A COMPUTATIONAL FRAMEWORK FOR STEREO IMAGING

BY

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THESIS

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To my family

Abstract

Stereo vision recovers depth information from a 3-D scene by exploiting differences between two different 2-D projections. This involves two processes: analysis and reconstruction. The former estimates camera parameters – calibration – and obtains the relative position of the same 3-D point in the two different images – correspondence estimation. The latter deals with the extraction of the 3-D scene information. These two ill-posed problems are the focus of research in stereo imaging.

In this thesis a complete framework for stereo analysis is proposed. New strategies are devised to deal with the underlying problems. With respect to the calibration problem a Tukey's outlier detection technique and a scaling based on the Karhunen-Loève transform are proposed. A robust estimation procedure based on clustering and the Least Median of Squares technique is introduced. Additionally, the clustering uses correlation and redundancies in the magnitude and position of the disparity vectors. This leads to an approach which combines semivariograms and k-means strategies.

For the correspondence problem two similarity measures for disparity estimation are proposed. The first measure is based on the Pearson's correlation coefficient where: a) the median is used instead of the mean and b) the $L_1 - norm$ is used instead of the $L_2 - norm$. The second measure uses a weighted sum of absolute differences exploiting the spatial variability in the correlation window. It uses the ordinary Kriging equations for the calculation of the values of the weights.

Image synthesis is used in the evaluation of disparity inaccuracies. Sensitivity analysis is conducted to assess the effect of disparity inaccuracies in the virtual images.

Specific contributions of this work are: analysis and development of a robust estimation technique for camera calibration, study of similarity measures for correspondence estimation, and sensitivity analysis for the evaluation of disparity estimation using intermediate (synthetic) images.

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The Road Not Taken

Two roads diverged in a yellow wood,
And sorry I could not travel both
And be one traveler, long I stood
And looked down one as far as I could
To where it bent in the undergrowth;

Then took the other, as just as fair,
And having perhaps the better claim,
Because it was grassy and wanted wear;
Though as for that, the passing there
Had worn them really about the same,

And both that morning equally lay
In leaves no step had trodden black.
Oh, I kept the first for another day!
Yet knowing how way leads to way,
I doubted if I should ever come back.

I shall be telling this with a sigh
Somewhere ages and ages hence:
Two roads diverged in a wood, and I-
I took the one less traveled by,
And that has made all the difference.

Robert Frost (1874–1963)

Contents

"Metaphysics is universal and is exclusively concerned with primary substance. And here we will have the science to study that which is just as that which is, both in its ***essence*** *and in the* ***properties*** *which, just as a thing that is, it has."*
*(***Aristotle***, 340BC)*

CHAPTER 1

INTRODUCTION

The vision system of biological creatures is based on the two eyes and the brain, where the eyes capture aspects of the 3-D physical information and the brain recovers the distance or third dimension. In an attempt to simulate this system, two cameras are used as the eyes for capturing 2-D projections – images – of the physical 3-D world-scene. A computer takes the place of the brain in the computational modelling, processing, and interpretation of the 2-D projections. This is the task of stereo vision: the recovery of the original physical 3-D information – depth – in a manner similar to the way biological creatures perceive depth.

Once the depth information is available, it is possible to represent – to render – it in a 3-D way. These representations become useful in different areas. For instance, in medicine it is useful for 3-D visualizations of internal organs for inspection and diagnosis. Three-dimentional teleconferencing is able to capture the attention of an audience for longer. A missile can locate the target with more accuracy by using the depth information. General applications areas are: Education [Chi1995, Bra2000, Mao2003, You2003], Entertainment [Per2000, Pos2001, May2002, Si-J2004], Industry [ASAE1983, Nor1989, Bha1998a, Jia2002, Whi2003], Medicine [Zan1998, Jia2002a, Jac2002], Military [Pit1996, Yic1999], Navigation [Mul2005, Hal1994] Robotics [Kim1994, Dif2004, Ada2004] among others.

1.1 The Stereo Vision Problem

The stereo vision problem can be defined as the recovery of the 3-D structure of a scene from its 2-D image representations. This is an inverse problem. The forward problem can be described using the structure of the problem in Figure 1.1 where the 3-D scene is the input which is captured by a system – a camera – to produce 2-D images – the output.

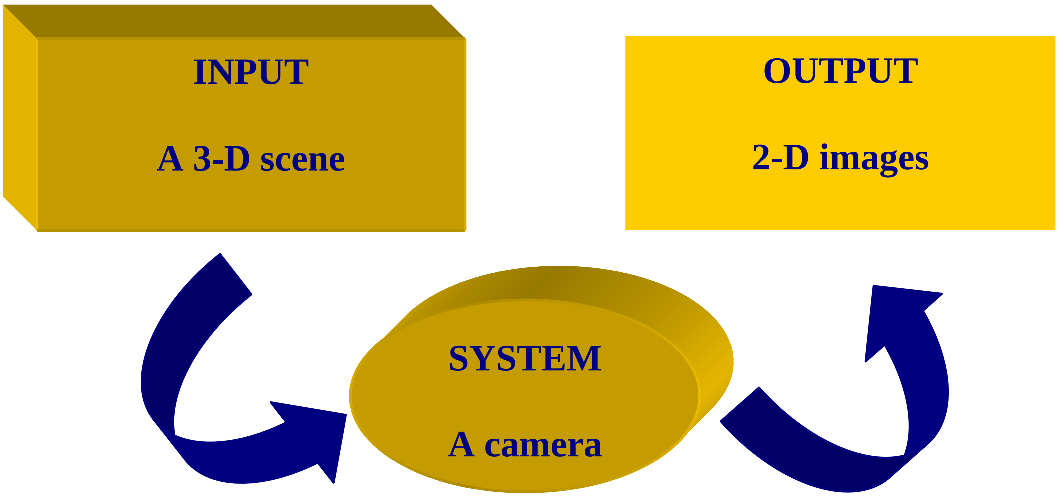

Fig. 1.1.: The structure of a problem

In general, an inverse problem consists of a model describing the relation between an input – the 3-D scene – and an output – 2-D images – where the output is known and the input have to be estimated. The solution of this problem is the estimated input that satisfies the relation between the input and the output defined by the model.

Hadamard characterized a well-posed problem by the existence, uniqueness, and stability of the solution [Had1923]. A problem which does not satisfy at least one of these three conditions is called *ill-posed*. A consequence of the instability of an ill-posed problem is that small perturbations – measurement errors – in the data have large influence on the solution.

