KNOWLEDGE BASED 3D-MODELLING BY SELFORGANISED LEARNING ALGORITHMS
Image understanding based on automated knowledge refinement

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Abstract: This paper discusses the design and implementation of a knowledge based Modelling system KMS, which combines semantic and rule based approaches in the modelling process. The design and implementation of the semantic concepts are controlled dynamically to achieve an optimal degree of reality and to employ efficient interactivity and accessibility for the user. The model-based controlling module is developed to achieve efficiency and consistence in the basic analysis process, and to avoid the static structure that frequently occurs in data driven systems. By using a hypothesis and verification scheme in order to ensure interactivity and accessibility without sacrificing efficiency the KMS evokes the important task of merging the use of heuristic knowledge in form of a knowledge base with domain specific requirements. By detecting contradicting and inconsistent rules and by performing tests in the knowledge base and finally by creating new hypothesis to solve the problems, the controlling process also provides the decision module with a concept for automated knowledge refinement. This paper focuses on the implementation and Multimedia adaptation of the learning processes in correlation with the linked databases.

1 INTRODUCTION

The goal of knowledge based modelling and construction systems is high quality, robustness, error tolerance and good capabilities for all kinds of extension. This means within the controlling of a system temporary or local solutions have to be avoided, and additionally learning and evaluation feedback must be performed especially as long as the learning process proceeds so that complex problems can be resolved. Consequently this process results to learning across multiple levels with close relationship and efficient consumption of knowledge inside every learning phase. This feature enables the propagation of efficient learning inside every level for its subsequent stage, which provides the controlling process with important decision and evaluation criterions for learning strategies in the higher levels. Therefor each resulting model has the capability of processing different sensor or data sources with an individual evaluation and verification instance. Due to the complex domain and scene specific requirements the integrated MEN (Mixed Expert Network) system must operate as

data fusion controller. The individual model parts decide with independent controlling mechanisms, but create new information for the knowledge base with extensive correlation on the output side, where linking and assignment between the different models is performed, so that the global system reliability can be evaluated and performance can be increased as often as it is necessary.

In construction and modelling systems the relations between experience and knowledge rules are strongly dependent from the scene and domain specific requirements. When the domain specific requirements change, the rules (or behaviours) have to be changed accordingly. The supervised learning method based on experience knowledge rules assignment provides a construction and modelling system with the malleability for environmental changes. This feature enables the decision part of the system to overcome the problem of domain specific changes (i. e., noisy environments) and to learn the effect of altering scene specific requirements. Unlike the behaviour of genetic knowledge systems, the malleability of synthetic computer systems is quite limited. Modifications in algorithmic computer software almost leads to
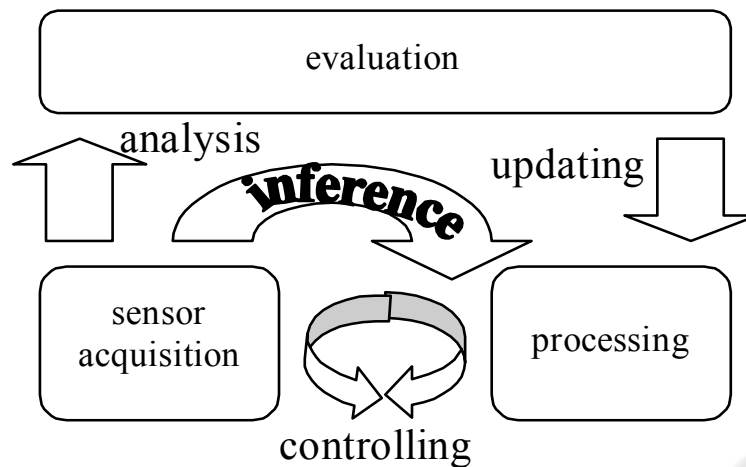
Figure 1: Architecture of the knowledge processing

completely different functions and behaviour. This may lead to the necessity that no alternate than reprogramming becomes the only possible solution in most of these cases independent from the degree of modification within the requirements.

The influence of the environment in combination with the complexity and structure of the data can be considered and integrated if the scene specific and domain specific restrictions can be expressed in terms of the inference machine algorithms. In order to obtain the benefit of learning based knowledge systems concerning reliability and function this approach aims to provide the construction and modelling process with the rules of decision strategies in learning systems. In addition high level image interpretation can be demonstrated by help of genetic algorithms, which have to be derived from the kernel concepts. Accordingly biological inherit mechanisms which are based on continuous evolutionary learning could be integrated into the decision part of the system. In addition self-learning concepts, genetic decision controlled algorithms as well as inherit by clustering can be applied. By help of these important strategies the system process structure can be organised with the ability to synchronise and optimise the learning modules in specific jobs.

However, most of the feature extraction systems in related work are based on classification methods (Mosterman, 1999), whereas this proposal focuses the field of shape detection by merging of active sensors e. g. SAR (Synthetic Aperture Radar) and the resulting features of optical image processing to implement the feature extraction.. Furthermore the proposed concept does not require any geometrical information like matching points or height. in

opposite to (Fink 1987), where interferometric data is required.

2 RELATED WORK AND SYSTEM STRUCTURE

The operating system distinguishes between three processing modules. The basic module analyses the reliability of the active sensors as well as the passive sensor acquisition and employs methods to transform data between each other. Processing and controlling of the active sensor result data is performed in the second module, especially the feature extraction of regions with higher density. In the subsequent module the data analysis and evaluation for decision is implemented, where the results of the basic modules are considered. The outgoing data of each module will be evaluated under the aspect of emphasising the hypothesis that fulfils the given constraints. In Fig. 1 the structure of the whole system connecting the different modules is displayed.

2.1 Architecture of the knowledge based controlling and modelling system

The knowledge based module combines controlling, processing and behaviour models of the system as described in (Canton 1983). This module is invoked if one of the processing parts fails to detect decision states in a given situation. In several processes it can

Figure 2: Example building inside the University of Dortmund, Germany.

be used to detect contradictions in the module states, and support engineers and modelling experts in correcting and modifying the system kernel. The initial rely value for new errors is kept low however, when modifying or extending the domain specific or scene specific database with new rules or semantic elements. When the same restrictions are detected again, the rely value of these rules will be evaluated and they will be considered as temporary. They will only get a continuous attribute, if their rely value ranges above a given limit which results from several analysis processes of the same occurrence. New tests may be performed within the different modules of the database, but only after precise validation by construction and modelling experts. Efficient and reliable databases are built up in this way for the domain specific and scene specific knowledge with optimal premises for analysis and synthesis within the whole modelling process. An example object is displayed in Fig. 2 and has been chosen to verify the proposed concept in the following paragraphs.

2.2 Hierarchical process structure

In most controlling and modelling systems the processes are organised in a sequential hierarchical order. There are three types of processes which generate and update the results: Basic processes employ the physical data, which are initialised by the start up process. In the case of signal processing e. g. image processing the operators of feature extraction are filled with initial parameters. Verifying methods and improving processes take existing result data and update them to generate reliable and precise results. The concepts for altering specific operators or even criterions for evaluation can be performed by taking into account domain specific knowledge as in knowledge-based systems, rather than deriving decisions from data driven algorithms or optimisation techniques, as in, for example static modelling algorithms. Verifying methods can take predefined or resulting data or decisions as input and try to built up a hypothesis in one or more system parts, or they can take decisions that violate specific restrictions and try to eliminate the constraint violations by help of "iterative repair". Terminating processes remove inconsistent or non reliable statements from the amount of hypothesis and keep the total size of the hypothesis low. The kernel of the knowledge base does not define the function of the processes but only their possible modifications. This gives us complete freedom to use a broad range of methods encapsulated as system processes. The connection and the working structure of the different process modules is realised by the working result of the other modules.

3 OBJECT FEATURE EXTRACTION USING DOMAIN SPECIFIC CONSTRAINTS

When the acquisition module has terminated, the primitives of the active sensor are transformed to the grey level images by 3D projection assuming given values for height and width as basic hypothesis. Within the transformation only primitives with a higher threshold level are taken into account and missing object data is to be substituted by polygon approximation or "splining" (Buescher 2000). The precision grade of this process is sufficient since the elements are small enough so that reliable solutions can be expected. A representable subset of resulting primitives has been extracted from our example image and the result is displayed in Fig 3. After passing this state successfully the resulting primitives can be used to represent the associated element part as stable fundamental 3D object element. The goal of this step is the complete assignment between object primitives and transformed image primitives with a degree of reliability that allows the elimination of contradictions in lower states of the process. The quality of the individual solutions is dependent on several parametric constraints : degree of shape and shading structure of the object, absence of planar surfaces, texture intensity of the embedded object elements on the whole scene. The assignment and the evaluation of the controlling process is performed by a special neural network with three layers and four learning steps. The learning effort is achieved by updating the weights with a subsequent mean squared error minimisation based on update of the membership functions.

