc. by projection of an appropriate texture onto the surface.

Analysis by synthesis is a strategy to estimate motion, shape and the surface properties of objects like color and texture simultaneously [13]. The basic idea is that a 3D model of the observed scene is used to predict the views which are obtained from the real camera which observes the real 3D scene. For this purpose a model image sequence is calculated by perspective projection of the dynamic 3D model onto a virtual model camera target. The measurable differences between the real image sequence and the model image sequence are then minimized by recursive adjustment of the model parameters. The set of parameters which minimizes the error criteria together with the parametric model constitutes then the best 3D model for the description of the scene. Since the parameters represent an explicite description of the object shapes, the motion parameters and the surface properties, like textures, an explicite modelling of the scene can be obtained. The approach requires an initial model scene as a first estimate of the scene content which is then modified during the analysis of the image sequences. The construction of the initial model is based on some few selected images of the sequence and requires scene specific knowledge.

These principles have been applied to the modelling of terrain from stereoscopic aerial photos for flight simulators, the assessment of objects under laboratory conditions from multiple views, and to future model based communication systems.

Presently the modelling of complex outdoor street scenes as they are needed for driving simulators, city planning purposes etc., are investigated. The approach is based on the analysis of sequences of stereoscopic image pairs. Starting with conventional stereoscopic correspondence analysis a 3D model scene with 3D surface geometry is generated. Not only the scene geometry but also surface texture is stored within the model. The 3D model permits to detect and correct geometric errors by comparison of synthesized images with real input images through analysis by synthesis techniques. 3D camera motion can be estimated directly from the image sequence to track camera motion and to fuse measurements from different viewpoints thoughout the sequence into a common 3D model scene. First results have been published in [15].

5. KNOWLEDGE REPRESENTATION

An image cannot be analyzed without knowledge about the context in which the image has to be interpreted. The direct comparison of computer vision methods with the performance of the human visual system has for a long time given the impression that the human eye is the better sensor. In reality it is the background knowledge of the human interpreter about the scene and the ease of the use of his knowledge which makes the human visual system superior in its abilities to interprete a scene. For this reason considerable effort has recently been observed to store in a systematic fashion knowledge content about the scene and about the image processing methods in computer vision systems and to make this knowledge available for the image analysis task.

There are various paradigms for image representation. Of particular significance are the paradigms for explicite knowledge representation, because these knowledge content can directly be understood by a human. The use of these paradigms becomes advantageous, when complex systems are developed or when systems have to be updated, or modified, for instance in connection with the extension of a computer vision system to new image analysis tasks. Systems which employ explicite knowledge representation are generally referred to as "knowledge based systems". In the area of knowledge based vision systems a number of activities can today be observed in Germany [16], [17], [18], [19], [20], [21], [22]. One has to differentiate between systems where the knowledge content are related to the scene and systems where the knowledge content are related to the image processing methods. Since the paradigms for explicite knowledge representations like semantic nets and rule based systems cannot be efficiently implemented on the presently available general purpose computers, the applications of these paradigms tend to be found in areas, where the processing time plays a minor role, namely in system configuration [16],[17],[20],[21]. One example is the configuration system CONNY [21] which will be treated in more detail in the following.

The system CONNY has been built to investigate the basic concepts of a self–configuring image analysis system. It permits a complete and fully automated selection of the processing path and the adaptation of the parameters for the low–level part of image analysis, i.e. preprocessing and segmentation.

For the solution of the problem knowledge of a human expert has to be transferred into the knowledge based system about

- known complex and elementary image analysis operators,
- the properties of the operators and the influence of modifications of the parameter values,
- the characterization, respective the interpretation of image processing results,
- the evaluation of the image analysis results in respect to the user specified task, and
- the strategies to configure an image analysis process.

The set of all meaningful sequences of image analysis operators is represented by an operator tree. The declarative knowledge content, like which image processing operators are available, the knowledge content about their parameter values, etc. are represented as data objects. The objects are interconnected by relations.