On the other hand, a linear classical problem is the solution of an integral equation. Using functional analysis [Ped1999], an inverse problem can be symbolized by means of the Fredholm integral equation:

$$\int_I K(s,t)\,x(t)\,dt = y(s) \tag{1.1}$$

where $x(t)$ is the unknown functional, $y(s)$ is a known right-hand-side and $K(s,t)$ is called the *kernel*. The Fredholm integral equation is said to be the *first*-kind, if the unknown functional appears only inside the integral. When the *first*-kind Fredholm integral equation is made discrete – more details can be found in Hansen [Han1998] – it can be written as a system of linear equations. The system of linear equations can be expressed in matrix notation as:

$$Kx = y\,. \tag{1.2}$$

The inverse problem is to estimate x from K and y. The problem is that the inverse K^{-1} is unbounded (if it exists). This is due to errors. Errors were added when the *first*-kind Fredholm integral equation was made discrete and more errors – rounding errors – are going to be added during the solution. The result is that the solution x might not be robust against perturbations. This fact is mirrored in a system of linear equations in the sense that the condition number of K is large.

An indicator of the instability of a system of linear equations is the condition number of the matrix K – in Equation (1.2). The condition number is a measure of the robustness of the solution to perturbation. A matrix with a large condition number is an *ill-conditioned* matrix [Gol1996].

The inverse problem – estimate x from K and y – is an ill-posed problem in the sense of Hadamard and neither a simple nor a complicated reformulation of the problem will improve the ill-posed problem. In a strict mathematical sense, we are not able to solve an ill-posed problem. However using *a priori* information we can obtain an answer close to the correct solution.

Regarding the stereo vision problem, in the forward problem a 3-D scene is captured by a camera to produce 2-D images. The inverse problem is to infer the 3-D information of the scene from a set of 2-D images. Moreover, there is the lack of information about depth that it makes the stereo vision problem an ill-posed problem in the original sense of Hadamard.

1.2 Stereo Vision Solution

The solution of the stereo vision problem is based on the recovery of 3-D information from a set of projection images. A stereo rig – two cameras looking at the same 3-D scene, in Figure 1.2 – is used in capturing the project images (output).

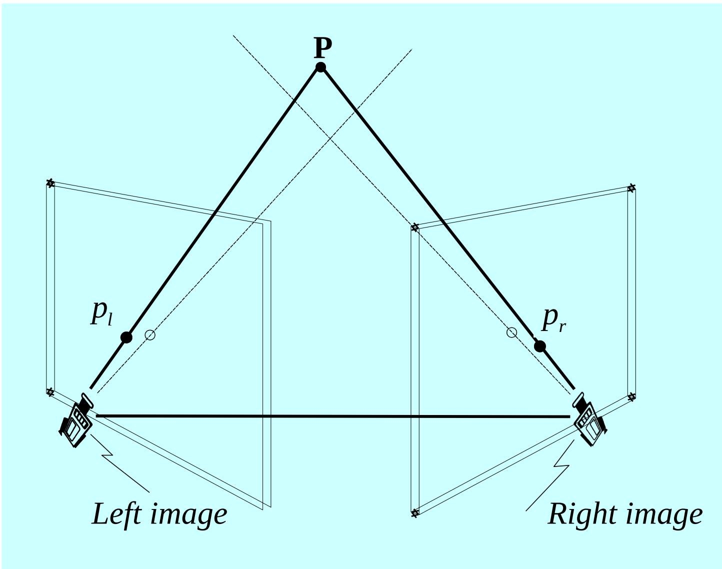

Fig. 1.2.: Stereo rig

Epipolar geometry is used for defining the relation between the 3-D scene (input) and the projection images (output):

$$p_l^T F p_r = 0 \tag{1.3}$$

The epipolar equation – in Equation (1.3) – is the model describing the geometry of the stereo system. It is a function of two corresponding points – p_l and p_r – in the left and right images, and a matrix F – the fundamental matrix.

The solution of stereo vision problem involves two processes: analysis and reconstruction. The former estimates camera parameters and obtains the relative position of the same 3-D point in the two different images. The latter deals with the extraction of the 3-D scene information.

In other words, the calibration problem is to obtain the geometry that describes the relation in the stereo system. The fundamental matrix, F or f, encodes the geometry of the stereo system. Thus, the estimation of the fundamental matrix is known as the calibration problem. The estimation of corresponding points is known as the correspondence problem. Once the calibration and correspondence problems are addressed, the reconstruction of the 3-D scene is done by triangulation.

For the estimation of the fundamental matrix, we have to assume that a set of corresponding points is available. On the other hand, in order to reduce the search space and obtain a more reliable estimation of corresponding points, it is required that the images are calibrated. Hence the solution of the calibration problem is dependent on the solution of the correspondence problem and *vice versa*.

In the calibration problem, the epipolar equation can be written as a system of linear equations [Lon1981]. The linear equations can be expressed in matrix notation as:

$$U_n f = 0 . \tag{1.4}$$

where the matrix U_n contains the corresponding points information and the vector f contains the elements of the fundamental matrix.

Linear methods for the estimation of the fundamental matrix are based on Equation (1.4). The matrix – in the system of linear equations – is ill-conditioned.

1.3 Thesis Statement and Contributions

The process of analyzing images of 3-D scenes taken from two different viewpoints in order to estimate depth is called stereo analysis. Stereo analysis plays an important role in a large number of applications such as robot navigation, augmented reality applications, and telecommunications. For instance, a crucial application of such technology is in videocommunication with telepresence. Usually this is implemented by means of autostereoscopic multiviewpoint technology that enables realistic 3-D impression. Such systems are underpinned at technical level by stereo analysis algorithms. The underlying models analyze the information supplied for a stereo camera in order to reconstruct 3-D scenes. In this thesis several aspects of stereo analysis are tackled. The main body of this work discusses and describes state-of-the-art stereo vision methods, examines the fundamentals of imaging geometry, and discusses the central problems in stereo analysis: the calibration and correspondence problems. Image synthesis is used for the evaluation of disparity estimations.

Calibration is focussed on the estimation of the fundamental matrix using linear techniques. It is constrained by the instability of the solution – ill-posed problem – and the solution of a linear system of equations in which the matrix of the system is ill-conditioned. In order to obtain an estimation of the fundamental matrix, a set of corresponding points is used in the solution of the system of linear equation in (1.4). Since the corresponding points are estimations, they can contain outliers. The Tukey technique [Tuk1977] is used for identifying outliers in the input data. The solution of a linear system of equations – in which the matrix of the system is ill-conditioned – is tackled by using the Karhunen-Loève transform [Boz1995], while a detailed comparison to traditionally used methods is given. The instability of the solution provides the motivation for the use of robust statistics techniques: the Least Median of Squares technique is used in a Monte-Carlo scheme. In order to impose constraints on the distribution of the corresponding points used for the fundamental matrix estimation, a robust estimation procedure based on clustering and the Least Median of Squares technique is introduced. Additionally, the algorithm uses correlation and redundancies in the magnitude and the position of the disparity vectors. It utilises a model which combines a grid-semivariogram [Cre1993] and the k-means algorithm. A detailed comparison to Zhang [Zha1998] and Torr and Murray [Tor1993] approaches is presented.

The estimation of corresponding points depends on the similarity measure and the computational strategy. This work is centred in the similarity measures. In this respect, two novel measures of similarity are proposed. The first one, median correlation is based on Pearson's coefficient of correlation, where the median is used instead of the mean, and the $L_1 - norm$ is used instead of the $L_2 - norm$. The second measure is a weighted sum of absolute differences. It exploits the spatial variability in the correlation window. The spatial correlation is measured using the semivariogram function to determine the range of influence. The values of the weights are determined using the ordinary Kriging technique [Cre1993]. In this way, points closer to the centre have larger weights than those distant from it. The performance of the proposed measures is compared to traditionally used measures.

Once the calibration and correspondence problem are addressed, a field containing the disparities between corresponding points is generated. This field is called a dense-disparity map. Image synthesis is used for the evaluation of disparity estimations. Sensitivity analysis is conducted to assess the quality of virtual images created using distorted disparity maps.

Specific contributions of this work are: analysis and development of a robust estimation technique for camera calibration, study of similarity measures for correspondence estimation, and sensitivity analysis for the evaluation of disparity estimation using intermediate (synthetic) images.

1.4 Structure of the thesis

This thesis is comprised of six main chapters, of which Chapter 2 presents a general overview of the stereo-vision problem and a review of the state-of-the-art. Chapter 3 presents the geometry for stereo images. Chapters 4 to 6 describe the three parts of the contributed elements of this work and Chapter 7 presents the experimental results.

Chapter 2 consists of three main parts. It presents concisely the stereo vision problem and contains a survey of the most representative contributions on calibration and correspondence problems, and image synthesis. Chapter 3 provides an explanation of the geometrical relation between a 3-D scene and its 2-D representations. Section 3.1 presents the pinhole camera model. Intrinsic and extrinsic parameters are introduced in Sections 3.2 and 3.3. The epipolar geometry is presented in Section 3.4. Sections 3.5 to

3.7 describe definitions of the essential matrix, the epipolar lines, and the fundamental matrix.

Chapter 4 contains a characterization of the geometric calibration problem. Section 4.1 presents techniques most commonly used in the estimation of the fundamental matrix. Techniques for normalization of the input data are presented in Section 4.2. We propose a scaling based on the Karhumen-Loève transform in Section 4.3. Sections 4.4 to 4.7 focus on the robust estimation of the fundamental matrix, which is justified by the characteristics of this problem. Section 4.7 proposes a robust estimation procedure based on clustering using spatial dependences among neighbouring disparity vectors and the Least Median of Squares technique.

Chapter 5 addresses the correspondence problem, which is studied from the measurements' viewpoint. Section 5.1 presents the matching estimation problem, matching errors and constraints. The block-matching strategy is described in Section 5.2. Measures of correlation commonly used in the block-matching strategy, are presented in Section 5.3. We propose a robust correlation measure – the median correlation – based on Pearson's coefficient of correlation, which uses the median and the $L_1 - norm$ in Section 5.4. In Section 5.5, we introduce the weighted sum of absolute differences, where the semivariogram function is used to determine the range of influence and the ordinary Kriging technique is used to determine the values of the weights.

Chapter 6 is concerned with the application of disparity estimations. Disparity estimation is in Section 6.1. Theoretical formulations for generating a virtual image using affine and Euclidean view synthesis are described in Sections 6.2 and 6.3. A technique based on interpolation is presented in Section 6.4. Using the hypothesis that ideal disparities cannot be estimated, we propose the use of sensitivity analysis for examining the effect of disparity inaccuracies in Section 6.5.

Chapter 7 presents experimental evaluations of techniques described in Chapters 4 to 6, and Chapter 8 contains the conclusions of this work and recommendations for further work.

"Yesterday's meditation has thrown me into such doubts that I can no longer ignore them, yet I fail to see how they are to be resolved. It is as if I had suddenly fallen into a deep whirlpool; I am so tossed about that I can neither touch bottom with my foot, nor swim up to the top."
The Second Meditation,
(René Descartes)

CHAPTER 8

CONCLUSIONS

In this thesis, a framework for stereo analysis was presented. New strategies were devised to deal with the underlying problems. With respect to the calibration problem the box-and-whisker plot was used in detecting outliers on disparity vectors. Outliers due to bad-location were identified by this technique. The results of the box-and-whisker analysis depend on the behaviour of the input data set. This technique cannot be used automatically; its results have to be validated before taking the decision to eliminate points. A scaling transformation based on the Karhunen-Loève transform (KLT) was proposed in order to deal with the ill-conditioned characteristic of the matrix of the system of linear equations. The KLT scaling produced slightly better results than the isotropic scaling. A circular, symmetric, and homogeneous selection of points was introduced. This led to a new scaling based on the centroids and the average radius. When the corresponding points are distributed homogeneously in the image, the estimation of the fundamental matrix is improved. However, it is possible to obtain sets of points belonging to the same object that make the estimation of the fundamental matrix unstable. Based on the fact that the estimation of the fundamental matrix is unstable when the points used for its computation lie on a small number of planes, a clustering technique was introduced using disparity vectors. This technique forces the selection of at least one point from each plane. The k-means algorithm produced the best partition. In order to tackle the main drawback of the k-means algorithm – the dependence of the results on the initialization groups – a new strategy for establishing the initialization groups was proposed. This was based on grid clustering derived from the spatial dependence amongst disparity vectors, using the semivariogram parameter range to determine the grid size. The grid cluster information was used to determine the number of clusters and the initialization groups. The LMS was chosen as the robust statistics estimator because it has a high-breakdown point and is appropriate for this problem. The k-means and grid based on semivariogram clustering were introduced for selecting points in the LMS schema. An efficient least median of squares approach was derived by combining k-means and grid based on semivariogram clustering. This approach produces a better estimation of the scene geometry by including all disparities and spatial positions in the sample.

For the correspondence problem, we focused on similarity measures that are used in a block-matching scheme. The meaning of the word correlation was stated as: *connection* and *concordance*. The ground-truth correlation analysis shows that negative correlation scores are obtained in occlusion areas and areas of discontinuity. This result can be used for identification of those areas. The Median Correlation (MC) was proposed as a similarity measure for the estimation of corresponding points in stereo vision. Since, the MC can reach its maximum value more than once in the search window, a point in the left image may be paired to several points in the right image and *vice versa*. A relaxation technique is required in order to deal with these ambiguities. A weighted sum of absolute values (WSAD) was introduced considering the intensity differences as a spatial process. The spatial correlation was measured by using the semivariogram and the values of the weights were computed by solving the ordinary Kriging equations. Disparity maps obtained by using the WSAD show smooth disparities within the objects' surfaces and the depth separations are preserved adequately. Objects in the foreground are easily identified; that makes WSAD suitable for depth segmentation. The correlation window size depends on the spatial variability. When there is large variability in the surrounding area a small correlation window size is required. On the other hand, when there is small variability in the surrounding area a large correlation window size has to be used.

Intermediate virtual images were used in the evaluation of disparity inaccuracies. Sensitivity analysis was conducted to assess the effect of disparity inaccuracies in the virtual images. A visual error measure was proposed in order to approximate the subjective error perception of the human eye. Regarding the magnitude of the perturbations, PSNR values decreased exponentially with images that consist mainly of texture. Based on the simulation results, small perturbations – two or three pixels – produced the largest reduction in the PSNR value. However, the percentages of visual errors were more affected by the frequency of perturbations than by the magnitude of perturbations.

Although there was deterioration in the quality of virtual images that were created by using estimated disparity fields, these new intermediate images are perceived by the human eye as realistic. These results were obtained by using two low-complexity algorithms: a bidirectional local maximisation algorithm for disparity estimations and an intermediate image interpolation technique for creating virtual images. An important issue is the identification of areas of occlusion.

There is much scope for further research in this area. A strategy for detection of outliers using object information is required. Therefore, one line of future research will be to develop an error measure for the evaluation of the fundamental matrix estimation that provides a measure of scene geometry representation. Another direction will be to incorporate the meaning of the correlation score – quantity and sign – in the identification of occlusion areas and areas of discontinuity. Investigation is also required into the structure of spatial variability in correlation windows. This could be attempted using a Markov-Bayes model. Research is also required on the numerical stability of the system of linear equations used by Affine and Euclidean image synthesis.

As the biggest library if it is in disorder is not as useful as a small but well-arranged one, so you may accumulate a vast amount of knowledge but it will be of far less value than a much smaller amount if you have not thought it over for yourself.
(**Arthur Schopenhauer)**

REFERENCES

Ada2004 Adachi, Y., H. Tsunenari, Y. Matsumoto, and T. Ogasawara, Guide robot's navigation based on attention estimation using gaze information. In Proceedings IEEE/RSJ International Conference on Intelligent Robots and Systems, Vol. 1, 2004, pp. 540 - 545

Ade1991 Adelson E. H. and J. R. Bergen. The plenoptic function and the elements of early vision. In Chapter 1of Computational Models of Visual Processing Edited by Michael Landy and J. Anthony Movshon, MIT Press, Cambridge Mass. 1991

Ado2002 Adover J. G., R. A. Maronna and V. J. Yohai. Relation Between Maximum Depth and Projection Regression Estimates. In Journal of Statistical Planning and Inference. No. 105, 2002, pp. 363-375

Aka1974 Akaike, H. A New Look at the Statistical Identification Model. In IEEE Transaction on Automatic Control, Vol. 19, No. 6, 1974, pp. 716-723

Alv2000 Alvarez L., R. Deriche, Sanchez J., and J. Weickert. Dense Disparity Map Estimation Respecting Image Discontinuities: A PDE and Scale-Space Based Approach. INRIA Sophia-Antipolis RR-3874, 2000, 31 pages

Ara1998 Araujo H., Carceroni R. L., and C. Brown C. A Fully Projective Formulation to Improve the Accuracy of Low's Pose-Estimation Algorithm. Computer Vision and Image Understanding May 1998. Vol. 70, No 2, pp. 227-238

Arm2003 Armangué X., and J. Salvi. Overall View Regarding Fundamental Matrix Estimation. In Image and Vision Computing, Vol. 21, 2003, pp. 205-220

ASAE1983 ASAE. Robotics and intelligent machines in agriculture. In Proceedings 1st International Conference in Robotics and Intelligent Machines in Agriculture. America Society of Agricultural Engineers, Tampa, FL, 1983

Asc1963 Ascombe F. and Tukey J. W. The Examination and Analysis of Residuals. In Technometrics, 1963, pp. 141-160.

Avi2001 Avidan S. and Shashua A. Threading Fundamental Matrices. IEEE Transaction on Pattern Analysis and Machine Intelligence, Vol. 23, No. 1, 2001, pp. 73-77

Bad1978 Badler N. and Bajcsy R. Three-dimensional Representation for Computer Graphics and Computer Vision. In ACM SIGGRAPH 1978, pp. 153-160

Bad1996 Bad-Hadiashar A. and Suter D. Motion Estimation Using Robust Statistics. Monash University Australia, Technical Report MECSE-96-4, 1996

Bak1981 Baker H. H., and T. O. Binford. Depth from edge and intensity based stereo. In Proceedings 7th International Joint Conference in Artificial Intelligence, Vancouver Canada, 1981

Ber1988 Bertero M., T. A. Poggio, and Torre V. Ill-Posed Problems in Early Vision. In Proceedings IEEE (Special issue on computer vision) Vol. 76, No. 8, 1988, pp. 869-889

Ber1889 Bertrand J. Calcul des probabilities. Gauthier-Villars, Paris, 1889

Bes1992 Besl, P, and N. McKay. A Method for Registration of 3-D Shapes. In IEEE Transactions in Patterns Analysis and Machine Intelligence, Vol. 4, No. 2, 1992, pp. 239-256

Bha1998a Bhandarkar, S.M., T. D. Faust, and T. Mengjin. A computer vision system for lumber production planning. In Proceedings Fourth IEEE Workshop on Applications of Computer Vision, 1998, pp. 134 – 139

Bha1998b Bhat D. N., and S. K. Nayar. Ordinal Measures for Image Correspondence. In IEEE Transactions in Pattern Analysis and Machine Intelligence, Vol. 20, No. 4, 1998, pp. 415-423

Bir1996 Birchfield S., and C. Tomasi. Depth Discontinuities by Pixel-to-Pixel Stereo. Stanford University, Technical Report STAN-CS-TR-96-1573, 1996, 56 pages

Bir1998 Birchfield S., and C. Tomasi. A Pixel Dissimilarity Measure That Is Insensitive to Image Sampling. In IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 20, No. 4, 1988, pp. 401-406

Boa1922 Boas F. The Measurement of differences between variable quantities. In Journal of the American Statistical Association, Vol. 18, No. 140, 1922, pp. 425-445

Bob1998 Bober M., N. Georgis and J. Kittler. On Accurate and Robust Estimation of Fundamental Matrix. In Computer Vision and Image Understanding, Vol. 72, No. 1, 1998, pp. 39-53

Bou1995 Boufama B., and R. Mohr. Epipole and Fundamental Matrix Estimation using Virtual Parallax. In IEEE Fifth International Conference on Computer Vision, 1995, pp. 1030 -1036

Box1978 Box, G.E.P., W. G. Hunter, and J. S. Hunter. Statistics for Experiments: An Introduction to Design, Data Analysis, Model Building. John Wiley and Sons, New York, 1978

Boz1995 Boztas, S. and T. Sikora. Approximate Shape Adaptive KLT Transforms. Prepared for Heinrich Hertz Institute, Berlin, Germany, 1995, 16 pages

Bra2000 Brand, O., L. Petrak, D. Sturzebecher, and M. Zitterbart. Supporting tele-teaching: visualization aspects. In Proceedings of the 26th Euromicro Conference, Vol, 2, 2000 pp. 64 - 71

Cal2001 Calic J., Izquierdo E., "Towards Real-Time Shot Detection in the MPEG Compressed Domain", 3rd Workshop on Image Analysis for Multimedia Interactive Services, Tampere, Finland, 16-17 May 2001, Pages 1-5

Cal2002 Calic J., Izquierdo E., “Temporal Segmentation of MPEG Video Streams”, EURASIP Journal on Applied Signal Processing, Issue 6, Pages 561—565, 2002/6/26

Cal2002a Calic J., Izquierdo E., “A Multiresolution Technique for Video Indexing and Retrieval”, 2002 International Conference on Image Processing (ICIP 2002), Rochester, September 22-25, 2002, Volume 1, Pages 952—955

Cal2002b Calic J., Sav S., Izquierdo E., Marlow S., Murphy N., O'Connor N., "Temporal Video Segmentation For Real-Time Key Frame Extraction", 27th IEEE International Conference on Acoustics, Speech, and Signal Processing, Orlando, FL, 13-17 May 2002, Volume 4, Pages 3632-3635

Chi1995 Chiricozzi, E., F. Mancini,.G. Paladin, and I. Ruggieri. Procedures and classroom architectures for the development of tele-teaching activities. In Education, IEEE Transactions on, Vol. 38, Issue 1, 1995 pp. 83 – 89

CMU http://www-2.cs.cmu.edu/afs/cs.cmu.edu/project/cil/ftp/

Col1980 Coleman D., Holland P., Kaden N., Klema V., and Peters S.C. A System of Subroutines for Iteratively Reweighted Leas-Squares Computations. In ACM Transactions on Mathematical Software, Vol. 6, 1980, pp. 327-336

Cox1996 Cox I. J., S. L. Higorani, S.B. Rao, and B. M. Maggs. A Maximum Likelihood Stereo Algorithm. In Computer Vision and Image

Understanding, Vol. 63, No. 3, 1996, pp. 542-567

Cra2000 Cramariuc B., I. Shmulevich, M. Gabbouj, and A. Makela. A New Image Similarity Measure Based on Ordinal Correlation. In IEEE Proceeding International Conference on Image Processing, Vol. 3, 2000, pp. 718-721

Cre1993 Cressie N. Satatistics for Spatial Data. John Wiley and Sons,1993

Cro1998 Cross A. D. J., and E. R. Hancock. Graph Matching with a Dual-Step EM Algorithm. In IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 20, No. 11, 1998, pp. 1236-1253

Csu1997 Csurka G., C. Zeller, Z. Zhang, and O. D. Faugeras. Characterizing the Uncertainty of the Fundamental Matrix. In Computer Vision and Image Understanding, Vol. 68, No. 1, 1997, pp 18-36

Dor2002 Dorado A., Izquierdo E., "Fuzzy Color Signatures", IEEE Proceedings International Conference on Image Processing (ICIP 2002). Rochester, New York, 22-25 September 2002, Volume 1, Pages 433-436

Dor2003 Dorado A., Izquierdo E., "Semantic Labeling of Images Combining Color, Texture and Keywords", IEEE Proc. 10th International Conference on Image Processing, Barcelona, 14-18 September 2003, Pages 9-12

Dor2003a Dorado A., Izquierdo E., "Semi-Automatic Image Annotation Using Frequent Keyword Mining", IEEE Proceedings 7th International Conference on Information Visualisation (IV 2003). London, England, 16-18 July 2003, Pages 532-535

Dra1981 Draper and Smith. Applied Regression Analysis. 2nd ed. John Wiley and Sons, New York, 1981

Fau1986 Faugeras, O. D., and G Toscani. The Calibration Problem for Stereo. In Proceedings of Computer Vision and Pattern Recognition, Miami Florida, 1986, pp. 15-20

Fau1992 Faugeras, O. D., Q. T. Luong, and S. J. Maybank. Camera Self-Calibration: Theory and Experiments. In Proceedings European Conference on Computer Vision, 1992, pp. 321-334

Fau1993a Faugeras O. D. Three Dimensional Computer Vision: A geometric viewpoint, MIT Press, 1993

Fau1993b Faugeras O., B. Hotz, H. Mathieu, T. Viéville, Z. Zhang, P. Fua, E. Théron, L. Moll, G. Berry, J. Vuillemin, P. Bertin and C. Proy. Real Time Correlation-Based Stereo: Algorithm, Implementation, and

Applications. INRIA Sophia-Antipolis RR-2013, 1993, 49 pages

Fau1998 Faugeras O., and R. Keriven. Variational Principles, Surfce Evolution, PDF's, Level Set Methods, and the Stereo Problem. In IEEE Transactions on Image Processing, Vol. 7, No. 2, 1998, pp. 336-344

Fau2001 Faugeras O., and Luong Q-T. The Geometry of Multiple Images. MIT Press, 2001

Fis1981 Fischler M. A., and R. C. Bolles. Random Sample Consensus: A Paradigm for Model Fitting with Application to Image Analysis and Automated Cartography. In Communications of the ACM, Vol. 24, No. 6, 1981, pp. 381-395

Fle1996 Fleck M., D. Forsyth, and C. Pregler. Finding naked people [in images]. In Proceedings European Conference in Computer Vision, Springer-Verlag, New York, 1996, pp. 593-602

Fus1997 Fusiello A., V. Roberto, and E. Trucco. Efficient Stereo with Multiple Windowing. In IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 1997, pp. 858-863

Gal1885 Galton F. Regression Towards Mediocrity in Hereditary Stature. In Journal of the Anthropological Institute, No. 15, 1885, pp. 246-263

Gen1999 Genc Y. Weak Calibration and Image-Based Rendering Algorithm. PhD Thesis, University of Illinois at Urbana-Champaign, 1999.

Gen2001 Genc Y. and Ponce J. Image-based rendering using parameterized image varieties. International Journal of Computer Vision, Vol. 41, No. 3, 2001, pp. 143-170

Gid1987 Gideon R. A., and R. A. Hollister. A Rank Correlation Coefficient Resistant to Outliers. In Journal of the American Statistical Association, Vo. 82, No. 398, pp. 656-666

Gil1981 Gill, P. R., W. Murray, and M. H. Wright. The Levenberg-Marquardt Method. §4.7.3 in Practical Optimization, London: Academic Press, 1981, pp.136-137

Gir1993 Girod B. What's wrong with mean-squared error. In Digital Images and Human Vision, A. B. Watson, Ed. Cambridge, MA: MIT Press, 1993, pp. 207-220

Gol1996 Golub G. and C. F. Van Loan. Matrix Computations. John Hopkins, Baltimore, 1996

Gou2000 Goulermas J. Y. Evolutionary Techniques for the Stereo Correspondence Problem. PhD thesis, University of Manchester Institute of Science and Technology, 2000

Gou2003 Goulermas J. Y., and P. Liatsis. A Collective-Based Adaptive Symbiotic Model for Surface Reconstruction in Area-Based Stereo. In IEEE Transactions on Evolutionary Computation, Vol. 7, No. 5, 2003, pp. 482-502

Gou2005 Goulermas J. Y., and P. Liatsis. A Constrained Nonlinear Programming Framework for the Solution of the Stereo Correspondence Problem. Accepted in IEEE Transactions on Circuits and Systems for Video Technology, 2005

Gut2004 Gurtierrez S., and J. L. Marroquin. Robust Approach for Disparity Estimation in Stereo Vision. In ELSEVIER Image and Vision Computing, No. 22, 2004, pp. 183-195

Had1923 Hadamard J. Lectures on Cauchy's Problem. Yale University Press, New Haven, 1923

Han1998 Hansen, P. C. Rank-Deficient and Ill-Posed Problems, 2nd ed. SIAM, Philadelphia, 1998

Han1998 Hanke M., Izquierdo E., März R., "On Asymptotics in Case of Linear Index-2 Differential-Algebraic Equations", SIAM Journal on Numerical Analysis 1998, Volume 35, Issue 4, Pages 1326-1346

Har1997a Hartley R. Kruppa's Equations derived from the Fundamental Matrix. In IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 19, No. 2, February 1997, pp. 133-135

Har1997b Hartley R. In Defence of the Eight-Point Algorithm. In IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 19, No. 6, June 1997, pp. 580-593

Has2004 Hasinoff, S.W., S. B. Kang, and R. Szeliski. Boundary Matting for View Synthesis. In Conference on Computer Vision and Pattern Recognition Workshop, 2004, pp. 170 - 170

Haw1984 Hawkins D.M., Bradu D. and Kass G.V. Location of several outliers in multiple regression data using elemental sets. In Technometrics, Vol. 26, 1984, pp. 197-208

Hei2000 Heikkilä J. Geometric Camera Calibration Using Circular Control Points. In IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 22, No. 10, 2000, pp. 1066-1077

Hil2004 Hilton, A., and J. Starck**.** Multiple view reconstruction of people. In Proceedings 2nd International Symposium on 3D Data Processing, Visualization and Transmission, 3DPVT, 2004, pp. 357 - 364

Hua1989 Huang T. S. and O. D. Faugeras. Some Properties of the E-Matrix in Two-View Motion Estimation. In IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 11, No. 12, 1989, pp. 1310-1312

Hua1994 Huang T. S. and A. N. Netravali. Motion and Structure from Feature Correspondences: A Review. In Proceeding of the IEEE Vol. 82, No. 2, 1994, pp. 252-268

Hub1973 Huber, P.J. Robust regression: Asymptotics, conjectures and Monte Carlo. In The Annals of Statistics, Vol. 1, 1973, pp. 799-821

Hub1981 Huber, P.J. Robust Statistics. John Wiley & Sons, New York, 1981

Hun1919 Huntington E. V. Mathematics and Statistics, with and Elementary Account of the Correlation Coefficient and the Correlation Ratio. In The American Mathematical Monthly, Vol. 26, No. 10, 1919, pp. 421-435

Izq1995 Izquierdo E., Ernst M., “Motion/Disparity analysis for 3D-Video-Conference Applications”, 1995 International Workshop on Stereoscopy and 3-Dimensional Imaging, Santorini, Greece, September 1995

Izq1997 Izquierdo E. Stereo Matching for Enhanced Telepresence in Three-Dimensional Videocommunications. In IEEE Transactions on Circuits and System for Video Technology, Vol. 7, No. 4, 1997, pp. 629-643

Izq1998 Izquierdo E., Kruse S., "Image Analysis for 3D Modeling, Rendering, and Virtual View Generation", Elsevier Journal Computer Vision and Image Understanding, 1998, Volume 71, Issue 2, Pages 231-253

Izq1998a Izquierdo E., "Stereo Image Analysis for Multi-viewpoint Telepresence Applications", Elsevier Journal Signal Processing: Image Communication, Volume 11, Issue 3, Pages 231-254

Izq1999 Izquierdo E., Ghanbari M., "Nonlinear Gaussian filtering approach for object segmentation", IET Proceedings - Vision, Image and Signal Processing, Volume 146, Issue 3, Pages 137-143

Izq1999a Izquierdo E., Feng X., "Modeling Arbitrary Objects Based on Geometric Surface Conformity", IEEE Transactions on Circuits and Systems for Video Technology, Volume 9, Issue 2, Pages 336-352

Izq2000 Izquierdo E. and J.-R. Ohm, “Image-based rendering and 3D modelling: A complete framework”, In ELSEVIER Signal Processing Image Communication, No. 15, 2000, pp. 817-858

Izq2002 Izquierdo E. Computational Experiment with Area-Based Stereo for Image-Based Rendering. In Proceeding of the First International Symposium on 3D Data Processing Visualization and Transmission, 2002.

Izq2002a Izquierdo E. How accurate should be disparity estimated for image-based rendering? In International Symposium on Video/Image Processing and Multimedia Communications, Zadar, Croatia, 2002, pp. 69-74

Izq2002b Izquierdo E., "Using Invariant Image Features for Synchronization in

Spread Spectrum Image Watermarking", Springer EURASIP Journal on Advances in Signal Processing, Issue 4, Pages 412-419

Izq2002c Izquierdo E., Ghanbari M., "Key Components for an Advanced Segmentation System", IEEE Transactions on Multimedia, Volume 4, Issue 1, Pages 97-113

Izq2003 Izquierdo E., Guerra V., "An Ill-Posed Operator for Secure Image Authentication", IEEE Transactions on Circuits and Systems for Video Technology, Volume 13, Issue 8, Pages 842-852

Izq2003a Izquierdo E., Casas J., Leonardi R., Migliorati P., O'Connor N., Kompatsiaris I., Strintzis M., "Advanced Content-Based Semantic Scene Analysis and Information Retrieval: The Schema Project", 4th European Workshop on Image Analysis for Multimedia Interactive Services, World Scientific Publishing, London, England, 9-11 April 2003, Pages 519-528

Izq2003c Izquierdo E., and V. Guerra-Ones. Estimating the Essential Matrix by Efficient Linear Techniques. In IEEE Transactions on Circuits and Systems for Video Technology, Vol. 13, No. 9, 2003, pp. 925-935

Jac1924 Jackson D. The Algebra of Correlation. In The American Mathematical Monthly, Vol. 31, No. 3, 1924, pp. 100.121

Jac2002 Jacob, M., T. Blu, and M. Unser. 3-D reconstruction of DNA filaments from stereo cryo-electron micrographs. In Proceedings IEEE International Symposium on Biomedical Imaging. 2002, pp. 597 - 600

Jol1993 Jolion J.-M. Computer Vision Methodologies in Image Understanding, Vol. 59, No. 1, January 1994, pp. 53-71

Kaj1986 Kajiya J. T. The Rendering Equation. In ACM, Vol. 20, No. 4, 1986, pp. 143-150

Kan1994 Kanade T., and M. Okutomi. A Stereo Matching with an Adaptive Window: Theory and Experiment. In IEEE Transaction on Pattern Analysis and Machine Intelligence, Vol. 16, No. 9, 1994, pp. 920-932

Kan1995 Kanade T., P. J. Narayanan, and P. W. Rander. Virtualized Reality: Concepts and Early Results. In IEEE Proceedings Workshop on Representation of Visual Scenes, 1995, pp. 69-76

Kan1997 Kang S. B. A Survey of Image-based Rendering Techniques. Cambridge Research Laboratory, Technical Report Series, CRL97/4, 1997, 27 pages

Kan2000 Kanatani K. Optimal Fundamental Matrix Computation: Algorithm and Reliability Analysis. In 6th Symposium on Sensing via Image Information, 2000, Yokokahma, Japan

Kay2001 Kay S., Izquierdo E., "Robust Content Based Image Watermarking", 3rd Workshop on Image Analysis for Multimedia Interactive Services (WIAMIS 2001), Tampere, Finland, 16-17 May 2001, Pages 53-56

Ken1938 Kendal M. G. A New Measure of Rank Correlation. Biometrika, Vol. 30, No. 1/2, 1938, pp. 81-93

Kim1994 Kim, W. S. Virtual reality calibration for telerobotic servicing. In Proceedings IEEE International Conference on Robotics and Automation, 1994, pp. 2769 - 2775

Kim1996 Kim Y.S., K.P. Han, J. J. Lee and Y-H Ha. Robust 3D depth estimation using genetic algorithm in stereo pairs. In IEEE proceedings Asian Pacific Conference on Circuits and Systems, 1996, pp. 357-360

Kop1983 Kopydlowski D. 100% inspection of crossbars using machine vision. Publication MS83-210, Society of Manufacturing Engineers, Dearborn, MI, 1983

Kro1988 Krzanowski, W. J. Principles of Multivariate Analysis: A user's perspective. Oxford University Press, 2000

Kum1994 Kumar R. Robust Methods for Estimating Pose and a Sensitivity Analysis. In Image Understanding, Vol. 60, No. 3, 1995, pp. 313-342

Kut1998 Kutulakos K., and J. Valino Calibration-free augmented reality. In IEEE Transactions on Visualization and Computer Graphics, Vol. 4, No.1, 1998, pp. 1-20.

Lav1994 Laveau S., and O. Faugeras. 3-D Scene Representation as a Collection of Images and Fundamental Matrices. In INRIA Sophia-Antipolis RR-2205, 1994, 25 pages

Lee1994 Lee J. J., J-C Shim and Y-H Ha. Stereo correspondence using hopfield neural network of new energy function. In Pattern Recognition Vol. 27, 1994, pp. 1513-1522

Liu1990 Liu Y., T. S. Huang, and O. D. Faugeras. Determination of Camera Location from 2-D to 3-D Line and Point Correspondences. In IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 12, No. 1, 1999, pp. 28-37

Lon1981 Longuet-Higgins H. C., A computer Algorithm for Reconstructing a Scene from Two Projections. In Nature, Vol. 293, 1981, pp. 133-135

Lou1993a Loung Q.-T., and O. D. Faugeras. Determining the Fundamental Matrix with Planes: Instability and New Algorithms, in IEEE Proceedings Computer Vision and Pattern Recognition, 1993, pp. 489-494

Lou1993b Luong Q.-T., R. Deriche, O. Faugeras, and T. Papadopoulo. On Determining the Fundamental Matrix: Analysis of different methods and experimental results. In INRIA Sophia-Antipolis RR-1894, 1993, 28 pages

Lou1994 Loung Q.-T., and O. D. Faugeras. On the Direct Determination of Epipoles: a case study in algebraic methods for geometric problems, in

IEEE Proceedings of the 12th International Conference on Pattern Recognition, 1994. Vol. 1 - Conference A: Computer Vision & Image Processing - pp. 243 -247

Lou1996 Loung Q.-T., and O. D. Faugeras. The Fundamental Matrix: Theory, Algorithms, and Stability Analysis. In International Journal of Computer Vision, Vol. 17, 1996, pp. 43-75

Lou1998 Loung Q.-T., and O. D. Faugeras. On the Determination of Epipoles Using Cross-Ratios, in Computer Vision and Image Understanding, Vol. 71, No. 1, 1998, pp. 1-18

Mai1996 Maimone, M. W. Characterizing Stereo Matching Problems using Local Spatial Frequency. PhD thesis, Carnegie Mellon University, 1996

Mao2003 Maoyuan C., D. Zaili; and T. Yantao. A centralized tele-teaching system for industrial robots using virtual reality. In Proceedings IEEE International Symposium on Computational Intelligence in Robotics and Automation, Vol. 2, 2003 pp. 943 - 949

Mar1982 Marr D. Vision. Freeman, New York, 1982

May1992 Maybank S. J., and O. D. Faugeras. A Theory of Self-Calibration of Moving Cameras. In International Journal of Computer Vision, Vol. 8, No. 2, 1992, pp. 123-151

May2002 Maynes-Aminzade, D., R. Pausch, and S. Seitz. Techniques for interactive audience participation. In Proceedings. Fourth IEEE International Conference on Multimodal Interfaces, 2002, pp. 15 – 20

McM1995 McMillan L., and G. Bishop. Plenoptic Modelling: An Image-Based Rendering System. In Proceeding of SIGGRAPH 95, Los Angeles, California, 1995, pp. 39-46

Mil1996 Mili L. and Coakley C.W. Robust Estimation in Structured Linear Regression. In The Annals of Statistics, Vol. 24, No. 6, 1996, pp. 2593-2607

Mou2003 Mourgues F., T. Vieville, V. Falk, and È. Coste-Manière. Interactive guidance by image overlay in robot assisted coronary artery bypass. In Medical Image Computing and Computer Assisted Intervention, Montréal, Canada, 2003, Springer

Mra2004 Mrak M., Abhayaratne C., Izquierdo E., "On the influence of motion vector precision limiting in scalable video coding", IEEE Proceedings 7th International Conference on Signal Processing (ICSP 2004). Beijing, China, 31 August - 4 September 2004, Volume 2, Pages 1143-1146

Mra2005 Mrak M., Sprljan N., Izquierdo E., "Motion estimation in temporal subbands for quality scalable motion coding", IET Electronics Letters, Volume 41, Issue 19, Pages 1050-1051

Mró2004 Mrówka E., Dorado A., Pedrycz W., Izquierdo E., "Dimensionality Reduction for Content-Based Image Classification", IEEE Int. Conference on Information Visualisation, London, 14-16 July 2004, Pages 435-438

Mul2001 Mulligan J., V. Isler, and K. Daniilidis. Performance Evaluation of Stereo for Tele-presence. In IEEE Proceedings Eighth International Conference on Computer Vision, V2, 2001, pp. 558-565

Mun1992 Mundy J. L., and A. Zisserman. Geometric Invariance in Computer Vision, MIT Press, 1992

Mur2001 Murino V., U. Castellani, and A. Fusiello. Disparity Map Restoration by Integration of Confidence in Markov Random Fields Models. In IEEE International Conference on Image Processing, Vol. 2, 2001, pp. 29-32

Nor1989 Norton-Wayne, L., A. Mackellar, and C. Nicklin. Measurement of garment dimensions using machine vision. In Third International Conf. on Image Processing and its Applications, 1989, pp. 197 – 201

OCo2003 O'Connor N., Sav S., Adamek T., Mezaris V., Kompatsiaris I., Lui Z., Izquierdo E., Bennström C., Casas J., "Region and Object Segmentation Algorithms in the Qimera Segmentation Platform", 3rd International Workshop on Content-Based Multimedia Indexing (CBMI 2003), Rennes, France, 22-24 September 2003, Pages 1-8

Ohm1998a Ohm J. R., K. Grüneberg. E. Hendriks, M. E. Izquierdo, D. Kalivas, M. Karl, D. Papadimatos, and A. Redert. A Realtime Hardware System for Stereoscopic Videoconferencing with Viewpoint Adaptation. In Signal Processing Image Communication, Vol. 14, 1998, pp. 147-171

Ohm1998b Ohm J.-R., E. Izquierdo, and K. Müller. System for Disparity-Based Multiple-View Interpolation. In IEEE Proceedings International Symposium on Circuits and Systems, Vol. 5, 1998, pp. 502-505

Oht1985 Ohta Y., and T. Kanade. Stereo by intra- and inter-scaling search using dynamic programming. In IEEE Transaction on Pattern Analysis and Machine Intelligence, Vol. 7, 1985, pp. 139-154

O'Su2003 O'Sullivan **C.,** J. Dingliana**,** T**.** Giang**,** and M. K**.** Kaiser. Evaluating the visual fidelity of physically based animations. In ACM 2003, pp. 527-536**.**

Pea1895 Pearson K., Mathematical contribution to the theory of evolution III. Regression, heredity, and panmixia. In Philosophical Transaction of the Royal Society of London, series A. Vol. 187, 1896, pp. 253-318

Pea1914 Pearson K. On an Extension on the Method of Correlation by Grades or Ranks. In Biometrika, Vol. 10, No. 2/3, 1914, pp. 416-418

Pea1916 Pearson K. On Some Novel Properties of Partial and Multiple Correlation Coefficients in a Universe of Manifold Characteristics. In

Biometrika, Vol. 11, No. 3, 1916, pp. 231-238

Pea1920 Pearson K. Notes on the History of Correlation. In Biometrika, Vol. 13, No. 1, 1920, pp. 25-45

Pea1925 Pearson K. On First Power Methods of Finding Correlation. In Biometrika, Vol. 17, No. 3/4, 1925, pp. 459-469

Ped1999 Pedersen M. Functional Analysis in Applied Mathematics and Engineering. Chapman & Hall/ CRC, Boca Raton, Florida, 1999

Per2000 Pers, J.; and S. Kovacic. Computer vision system for tracking players in sports games. In IWISPA 2000. Proceedings of the First International Workshop on Image and Signal Processing and Analysis, 2000, pp. 177 – 182

Pin2000 Pinheiro A., Izquierdo E., Ghanhari M., "Shape Matching using a Curvature Based Polygonal Approximation in Scale-Space", IEEE Proceedings International Conference on Image Processing (ICIP 2000). Vancouver, BC, 10-13 September 2000, Volume 2, Pages 538-541

Pog1981 Poggio T. Marr's Computational Approach to Vision in Trends Neuro Science, Vol. 4, No. 10, 1981, pp. 258-262

Pop2001 Popescu V. Forward Rasterization: A Reconstruction Algorithm for Image-Based Rendering. PhD Thesis, University of North Carolina at Chapel Hill, 2001

Pos2001 Pose, R. Steerable interactive television: virtual reality technology changes user interfaces of viewers and of program producers. In Proceedings. Second Australasian User Interface Conference AUIC, 2001, pp. 77 - 84

Reg1994 Regan M., and R. Pose. Priority Rendering with a Virtual Reality Address Recalculation Pipeline. In ACM SIGGRAPH, 1994, pp. 155-162

Rig1995 Rigoutsos I. and R. Hummel. A Bayesian Approach to Model Matching with Geometric Hashing. In Computer Vision and Image Understanding, Vol. 62, No. 1, 1995, pp. 11-26

Rod1988 Rodgers J. L., and A. Nicewander. Thirteen Ways to Look at the Correlation Coefficient. In The American Statistician, Vol. 42, No. 1, 1988, pp. 59-66

Ros1993 Rosin P. L. A note on the least squares fitting of ellipses. In Patter Recogniyion Letters, Elsevier Science Publishers, Vol. 14, 1993, pp. 799-808

Rou1984a Rousseeuw P. J. Least Median of Squares Regression. In Journal of the American Statistical Association, Vol. 79, 1984, pp. 871-880

Rou1984b Rousseuw P. J. and Yohai V. Robust Regression by Means of S-estimators. In Robust and Non-linear Time Series Analysis, edited by J. Franke, W Hardle and R. D. Martin, Lecture Notes in Statistics, Springer Verlag, Vol. 26, 1984

Rou1987 Rousseeuw P. J. and Leroy A. M. Robust Regression and Outlier Detection. Wiley-Interscience (Series in Applied Probability and Statistics), New York, 1987

Sch1996 Scharstein D. Stereo Vision for View Synthesis. In IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 1996, pp. 852-858

Sch1999 Scherer S., P. Werth, and A. Pinz. The Discriminatory Power of Ordinal Measures - Towards a New Coefficient. In IEEE Computer Society Conference on Computer Vision and Pattern Recognition, Vol. 1, 1999, pp. 76-81

Sch2001 Scharstein D., and R. Szeliski. A Taxonomy and Evaluation of Dense Two-Frame Stereo Correspondence Algorithms. In Microsoft Corporation, Technical Report MSR-TR-2001-81, 2001, 59 pages

Sch2001a Scharstein D., R. Szeliski, and R. