

VIRTUAL INFORMATION SYSTEMS

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ABSTRACT

The article advocates advantages of 3D virtual information systems and suggests possible techniques for their fast automatic acquisition from range and colour registered images together with solutions for virtual space navigation problems. The proposed system consists of five main parts - range image segmentation, texture analysis, virtual model geometry inference, texture synthesis, and the navigation in virtual environment.

Keywords: Virtual Reality Models, Range Images, Navigation

1 INTRODUCTION

Information systems of various kind are frequently used in diverse applications. The advances in technology allowed the shift from text oriented information systems to graphical ones. Graphical communication and presentation creates natural environment for users. 3D virtual reality information environment simulates natural surrounding for human beings in which people are accustomed to orient themselves. Single objects are presented in their mutual contextual relations in the simulated realistic time-spatial space and hence offers far richer information than the usual textual, still image or multimedia databases.

Manual creation of virtual reality models of real world scenes is tedious and error-

prone work as the scene complexity increases and automation may substantially reduce the laboriousness of the whole process. Range and vision sensors are already common and their mutual registration can be done using either standard photogrammetric techniques or an appropriate sensor setup. A range camera is a device which can acquire a 2D raster of depth measurements, as measured from a plane (orthographic) or single point (perspective) on the camera. Most range cameras are based either on the laser beam reflection principle or on a structured light scanning of projected light. To make virtual worlds realistic detailed scene models must be built. Satisfactory models require not only complex 3D shapes accorded with the captured scene, but also lifelike colour and texture. This will increase significantly the realism of the syn-

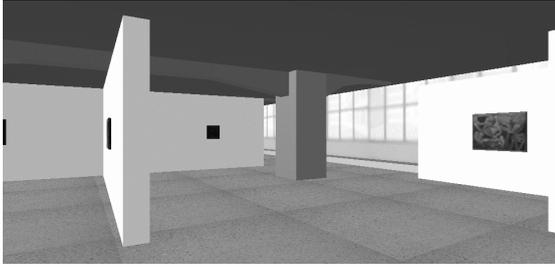


Figure 1: National Gallery Department of Modern Art - east wing.

thetic scene generated. Textures provide useful cues to a subject navigating in such a VR environment, and they also aid in the accurate detailed reconstruction of the environment.

Range image segmentation results guide both subsequent - geometry inference and texture analysis steps. We have introduced a novel multi-resolution fast model for realistic colour texture synthesis in [Haindl98c]. The texture Markov random field based model consists of a set of Gaussian Markov random field submodels for single orthogonal mono-spectral single-resolution texture factors. Parameters of the Markov random field submodels are estimated and subsequently used for given factors synthesis. Resulting synthetic colour texture is composed from these mono-spectral single-resolution factors after corresponding inverse transformations.

2 AUTOMATIC ACQUISITION OF VR MODELS

The core part of the virtual model acquisition system is the range image segmentation algorithm. Range image segmentation is a fundamental process affecting the overall performance of a virtual model acquisition system. There are many segmentation algorithms published in computer vision literature and a number of good survey articles [Besl],[Sinha] is available, however the problem is still

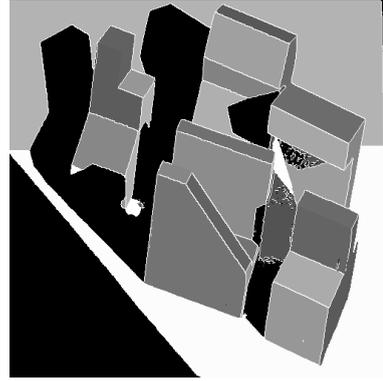


Figure 2: Segmentation of a range image scene with planar faced objects.

far from being solved. A mutual comparison of segmentation algorithms is very difficult because of lack of sound experimental evaluation results. A rare exception is results published in [Hoover] together with experimental data available on their Internet server. Our previous papers [Haindl98a],[Haindl98b] introduced fast range image segmentation algorithms for planar-faced and general-faced objects, respectively. Evaluation results of the algorithm [Haindl98a] using test data set and methodology from [Hoover] demonstrates comparable segmentation quality with the algorithms in [Hoover] while being of an order of magnitude faster than these techniques. Fig.2 shows an example of the segmented scene. The algorithm also lacks usual handicap of segmentation methods their lot of application dependent parameters to be experimentally estimated. Both algorithms combine a discontinuity detection step and the subsequent line or curve based region growing guided by these detected discontinuities.