3.1 Basic concept of the scene analysis and interpretation

The implemented methods can be divided into two groups : In the one group the methods can be transacted rapidly but within a set of rigid encapsulating envelopes. In the other group the transaction speed is slower with more dynamic and complicated structures on the objects. Common to all of them is the processing of 3D-structures obtained by feature extraction in the passive sensor images in the following sequential method parts :

- Performing the 3rd degree "Sobel" edge operator
- Emphasizing the interesting object structures

- In order to employ vector orientation for the different structures B-spline approximation is applied

Among the different groups of passive sensor images selection is performed considering domain and scene specific knowledge.

- The environment of every sensor primitive is analysed regarding to the viewing aspect. In this way hidden regions will be excluded.
- In the following process only the 3D-structure elements with parallel or right-angle orientation will be chosen.

In the next steps the group of selected object structures as well as the resulting Sobel operator images form the basic input data and information for the subsequent modelling process.

3.2 Knowledge based methods for relaxation and verification of the scene interpretation

In this section we briefly describe some of the methods that build up our controlling system. The methods can be grouped into three categories : process allocation methods that assign the model primitives to the image primitives and create an initial hypothesis of the scene for each aspect. Structuring methods that take a process allocation as input and transform the model primitive to every aspect image. Verifying methods that project groups of primitives on each aspect or between aspects to generate better improvements.

3.2.1 Linear algorithms

Searching in its simplest way can be performed by help of linear operators. The process whose results fulfil several criterions with optimal values in a given state s, is being performed and will be repeated as far as a predefined goal has been reached. In data driven modelling tasks it is helpful to describe the best solution by help of an evaluation function $Qe(a,s)$ and success criterions of fulfilling the restrictions. $Qe(a,s)$ is to be derived from the group of evaluation functions of finding the solution a in s. The restrictions are dependent from the different states and can be derived from the heuristic knowledge base. This concept, which is based on linear search is applied in the basic feature extraction module. Linear search is easy to perform and does not waste memory, but it has two disadvantages : its results may evoke contradictions or it may be aborted without any useful output. In (Huang 1996) an uncomplicated modification is suggested within the basic concept : Both

disadvantages can be avoided if the evaluation process with its operators and functions can be controlled dynamically.

3.2.2 Dynamic algorithms

The main goal of the dynamic controlled search concepts is the creation and adaptation of functions, that find the best solution for every transition between the different states of the whole system. These evaluation methods can be characterised by the following deterministic cost function :

$$V^*(s) = \min_{a \in A(s)} \left[c(a,s) + V^*(s_a) \right] \quad (1)$$

In dynamic programming, a deterministic control problem is solved by finding the function V that assigns the optimal cost $V^*(s)$ to each state s. A common way for finding the function V is done by an iterative method known as value iteration in which estimates Vi are plugged into the right-hand side of (1) so that an improved value function $Vi+1$ is obtained.

4 GENERIC KNOWLEDGE CREATION PROCEDURE

This new 3D-modelling procedure is derived from a

new recursive genetic algorithm RGA ,explained in section 5. The kernel of the concept is based on the consumption that the MEN (Mixed Expert System) is created step by step introducing additional knowledge in every new state such that the resulting knowledge base consists of a reliable part and a new one, which has to be proofed. The next section explains how the additional knowledge parts are linked and proofed to the existing knowledge base so that the complete structure forms a consistent platform for reliable decision strategies within an efficient modelling system. To improve and verify the automatically generated hypothesis a new analysis module is derived by applying supervised learning strategies which optimise and improve the final generation of the topologic structures. Within every reasoning decision it is the goal of the self learning system to add well fitting model parts and new knowledge elements which satisfy the object dependent criterions with the best evaluation. In addition the verification of the knowledge refinement process embedded in the learning module is performed by generating the physical model with the subsequent comparison to the reprojection in the original images. The evaluation result data can be transformed to comparable values as feedback of the recursive algorithm.

Figure 3: Result of the model primitive extraction after the knowledge refinement process

5 EVALUATING THE RESULTS OF THE LEARNING PROCESS

By updating the restrictions of the refinement process the MEN can be applied within the model structure generation in order to employ the necessary feedback for the evaluation. In case of missing or unreliable feedback caused by input data noise or contradictions in the knowledge base a new analysis by synthesis algorithm derived from the global model optimisation process has been implemented to overcome the assignment and correlation problem. Based on the actual state of the hypothesis the synthesis algorithm analyses the domain and scene specific knowledge step by step considering every update of incoming information until a satisfying level is reached for every corresponding evaluation. Because of the complex and dynamic behaviour of the underlying restrictions (Hepner 1994) the analysis by synthesis concept cannot directly be derived from the MEN – algorithm structure independent from the quality of the input information. For the modelling and construction of man made rigid objects considering data driven as well as knowledge based methods the initial estimation process could be verified in [Buescher 2000] applying several relaxation algorithms. Its kernel concept however is derived from a static dedicated evaluation process based on data driven optimisation methods and therefor hard to implement within the discussed modelling or construction tasks. The goal of this work is the introduction and implementation of efficient modelling concepts derived from the MEN method, which can be controlled dynamically. Starting from an initial state, in which every element of the knowledge base will be considered with the same reliability, the main modelling process, in which the new relaxation and regression methods will be applied, analyse and evaluate every subsequent state of the model and knowledge base with the goal of eliminating every contradiction between the different rules of the knowledge system and satisfying all given criterions as best as possible. Applied to the input image in Fig. 1 the result of this process is displayed in Fig. 3.

6 CONCLUSION

In this paper we described a knowledge-based solution approach for controlling 3D - Modelling and reconstruction for multiple different issues in the presence of several restrictions and requirements. The problem is of interest both to the academic community (it generalises the problems studied earlier) and to modelling experts. It captures additional restrictions and knowledge that exist in controlling systems. That means, it is not inconsistent and will become unstable by what has been modified during the learning process or due to the extension of the knowledge process. Selflearning and –organising methods are the benefit of the whole system. This capability enables the kernel to overcome the problems which arise from contradictions and to reach the goal of a high quality level. The concretising process and instantiation in the main system ensure, that the knowledge algorithms have to share their specific results for an optimal learning effort.

To the best of our knowledge, this is the first attempt to solve this general problem. Our solution approach is to divide the knowledge base into different levels, linking multiple solution strategies with each other, building up rules and assigning them to the functional behaviour. We have implemented the controlling processes as part of a knowledge based decision system for controlling 3D modelling and reconstruction. The knowledge based system is received in the specific marketplace and currently being used on several CAD stations and simulation systems in education and industry.

REFERENCES

Zadeh, L.A., 1994. Fuzzy logic, neural networks, and soft computing. In *Communications of the ACM.* vol. 37, pp. 77-84.

Jang, J.S.R., 1993. ANFIS adaptive network based fuzzy inference systems. In *IEEE Transactions on Systems, Man, and Cybernetics.* vol. 23, pp. 665-685.

Dague, P., Raiman, O., and Deves, P., 1987. Troubleshooting: When modelling is the difficulty, In *Proceedings of 6th National Conference on Artificial Intelligenc*e, Seattle, WA, August, pp. 600–605.

Mosterman, P.J., and Biswas, G., 1999 .Diagnosis of continuous valued systems in transient operating regions, In *IEEE Transactions on Systems, Man, and Cybernetic*s, vol. 29, no. 6, pp. 554–565.

Fink, P.K., and Lusth, J.C., 1987 .Expert systems and diagnostic expertise in the mechanical and electrical domains, In *IEEE Trans.on Systems, Man, and Cybernetic*s, vol. SMC-17, pp. 340–349.

Canton, R., Pipitone, F., Lander, W., and M. Marrone, 1983 .Model-based probabilistic reasoning for electronics troubleshooting, In *Proceedings of 8th IJCA*I, pp. 207–211.

Patil, R.S., 1981 .Causal representation of patient illness for electrolyte and acid-based diagnosis, In Technical

Report, no. 267, Massachussetts Institute of Technology, Laboratory for Computer Science, Cambridge, MA.

Huang, Y., and Miles, R., 1996 .Using case-based techniques to enhance constraint satisfaction problem solving, In *Applied Artificial Intelligence, an International Journa*l, vol. 10, no. 4.

Faugeras, O., 1995 .Stratification of 3-D Vision: Projective, Affine, and Metric Representations, In J. Optical Soc. Am. A, vol.12, pp. 465-484.

Büscher, E., 2000 .Generation of 3D – Scenes by knowledge based Adaption of parametric Models, In Proc. of the IASTED International Conference. INTERNET AND MULTIMEDIA SYSTEMS AND APPLICATIONS Nev. USA, pp. 411-417.

Bowyer, K. W. and Dyer, C. R., 1994 .Three-dimensional shape representation, In Handbook of Pattern Recognition and Computer Vision, Volume 2: Computer Vision (T. Y Young, Ed.), New York, Academic Press, pp.17-51.

Hepner, 1994 .Artificial Neural Network Classification Using a Minimal Training Set: Comparison to Conventional Supervised Classification, In Photogrammetric Engineering and Remote Sensing 56: 469-473.

Kanatani, K., 1996 .Statistical Optimization for Geometric Computation: Theory and Practice, In Amsterdam: Elsevier.