Reconstruction of Built Environments for Virtual Reality Applications Using Architectural Knowledge

1 Introduction

Visual recovery of the real world is a theme increasingly involved in various fields of commerce. In industrial manufacturing, CAD models are extracted from prototype objects which range from simple parts to complicated assemblies. It is a basic component in the generation of virtual worlds and objects for virtual reality applications, TV and cinema production. In the area of recovering models of existing environments, tourist, museum and archaeological sectors are interested in replication of existing buildings for promotion and public education. Companies involved in home sales and redesign are interested in modelling home prototypes that can be "virtually visited" by customers by means of the Internet. Industrial sectors needing this technology are the chemical, electrical and nuclear sectors, who are interested in analysis of their plants for monitoring and modification planning. Training sectors (such as for mining and fire fighting) are interested in using virtual and augmented reality for part of their training repertoire. Scanning building exteriors for reconstruction during restoration, generating engineering models of building interiors for walk-through, spatial analysis before modifications, update of models after modifications or comparison to engineering designs for verification of construction are other important applications for the architecture sectors.

The modelling of real world environment confronts two major problems: 1) the complex structure of such environments and 2) the difficulty of modelling the associated scene texture and reflectance with enough realism. At the level of structure recovery, the traditional approaches used in built environment construction require time-intensive manual survey, particularly in the absence of plans and CAD data. Besides, such surveys only give a sparse verification of a facility, rather than a detailed reconstruction and in consequence it is difficult to verify the accuracy of the resulting model. Secondly, hard effort and complex algorithms are needed to simulate scene illumination and texture, although the resulting rendering is not yet realistic enough and fails to resemble the real scene. Encouraged by the advances in computer vision techniques, a new alternative has emerged recently which uses captured scenes of the environment. Capturing these samples requires far less effort and the acquired data embodies a large amount of information about the environment structure and appearance. By an **appropriate** use of the visual details contained in the captured scenes of the environment, a realistic modelling can be obtained. Although important progress has been achieved in this direction many problems are still open and some issues need to be investigated.

For large scale scenes having features of different scales, an important issue is the coherence of the reconstruction or how to extract a coherent representation of the scene in terms of geometrical structure and appearance. As application areas we will take the case of industrial factories and buildings.

We propose we investigate

- **What domain-knowledge (conventional relationships between scene features, standard architectural templates) could be used to achieve a coherent representation**.
- **How to optimally combine the domain-knowledge information with the extracted acquired data to achieve this goal**.

Unlike reconstructing small scale objects where the viewer is free to move around the object and take images from many positions, large scale scenes in real environments do not usually offer such possibilities, either because the field of view of the user is limited (e.g. a viewer is watching a building from a window) or some natural obstacles hide many views of the scene or make some views inaccessible. We propose to investigate:

- **How to overcome the lack of information in these cases**.

2 Research background

There have been considerable efforts both in the computer vision community and the computer graphics community for producing models of the environment with faithful representation of the geometric and material attributes of the objects within it. There are two approaches for tackling the problem. 1) Image Based Rendering (IBR) where a scene is represented as a collection of images and new images are generated from the original images and 2) CAD-like modelling where a scene is represented by a 3D model together with texture maps extracted from real images. The problem in both cases is: given a set of (2D/3D) images, how can we build a visually convincing representation of the scene ?

The IBR approach involves six main steps: 1) establish point correspondences between images, 2) estimate the epipolar geometry between images, 3) build a representation of the scene using matched points, 4) specify the desired position of the new image, 5) transfer the scene representation into the new image and 6) map textures and colours from the original images to the new images. Much research has been undertaken with some success in the framework of IBR [7, 18, 21, 22, 23, 28].

The CAD approach involves three main steps: 1) camera calibration, intended to recover both the external (position and orientation) and internal parameters of the camera, 2) shape and structure modelling aiming to build a 3D geometric model of the scene and 3) texture modelling, to build a texture map for the geometric model from the original images. This approach has been used particularly within the computer vision community. The techniques developed in the framework of this approach can be divided into two categories, namely active methods using structured light or laser scanners [5, 9, 24, 25, 27] and passive methods using image views taken by a stereo or moving camera [2, 11, 16, 20, 29, 35].

At the current state of the art there is no agreement so far on which approach is the best. The choice is highly dependent of the application and the amount of information available. The idea of a universal and unified approach is abandoned at the current stage. Instead there is a set of techniques combined to solve specific applications. The CAD-like modelling approach is less memory demanding, IBR has the advantage of not requiring calibrated images. The problem of correspondences between image features is far more difficult in the IBR approach and the lack of metric measures in the IBR models makes the use of the computer graphics conventional rendering pipeline difficult.

3 Research objectives

The goal of this research project is to investigate and develop techniques for the reconstruction and modelling of large scale scenes and environments from either 2D images or 3D range data. Our attention will be oriented to large environments, in particular commercial buildings and factories in the framework of a virtual reality application.

Since other groups are already working with IBR approach and since we have already a good experience in extracting CAD models from range data [8, 12, 30, 31, 32, 33], we intend to investigate solutions within a CAD-like approach and bringing therefore more contributions to the comparison between the two approaches.

Buildings, industrial plants and factories can be represented by a set of a relatively simple geometric shapes with characteristic features, provided they are extracted adequately. These properties makes CAD representation appropriate. The still unsolved problem of correspondences between images is less complex with this representation. There are many visualization tools based on CAD-like representation in VR software packages, VRML, to cite just one. In addition, CAD representation is compact, which is important for storage and communications, and easily modified.

For industrial plants and factories we would like to investigate new techniques for the construction of 3D CAD models from range data. The complexity of such environments makes manual modelling very labour intensive. Recently there have been large efforts to automate the reconstruction taking advantage of increasing capabilities of robotic systems in terms of navigation and accuracy of the captured data from both laser scanners and cameras.

For historical buildings such as monuments, castles, towers, it is often difficult or impossible to have access to all the view points. There is a limited space of locations from which the user can take images. Modelling the whole historical scene from the set of available images will bring more convenience and facility. As a goal, we would like to investigate how to reconstruct the full scene using a minimal number of views.

Therefore the research project will focus on the following objectives:

1. For industrial plants: how to produce a coherent representation of a large scale scene ? In such environment, a whole feature (e.g. a long pipe, walls) cannot be covered by single image. It is rather captured in a large number of frames, moreover these pieces are not captured alone but with pieces of other features. These features are usually linked by geometric and topological relationships. The key open questions that we want to investigate:

    - How to extract, identify and match pieces of features in different frames ?
    - How to optimally fuse the captured pieces from the different frames ?
    - How to maintain and incorporate the relationships between the different features in the modelling process ?

    Central to this process is investigating whether the information from the multiple views should be fused before features are extracted, or whether the features should be extracted first from individual views and then fused (or a hybrid process).

2. For the architectural scenes: given a sequence of range and intensity images, how can we recover a reasonable representation of it in terms of geometry and appearance ? In many cases the view points from which the scene can be seen are confined to a limited space (e.g. an interior scene is just visible from a narrow corridor, the building is not accessible from all sides either for security or natural reasons). Moreover the view may be partially covered by foreground obstacles (either natural e.g. trees, or man made, e.g. barriers, other small buildings). In these case we want to investigate the following questions:

   - How can we recover the full (or at least a major part of the) building structure from a limited view space ?
   - How can we infer a plausible description of the scene without the undesired foreground obstacles ? E.g. a castle view without the trees on the foreground partially hiding it.

3. For the architectural scenes we propose to investigate how to exploit constraints typical of built environments (e.g. systematic rectangularity and parallel features, equally spaced sets of windows, parallel sets of pillars with same radius) or typical architectural structures (e.g. doorways) to improve model accuracy and completion? So far these structures are considered just as part of the external building patterns. From this perspective they are currently exploited only in texture mapping [19, 29]. Relying only on texture mapping is not sufficient to recover a faithful structure of these features and can not preserve their coherence at the different scales of visualization (e.g. when the viewer gets closer the faults in the mappings appear: set of windows no longer appear equally spaced, pillars no longer have the same radius). Besides, the texture mapping is limited by the given resolution. So we believe that external features of the building should be modelled when appropriate and the geometrical and architectural properties of their structures should be exploited rather than ignored. We proposed to investigate:

   - How to use standard architectural features (e.g. windows, doorways) and observed feature relationships (e.g parallel windows) to improve the quality of the acquired models.

4 Work plan

The achievement of the objectives defined in Section 3 will be conducted through these tasks:

4.1 T1: Extraction of architecture-specific features (6 Person-months)

There has been a reasonable amount of research on generic surface feature extraction, e.g. from principal curvatures or via fitting of splines or special surfaces, such as cylinders. In this context, we are particularly interested in the extraction of architecture-specific features, such as walls and pipes, which are examples of these generic features. While some time will need to be spent to adapt our previous top ranked research [15] for use here, there is no particularly interesting research here. What is still open are methods for deciding which class of feature is the appropriate model to use (both in terms of generic surface types, and specific architectural objects). One aspect of this problem is that locally, range data is often too noisy to guarantee correct shape classification, whereas using larger subsets of data requires correctly partitioning the data into regions that belong to the same shape. Thus, this topic is about investigating the classification problem, exploiting both mathematical properties of surfaces and specific properties of architectural objects. Also, as architectural features need to be represented at different styles and scales, investigation into multi-scale representations is needed. We will also be investigating the computational definition of several different architectural objects (e.g. rectangular rooms, doorways, straight pipe sections) and robust methods of least square fitting of the models to range data, in particular multi-parametric shape-fitting methods that also reject outlying data that belonging to other features. This phenomenon often occurs in areas of transition between surfaces, in particular with smooth transitions.

4.2 T2: Registration and fusion of multiple views (8 person-months)

The key issue is how to combine multiple data sets, taken from different positions and representing different but overlapping portion of the scene, so as to make more complete models. There has been research into accurate fusion of multiple range datasets at the level of raw data points or at the level of surfaces, but primarily only for small compact objects seen from their outside [8, 14, 26]. These approaches used the ICP (Iterated Closest Point) algorithm [6].

Here we are interested in views of large objects, where many views are needed to be registered to complete and/or to enhance the models. Historically the fusion of these types of multiple datasets for the purpose of scene modelling was first treated in robot vehicle navigation framework. Feature-based registration is a popular approach in the stereo-based navigation [1]. However the registration of multiple views in that case does not have to be as accurate as would be necessary for architectural modelling. The modelling of large scenes has recently had success through the use of the ICP algorithm for the fusion of multiple datasets acquired by means of a range camera coupled with a navigator robot [24, 25]. To work correctly and efficiently, the ICP algorithm needs a good initialization of the transformation between the two views. In this case a reasonable estimate is provided by the robot navigation module. However we want to broaden the field of our applications to general cases including places and parts of building not accessible by a navigator robot (e.g. steps, multi-level or random-level ground). Moreover, we wish to investigate fusion of scene fragments that are only poorly or partly constrained (e.g. two largely featureless wall patches).

The strategy which we propose to investigate for fusing large fragmented datasets consists in: 1) exploiting all the available types of information which could be extracted from the views, namely, the different features and their geometrical and texture attributes (there is image based fusion based on stereo and shape based fusion based on range data, but we are not aware of work that exploits both modalities simultaneously), 2) combining the different types of information in an optimization-based process. We believe that for many architectural scenes there are many salient and easily detected features to exploit for initial estimation of the registration. The geometrical and textural attributes of these features give useful clues for establishing correct feature correspondences for aligning image registration. This could be further enhanced if the geometrical positions of these features were determined within a constrained scheme. In previous work we have shown that the location and shape estimates of object features are significantly improved if we consider the geometrical and topological constraints between the different features [31, 33]. Consequently the transformation estimate based on these features is expected to be improved. Here we will investigate up to what degree a constrained feature-based algorithm (where constraints would be here of geometrical, topological and textural types) would improve scene data registration. Then we will investigate how to couple this scheme with the ICP algorithm. Secondly we will investigate how can we **globally** perform the registration between the different views rather than sequentially. This would alleviate the effects of the transformation error propagating. Some experiments applied on small scale objects have already shown encouraging results [4].

4.3 T3: Exploitation of architectural templates (8 Person-months)

Buildings and industrial factories are not arbitrary shaped objects, rather they conform to architectural conventions reflected by geometrical and topological relationships between the features. Examples include: doorways with a normal range of sizes and the vertical and the horizontal sides are usually nearly parallel, rows of windows of the same shape, equally spaced columns with equal radius, walls interact with specific angles, etc. In industrial plants, pipes have conventional orientations and specific relative orientations between them. What is needed is to preserve these properties in the constructed model to keep its coherence. These relationships are defined from specific domain knowledge and will be implemented interactively. The main issues to examine are how to incorporate these constraints in the modelling process. Complexities arises when multiple features are connected through many constraints. What strategy should be adopted for managing these constraints in terms of priority, over-constrained cases, inconsistency with captured data, etc? We have successfully developed an approach for modelling manufactured objects (including miniaturized factories) incorporating geometric constraints between the different features [30, 31, 32, 33]. We will investigate the possibilities of extension of this approach to large scenes.

4.4 T4: Recovery of scene from a limited view space (8 person-months)

In many cases the space for viewing the scene is limited or some obstacles cover part of the scene (e.g. barriers, furniture, etc.). Recovering a large part of the scene and the elimination of the undesired obstacles would be worthwhile to investigate. For the first problem, one approach would be to examine the available extracted features and deduce properties from their attributes which can tell about the general structure of the scene in terms of geometry and appearance. Similarly, the identification of distinguishing geometrical and appearance attributes between obstacles and the architectural scene can be used for the elimination of the undesired obstacles. The reconstruction need not require full surface data. For example one could use low accuracy range data (e.g. taken obliquely) or even only intensity data to project onto a partial surface extended behind an obstacle that you can see partially around. The exploitation of the architectural templates (described in Section 4.3) should bring more support for achieving this task by projecting observed surface consistency into unseen areas.

4.5 T6: Demonstration package (6 Person-months)

We propose to implement the research results in a demonstration package. The software will be developed under C++ in a PC environment. The Demonstration package will contain two independent parts. One part will be dedicated to architectural scene modelling. The input data will be historical building of the city of

Edinburgh. The second part is related to factory modelling and will use input data provided by our industrial collaborator. In the first part we will implement some algorithms for modelling the illumination variation of the scene. Although this theme is still an open issue, we will use some of the findings of the work of Yu and Malik [34] for estimating the lighting and the reflectance of models of an architectural scene under different natural lighting conditions. Simultaneously we will we will investigate another alternative which the principle stipulates, that the illumination variation of a scene at given conditions could be simulated by linear combinations of basis images. The basis images are extracted by means of Karhunen-Loéve transform or the SVD decomposition from a set of scene images taken under different illumination conditions from different viewpoints. The advantage of this approach is that it "bypasses" the modelling of surface reflectance and the lighting conditions of the scene. This approach was applied with some success on small objects exposed to a single point light source [3, 10, 35].

5 Relevance to beneficiaries

Organised local shape data along with associated reflectance and texture (i.e. surface colour and markings) can be used to generate CAD descriptions of the scanned environment. These CAD models are expressed in the description language of architectural design systems. Thus, the automatically created models will be suitable for human manipulation, display and analysis within standard tools.

The chief benefits of an automatic CAD model construction system are: 1) the potential for a large reduction in the time needed to create architectural models of existing structures (i.e. reducing days or weeks of surveying, data entry and editing, to minutes or hours of scanning and data processing), 2) the acquisition of dense measurements (e.g. every centimetre, rather than only surveyed control points), 3) the acquisition of the detail of real surfaces, as compared to bland uniformity of typical computer synthesised surfaces and 4) integration within a Virtual Reality system and the benefit of the advantages offered by Virtual Reality. For industrial buildings in particular it can offer a tool for project design reviews, inspection, simulation and operator training and contribute to minimising health and safety risks and the high cost of working in hostile environment.

The two commercial collaborators on this project are UK Robotics and CADcentre. They are two of the leading UK developers of tools for constructing CAD models of industrial plant, and will both benefit from the work proposed in this project. These industries are keen to capitalise on the new possibilities that reverse engineering technology opens to them. The third collaborator for the project is the Edinburgh Central Mosque. This is a new and prestigious mosque, located nearby to the research group. They have agreed to allow access to the mosque to acquire data for experimentation, and to promote the project results.

6 Dissemination and exploitation

We propose to publish the results and the findings of the research project in the computer vision, computer graphics literature and in appropriate industrial magazines. The industrial collaborators will have early and full access to our code, documentations and papers, so as to allow them a head start on exploitation in products.

We also have considerable contact with the research group at the Edinburgh Virtual Environment Centre (EdVEC) and expect to involve them in the exploitation of this technology.

7 Justification of resources

The project requests a Sun workstation (Ultra 10 Creator 3D) in order to maintain our current research context, while significantly increasing the computing power and memory space we have found necessary for simultaneous processing of multiple range images. A PC including graphic card will be used for the demonstrator. The digital camera will be used for acquiring images of architectural buildings. A range sensor for capturing 3D measurement data of the test scenes. A mobile range scanner of the EdVEC centre will be used as well to capture other range images.

The main consumables are the standard maintenance plus a fee payable to the Division of Informatics for providing printing, Ethernet, disk storage, security and Internet services. The human resources requested are for the employment of one experienced research assistant (Naoufel Werghi, first author of many of our recent publications), plus small amounts for secretarial support, computing officer support (to maintain and upgrade the research computing services) and technician support (for developing, installing and maintaining the lighting and image capture electro-mechanical equipment). The conferences proposed are the main European and international computer vision and graphics conferences.

References

[1] N. Ayache, O.D. Faugeras, "Building, registering and fusing noisy visual maps", Proc ICCV'87, London, pp.73-82, 1987.

[2] P. Beardsley, P. Torr, A. Zisserman. "3D Model Acquisition from Extended Image Sequences". In Buxton and Cipolla (Eds), Proc. 4th Eur. Conf. on Computer Vision, LNCS 1065, Cambridge, Springer-Verlag, pp 683–695, 1996.

[3] P. Belhumeur, D. Kriegman, "What is the set of images of an object under all possible lighting condition", Proc. ICCVPR'96, pp.270-277, June 1996.

[4] R. Benjemaa, F. Shmitt, "A solution for the registration of multiple 3D point sets using unit quaternions", Proc. ECCV'98, pp.34-50, Friburg, Germany, June 1998.

[5] J.A. Beraldin, L. Cournoyer, M. Rioux, F. Blais, S.F. El-Hakim, G. Godin, " Object Model Creation from Multiple Range Images", Proc. Int. Conf. on Recent Advances in 3-D Digital Imaging and Modeling, Ottawa, Canada, pp.326-333, 1997.

[6] P.J.Besl, N.D. McKay, "A method for registration of 3-D shapes", IEEE Trans. PAMI, Vol.14, No.2, pp.239-256, 1992.

[7] S. E. Chen and L. Williams, "View Interpolation for Image Synthesis, " Proc. SIGGRAPH'93, pp 279-288, 1993.

[8] D. W. Eggert, A. W. Fitzgibbon, R. B. Fisher, "Simultaneous Registration of Multiple Range Views For Use In Reverse Engineering of CAD Models", Computer Vision and Image Understanding, Vol 69, No 3, pp 253-272, March 1998.

[9] S.F. El-Kakim, S.Brenner, G.Rothe, "An Approach for Creating Virtual Environments using Range and Texture", Proc. ISPRC, Int. Symp. on Real Time Imaging and Dynamic Analysis, Hakodate, Japan, 1998, pp. 331-338.

[10] R. Epstein, P. Hallinan, A. Yuille, " 5 ± 2 eigenimages suffice: An empirical investigation of low-dimensional lighting models", Proc. IEEE Workshop on Physics-based modelling in Computer Vision, Cambridge, Massachusetts, pp.108-116, June 1995.

[11] A.Fitzgibbon, A.Zisserman, "Automatic Camera Recovery for Closed or Open Image Sequences", Proc ECCV'98, Vol.1 pp.311-325, june 1998.

[12] A. W. Fitzgibbon, D. W. Eggert, R. B. Fisher, "High-level CAD Model Acquisition from Range Images", Computer-Aided Design, Vol 29(4), pp321–330, 1997.

[13] R. Hartley, " An algorithm for self-calibration from several views, " Proc. ICCVPR, Seattle, WA, pp.908-912, 1994.

[14] A. Hilton, A. Stoddart, J. Illingworth, T. Windeatt, "Reliable surface reconstruction for multiple-range views", Proc. ECCV'94, Cambridge, UK, pp.117-126, 1996.

[15] A. Hoover, G. Jean-Baptiste, X. Jiang, P. J. Flynn, H. Bunke, D. Goldgof, K. Bowyer, D. Eggert, A. Fitzgibbon, R. Fisher, " An Experimental Comparison of Range Segmentation Algorithms," IEEE Trans. PAMI, Vol.18, No.7, pp.673-689, July 1996.

[16] S.B.Kang, R.Szeliski, " 3-D Scene Data Recovery Using Omnidirectional Multibaseline Stereo, " Int. Conf. on Computer Vision and Pattern Recognition, San Francisco, USA, pp.364-370.

[17] Q.T.Luong, O.Faugeras, " Self-calibration of moving camera from point correspondences, " IJCV, Vol.22, No.3, pp.261-289, 1997.

[18] L.McMillan, G.Bishop, "Plenoptic Modeling: an Image-Based Rendering System" Proc. SIGGRAPH'95, pp.39-46, 1995.

[19] T.Moons, D.Frere, J.Vandekerckhove, L.V.Gool "Automatic Modelling and 3D Reconstruction of Urban House Roofs from High Resolution Aerial Imagery", Proc ECCV'98, Vol.1 pp.410-425, june 1998.

[20] W. Niem, "Automatic Reconstruction of 3D Objects Using a Mobile Camera", Image and Vision Computing vol 17, No.2, pp.125-134, 1999.

[21] S. M. Seitz and C. R. Dyer, "Physically-Valid View Synthesis by Image Interpolation", Workshop on Representations of Visual Scenes, Cambridge MA, 1995.

[22] S.M Seitz, C.M Dyer, "View Morphing," Proc. SIGGRAPH'96, pp.21-30, 1996.

[23] S. M. Seitz, K. Kutulakos, "Plenoptic Image Editing", Proc. ICCV'98, pp.17-24 Bombay, India, 1998.

[24] Sequeira V., Gonçalves J.G.M., Ribeiro M.I. - "3D Reconstruction of Indoor Environments". Proc. IEEE International Conference on Image Processing (ICIP96): Special Session on Range Image Analysis, pp. 405–408, Lausanne, Switzerland, September 16-19, 1996.

[25] V. Sequeira, K. C. Ng, E. Wolfart, J.G.M Gonalves, and D.C. Hogg. "Automated 3D reconstruction of interiors with multiple scan-views", Proc. SPIE, Electronic Imaging '99, IS&T/SPIE's 11th Annual Symposium, San Jose Convention Center, San Jose, California, USA, January 1999.

[26] M.Socuy, D. Laurendo, " A general surface approach for to the integration of a set of range views", IEEE. Trans PAMI, Vol.17, No.4, pp.344-358, 1995.

[27] M.Socuy, G.Godin, R.Baribeau, F, Blais, M. Rioux, " Sensors and Algorithms for the Construction of Digital 3D-colour Model of Real Objects" Proc. IEEE Int. Conf. on Image Processing, Special Session on Range Image Analysis, ICIP'96, Lausanne, Switzerland, pp.409-412.

[28] R. Szeliski and H. Shum, "Creating Full View Panoramic Image Mosaics and Environment Maps", Proc. SIGGRAPH'97, pp 251-258, 1997.

[29] C.J. Taylor, P.E.Debevec, J.Malick, " Reconstructing Polyhedral Models of Architectural Scenes from Photographs" Proc. ECCV'96, Cambridge, UK, pp.659-668.

[30] N. Werghi, R.B. Fisher, A. Ashbrook, C.Robertson , " Improving model shape acquisition by incorporating geometric constraints", Proc. British Machine Vision Conference, pp. 520-529, Essex, UK, September 1997.

[31] N. Werghi, R.B. Fisher, A. Ashbrook, C.Robertson, " Modelling Objects Having Quadric Surfaces Incorporating Geometric Constraints ", Proc. ECCV'98, pp.185-201, Friburg, Germany, June 1998.

[32] N. Werghi, R.B. Fisher, A. Ashbrook, C.Robertson, "Improvement of Quadric Surfaces Estimation of Manufactured objects", accepted in Second World Manufacturing Congress, Durham, UK, September 1999.

[33] N. Werghi, R.B. Fisher, C.Robertson, A. Ashbrook, "Object reconstruction by incorporating geometric constraints in reverse engineering", to appear in Computer-Aided Design.

[34] Y. Yu, J. Malik, "Recovering photometric properties of architectural scenes from photographs", ACM SIGGRAPH'1998, pp.207-217.

[35] Z.Zhang, " Modelling Geometric Structure and Illumination Variation of Scene from Real Images", Proc. ICCV'98, pp.1041-1046, Bombay, India, 1998.

Figure 1: Programme of Work Timetable