3 VIRTUAL MODEL GEOMETRY INFERENCE

Range image segmentation results are used to build a virtual reality models that consist of single planes. However although even if a single planar face is correctly

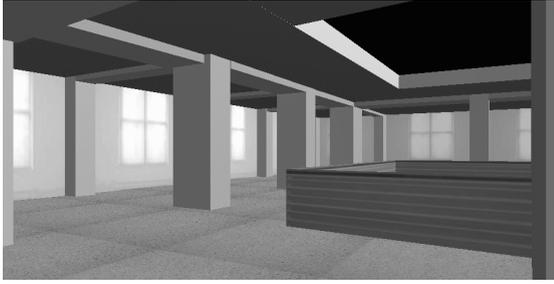


Figure 3: Gallery hall.

found, its corresponding range pixels values are too noisy to be of direct use for the face model construction. Such a model would have many small noise-generated faces. Noise filtering is done through the least-square fitting of a plane to a detected face perimeter pixels. Each face perimeter pixel is subsequently projected into this plane and the pixel projection is the corrected value which is used for a virtual model face geometry inference.

The range image segmentation thematic map serves also as the region map for the registered colour textured image. If a detected face has sufficient area for a reliable texture model parameter estimation then the corresponding colour image area is projected into a plane perpendicular to a viewing direction, otherwise this face is classified as too small for individual texturing. If it is required to texture such a small surface its model parameters can be imported interactively. In the following step a face texture model parameters are estimated. Finally individual textures are synthesized using the fast algorithm of the next section and combined with model geometry information.

4 TEXTURE MODEL

Virtual reality systems require object surfaces covered with realistic nature-like colour textures to enhance realism in virtual scenes. These textures can be either digitised natural textures or textures

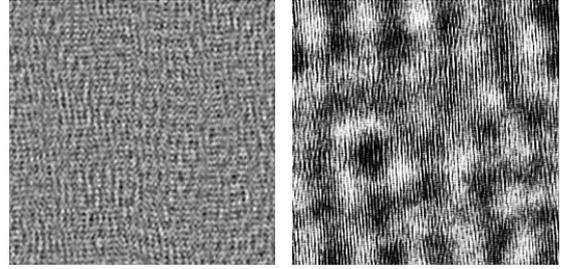


Figure 4: Synthetic canvas and wood texture.

synthesized from an appropriate mathematical model. Digitised solid textures are far less convenient, since they involve the 2D digitisation of a large number of cross-sectioned slices through some material and must be stored in a tabular form and evaluated by table lookup. Synthetic textures are more flexible and may be evaluated directly in procedural form.

Gaussian Markov random fields are appropriate models for texture synthesis not only because they do not suffer with some problems of alternative options (see [Haindl91] for details) but they are also easy to synthesize and still flexible enough to imitate a large set of natural and artificial textures.

Multiple resolution decomposition (MRD) such as Gaussian/Laplacian pyramids, wavelet pyramids or subband pyramids present efficient method for the spatial information compressing. The hierarchy of resolutions provides a transition between pixel-level features and region or global features and hence to model a large variety of possible textures. Unfortunately Markov random fields in general, and Gaussian Markov random fields in particular are not invariant to multiple resolution decomposition even for simple techniques like subsampling and the lower-resolution images generally lose their Markovianity. To avoid computationally demanding approximations [Gidas] of a non-Markov multigrid random field by

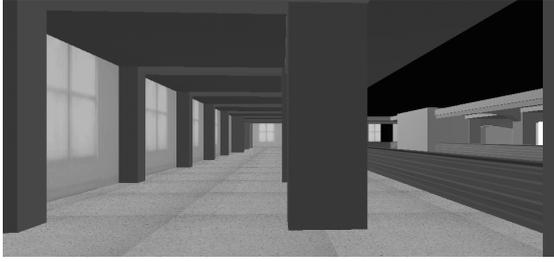


Figure 5: Gallery foyer.

MRFs we analyze each resolution component independently.

Modelling general colour texture images requires three dimensional models. If a 3D data space can be factorized then these data can be modelled using a set of less-dimensional 2D random field models, otherwise it is necessary to use some 3D random field model. Although full 3D models allow unrestricted spatial-spectral correlation modelling, its main drawback is large amount of parameters to be estimated and in the case of Markov models also the necessity to estimate all these parameters simultaneously. The factorization alternative is attractive because it allows using simpler 2D data models with less parameters (one third in the three-spectral case of colour textures). Unfortunately real data space can be decorrelated only approximately, hence the independent spectral component modelling approach suffers with some loss of image information. However this loss of information is indiscernible for human observers in most cases.