The objects own methods which can be used to apply procedural knowledge content which are specific for an individual object or a class of objects in an object oriented manner.

The configuration is achieved in three steps. Based on the task specification the configuration system is instantiated. In a second step the user provided reference knowledge, the quality requirements and boundary conditions are used in a direct configuration strategy to reduce the search space for the optimal configuration. The third step is called the adaptation phase. Here an indirect configuration strategy is used by specifying an optimization criterion on the basis of image quality in the test images and using search strategies to optimize the parameter adaptation.

In the adaptation phase for all possible processing paths the parameters are adapted and finally the path exhibiting the best processing results on the test images is selected as the final configuration result. The parameter adaptation requires several adaptation cycles. Each cycle includes the processing of a test image with the sequence of operators under investigation using test settings for the parameter values, an evaluation of the processing result and a modification of the parameter values.

Fig.KEIN MERKER shows an example for the intermediate results produced by the system in the parameter adaptation phase. Each image (except the original iconic input image in the upper left corner) represents one result in the parameter modification–, processing–, and evaluation cycle.

A vision system which uses explicite knowledge representation for knowledge content about the scene under real time conditions is presently being developed [22]. The system is used for the analysis of aerial images and image sequences. The knowledge content about the observed objects and their relations like lanes, highways, bridges, etc., are represented explicitely as rules of a production net. The architecture of the analysis system is based on the blackboard principle. Basic image primitives like line–elements, arcs, circles etc., and their attributes like position, direction, size, quality descriptors, etc. are extracted by standard image analysis methods from the aerial image under investigation and are written onto the blackboard. The relations between the basic primitives and the objects of higher abstraction level (like lanes, bridges, etc.) are expressed as rules of the production net. The different rules are implemented on a number of processors which have parallel access to the blackboard. The rules are used to develop a parse tree by iterative modification of the blackboard content.

In order to speed up the system the blackboard has been realized as associative memory in PLA technology. The size of the memory is presently 144 MByte and it permits entries of about 14,000 Bit length. The bit sequential and word parallel processing permits access times between 100 µs and 10 ms. A realization in ASIC technology is in development and will permit access times of less than 10 µs.

Fig.KEIN MERKER illustrates an application, where a highway bridge has to be recognized from an aerial photo. The basic primitives which are extracted from the image, are line segments which are assembled within the parsing process to structures like long line segments, street patches, parallel street patches, lanes, highways, and bridges. Images like the one in Fig.KEIN MERKER produce initially about 2000 basic primitives and 300 objects of higher abstraction level. Images of lower quality, obscured by noise, may result in up to 30,000 basic primitives. The parsing process for the type of application described here requires about 700 search passes through the memory. When for the implementation of the rules processors are used with an individual processing power of 10 MIPs, an overall analysis time of 50 ms per image can be achieved.

A disadvantage of knowledge based systems is that they are very complex. The maintenance of the systems requires several experts like the knowledge engineer, who has his background in the AI area and is responsible for the system itself and the domain expert, who is an expert in the particular area of application. Knowledge based systems which can learn the knowledge content automatically and directly from an image analysis are still in a very early state of development.

A more convenient method for the automated learning of knowledge content for computer vision systems is provided by the concept of neural nets. Because of the inherent parallel structure very high processing speeds can be obtained. The learning is mostly achieved by iterative local methods on the basis of the presentation of input–output pairs of information. Applications are frequently found in situations where a well defined relation between input and output patterns exists but its parametrical formulation is unknown. There are presently numerous applications in this field to be observed like the sorting of particular types of bottles, the recognition of plant diseases, the evaluation of surface qualities of industrial materials, the segmentation of traffic signs, the correction of lense properties in camera systems, the interpretation of the license plates, etc.. An area of current research in neural net technology is the investigation of more efficient learning procedures under the consideration of more global criteria.

6. HUMAN INTERFACE

In many cases, the acceptance of new computer vision systems is not only determined by its novel and superior processing capabilities but rather by a user friendly inclusion in an existing and well defined working environment. Two examples will be given, one from the preparation phase in the professional printing industry and one from the area of clinical cytology.

6.1 IMAGE ASSEMBLY FOR THE PRINTING INDUSTRY

Specific tasks in the professional repro industry require for a more efficient graphic preparation step prior to the actual printing new high performance image scanning techniques.

The final image is typically composed of objects from several individual images which are usually delivered as color slides. The layout for placing these objects in the final image maybe a scribble or an accurate scaled drawing done by the designer. The key problem is the scanning of the slides with correct zooming and rotation. The enormous amount of data of these images does presently not permit economical solutions for computer based rotation and zooming. Therefore these tasks are achieved by rotated mounting of each slide on the scanner and by appropriate choice of the sampling rate. Mounting the slides and calibrating the scanner constitute time consuming operator controlled processes.

Higher efficiency can be obtained by using a vision based system made possible by a CCD camera with programmable resolution from video size up to 2300×3000 pel. The video size scanning which allows up to 25 scans/s is used for slide positioning by displaying the scanned images on a monitor which also shows the designers layout in a transparent mode. Image rotation is achieved by physically rotating the slide and zooming by camera movements. When image object and layout are matching, the final high resolution scan can be done by choosing the required programmable camera resolution. Frequently additional color measurements are necessary for correction of color grading. Since a low resolution scan with less image data provides the full color information the color measurements can be obtained at high speed in a low resolution prescan.

In addition to a considerable speedup of these standard processing steps the system permits the direct assessment of 3D objects without using intermediate photographic processes.

6.2 SCREENING AND ANALYSIS SYSTEM FOR CYTOLOGICAL SPECIMEN

Due to the large numbers of specimen which have to be investigated every day and due to special quantification requirements implied by the new preparation techniques (immunochemical markers, ploidy estimation techniques) computer supported evaluation systems are applied to an increasing extent, especially in big cytology laboratories and hospitals.

The evaluation can either be supervised and guided by a cytotechnician (interactive or half automatic system) or it can be run completely automatically (automatic system). In both cases it is absolutely necessary, out of legal as well as ethical reasons, that the expert (cytologist, pathologist) who is responsible for the final diagnosis has the possibility to analyze the evaluation results and compare them with his own experience, respectively, with the experience of some other expert.

For that reason a special interface was developed which combines the presentation of the evaluation results with the direct access to an image data base, with the relocation possibility of the original cells via a scanning stage and with the access to different expert opinions in form of trained classifiers [23].

If uncertain borderline cases occur it is often necessary to consult other experts. This can be done via a telecommunication module which enables the exchange of measurement results, cell images, whole cell scenes or even allows the consultant to remote control the microscope and look at the slide parts which may be especially of interest to him.

A cytology evaluation system with the user interface described above was successfully applied in the grading of **borderline lesions of bone tumors** [24] and in the recognition of **early state bladder cancer**. The interface is now integrated in a commercial cytology evaluation system which is applied to all kinds of routine cell evaluation tasks.

7. CONCLUSIONS

In industrial automation there is a strong request for the analysis of 3D objects. **Presently** techniques based on **controlled illumination** are preferred. Other methods like stereo are still in an experimental stage. Several prototypes of vision systems to support safety measures and automated guiding of vehicles for future public traffic are developed in the PROMETHEUS project.

Dynamic 3D scenes have for a long time been modelled by computer graphic techniques. Since there are still severe problems in obtaining realistic looking "natural" scenes, there is an increased request for **3D modelling using computer vision techniques.**

Mechanisms for knowledge representation in vision systems play an important role in the development of systems which are robust, reliable, adaptive, easy to handle and easy to teach. On one hand **knowledge based systems** are under investigation, and on the other hand **neural nets** show an **increasing popularity** for various applications.

The acceptance in practical applicatons is frequently not determined by new and superior processing capabilities but rather by a user friendly inclusion in an existing and well defined working environment.

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