Texture modelling does not require computationally demanding MRD approximations (e.g. [Gidas]) because it does not need to propagate information between different data resolution levels. It is sufficient to analyze and subsequently generate single spatial frequency bands without assuming a knowledge of some MRF-type global multi-grid model. We assume colour texture factorized into orthogonal

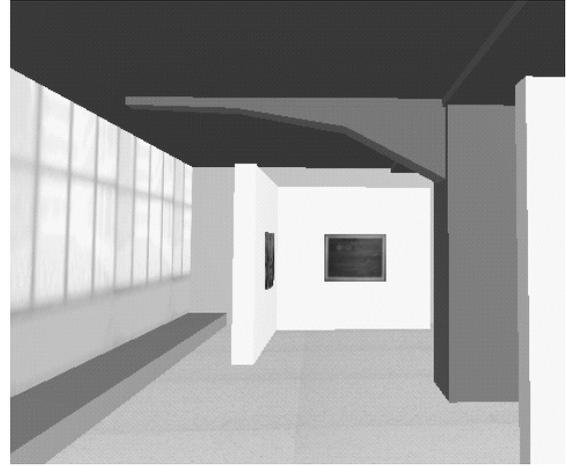


Figure 6: Part of exhibition in the Modern Art Department.



Figure 7: National Gallery - passage to the exhibition hall.

mono-spectral components [Haindl98c]. These components are further decomposed into a multi-resolution grid and each resolution data are independently modeled by their dedicated GMRF. Each one generates a single spatial frequency band of the texture. An analysed texture is decomposed into multiple resolutions factors using the Laplacian pyramid and the intermediary Gaussian pyramid techniques. Finally single mono-spectral single-resolution factors are collapsed into the final (Fig.4) synthetic colour texture.

5 VIRTUAL ENVIRONMENT NAVIGATION

Navigation in virtual environment is influenced by technology that is used for 3D scene description. There are two technologies mostly used: - QuickTime VR - 3D modelling techniques based on the use of tools like VRML or 3D Studio and others. In the first case the scene is organized in a form of cylinders where textures representing photos of the scene create the inner surface of such a cylinder. The user virtually walks inside of the cylinder and the image that corresponds to viewer's view field is distorted by means of image transformations that create illusion of walking through the scene.

The navigation in this type of scene representation is relatively easy and an average user can manage it within relatively short time. There exists a good software support for creation and browsing (and navigation) in this type of scene representation. Our attention is concentrated on the second case where a true 3D model is created. There exist several browsers that allow the user to browse freely in a 3D scene. Nevertheless there exist many problems that have to be solved in order to achieve satisfactory performance of such a browser in general 3D environment.

Serious problem is the user friendliness of the user interface of a 3D browser. Effective use of this interface requires some experience from the user what is not always the case. A solution to this problem would be automatic path generation that would define a trajectory of the virtual walk through. The parameters of the path (starting point, end point, usage of a staircase etc.) will be defined by the user. This solution would help us to solve another critical problem: is the performance of a computer high enough to generate the virtual walk through in real time? When taking into account average

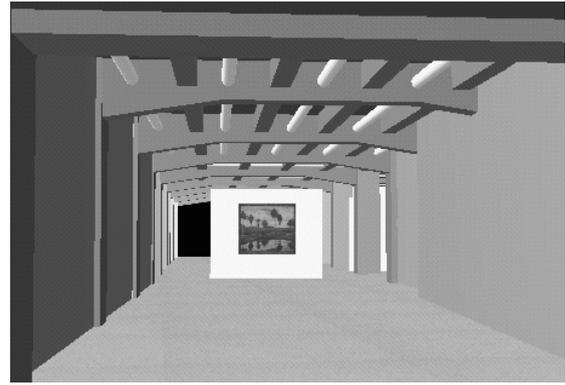


Figure 8: National Gallery - part of the exhibition.

personal computers currently in use and 3D scenes with some level of complexity we will get mostly negative answer.

The solution to this problem is to generate a sort of movie that represents the virtual walk-through in the scene. Such a movie can be played forwards and backwards thus providing necessary information about every part of the trajectory the user goes virtually through. Generation of a path from parameters given by the user is done automatically in a module that considers the ground plan of a 3D scene as a labeled graph. The labels represent various kind of information like accessibility of some location from the point of view of handicapped persons etc.

The process of the path finding is in principle finding a path in a graph. The path found is used for generation of a movie that represents the virtual walkthrough. The user interface has only few features. They do not require some specific knowledge (forward, backward, stop etc.). This fact allows the use of the navigational system even for novice users.

6 DISTRIBUTED VIRTUAL SYSTEMS

Large virtual information systems have to be distributed over Internet. There

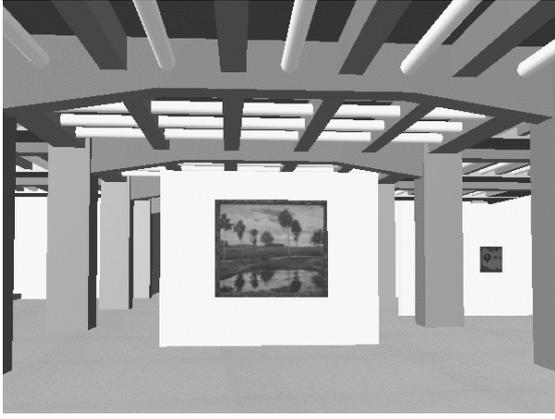


Figure 9: National Gallery - detailed view.

are several reasons why it should be so. One reason is the fact that the 3D model could be shared by more users at the same time. This means that each user will work with the part only that is of interest for him/her. In such way significant reduction of data transfer via network can be reached. This fact has a close relation to paragraphs above where new techniques for texture compression were discussed.

Combination of the both approaches could lead to the significant increase of the overall performance of the whole information system. Also the fact that information processing will be distributed among number of clients will increase the system performance. There exist several models of communication that allow to share computer resources in a computer network. There are many unsolved questions concerning mainly properties of user interfaces, coordination of activities of single users, data compression etc. All these topics are considered as potential research fields.

7 RESULTS

The proposed solution for the virtual information system construction is demonstrated on the model of the Department of Modern Art of the National Gallery. This

collection of images, drawings and statues from the period of 20th century is located in a functionalistic building in Prague. In order to test the navigation algorithm on real data we modelled manually the interior of the gallery building.

The Figs. 1,3, 5-10 show different images from the Virtual National Gallery example. The gallery model is created in the VRML2 language. The model uses synthetic textures Fig. 4 generated using our multiscale Markov random field based algorithm (section 4). The appearance of colour synthetic textures in the gallery model was visually indiscernible from their natural counterparts. All parts of the system are fully functional and were tested with satisfactory results. However due to lack of proper range camera we were not able to acquire range data from the gallery building. Instead the method of automatic acquisition of VR models from range data was successfully tested on the large set of range images from [Hoover]. A single range scene segmentation example from this set is illustrated in the Fig.2.



Figure 10: National Gallery - preparation of an exhibition.

8 CONCLUSIONS

Automatic acquisition of virtual models from registered range and colour real image data is possible combining novel efficient and robust methods demonstrated in the article. Satisfactory models require not only complex 3D shapes, but also life-like colour and texture. The multi-scale

texture model allows more realistic results than the single-scale one in natural scenes where the synthesis model is inadequate (lower order model, non stationary texture, etc.). The texture model allows large compression ratio for transmission or storing texture information while it has still moderate computation complexity. The test results of the virtual model acquisition algorithms briefly mentioned in this paper are encouraging and produced models look true-to-life. Very complex scenes with non-planar faced objects still require human feedback and corrections. However even in this case the model acquisition procedure significantly simplifies a virtual model building task.

Distributed virtual reality information system vastly improves access of citizens or professionals to culture knowledge bases collected in museums or galleries. Many cultural heritage monuments endangered by crowds of visitors or even already closed for public can be accessed through their virtual models. Other monuments stolen, damaged, moved from their natural environment (e.g. Elgin's marbles, Codex Gigas, etc.) can be completed with their original setup. Restoration plans, exhibition planning, manipulating of fragile physical objects, environment changes and many other cultural heritage maintenance problem can be cheaply and safely solved in simulated virtual information systems.

Finally some cultural heritage can be preserved only in digital form due to natural disasters or human ignorance. Another obvious application is virtual information and simulation systems for environments too dangerous, hostile, or even inaccessible for humans such as radiation contaminated environment, body interior for microsurgery treatment, etc.

Although recent technology advances al-

ready enables automatic or at least semi-automatic construction of distributed virtual models, some further research is still needed. The VRML2 language has many functional restrictions and some better distributed virtual reality modelling language is clearly required. Current state-of-art of image analysis has its limitations as well in reliable image segmentation of complex or inhomogeneously lighted scenes.

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REFERENCES

- [Berka] Berka, R., Brachtl, M., Slavik, P.: Three-Dimensional Information System on the World Wide Web. In: Multimedia 96, Springer Wien, pp.68-78, 1996,
- [Besag] Besag, J.: Spatial Interaction and the Statistical Analysis of Lattice Systems. *J. Royal Stat. Soc.*, B-36, pp. 192-236, 1974.
- [Besl] Besl, P.J. and R.C. Jain: Three-dimensional object recognition. *ACM Computing Surveys*, 17 (1):75-145, January 1985.
- [Gidas] Gidas, B.: A renormalization Group Approach to Image Processing problems. *IEEE Trans. Pattern*

- Anal. Mach. Int.*, PAMI-11, pages 164-180, 1989.
- [Haindl91] Haindl, M.: Texture Synthesis. *CWI Quarterly*, 4:305-331, 1991.
- [Haindl92] Haindl, M. and S. Šimberová: A Multispectral Image Line Reconstruction method. In: *Theory & Applications of Image Analysis*. P. Johansen, S. Olsen Eds., World Scientific Publishing Co., Singapore, 1992.
- [Haindl97] Haindl, M. and P. Žid: Fast Segmentation of Range Images. In: *Image Analysis and Processing*. Alberto Del Bimbo Ed., Lecture Notes in Computer Science 1310, Springer-Verlag, Berlin, 1997.
- [Haindl98a] Haindl, M. and P. Žid: "Fast Segmentation of Planar Surfaces in Range Images," In: Proceedings of the 12th IAPR Int. Conf. on Pattern Recognition, Brisbane 1998, Anil K. Jain, Sveth Venkatesh, Brian C. Lovell Eds., ISBN: 0-8186-8512-3, vol. II, pp. 985 - 987, IEEE Press.
- [Haindl98b] Haindl, M. and P. Žid: Range Image Segmentation by Curve Grouping, *Proceedings 7th Int. Workshop RAAD'98*, K. Dobrovodský Ed., ISBN: 80-967962-7-5, ASCO Art & Science, Bratislava, pp. 339 - 344, 1998.
- [Haindl98c] Haindl, M. and V. Havlíček: Multiresolution Colour Texture Synthesis, *Proceedings 7th Int. Workshop RAAD'98*, K. Dobrovodský Ed., ISBN: 80-967962-7-5, ASCO Art & Science, Bratislava, pp. 297 - 302, 1998.
- [Hoover] Hoover, A. G. Jean-Baptiste, X. Jiang, P.J. Flynn, H. Bunke, D.B. Goldof, K. Bowyer, D.W. Eggert, A. Fitzgibbon and R.B. Fisher: An Experimental Comparison of Range Image Segmentation Algorithms. *IEEE Trans. PAMI* 18(7):673-689, July 1996.
- [Jiang] Jiang, X.Y. and H. Bunke: Fast Segmentation of Range Images into Planar Regions by Scan Line Grouping. *Machine Vision and App.* 7(2)115-122, 1994.
- [Kashyap] Kashyap, R.L.: Analysis and Synthesis of Image Patterns by Spatial Interaction Models. in *Progress in Pattern Recognition 1*, (Eds.) L.N. Kanal A. Rosenfeld, Elsevier, North-Holland, 1981.
- [Kment] Kment, S.: 3D Navigational Systems for Buildings, BSc Thesis, CTU Prague, 1998.
- [Novák] Novák, O. Záluský, T. Blažek, V. and Z. Pichlík: Navigation System for National Gallery, Student Project, CTU Prague, 1999.
- [Sinha] Sinha, S.S. and R. Jain: *Handbook of Pattern Recognition and Image Processing*. Wiley, New York, 1994.
- [Slavík] Slavík, P., Berka, R.: Navigation System for Blind Users in Mobile computing Environment, In: Proceedings of IMC 98, Fraunhofer Institute Rostock, pp. 85-94, 1998.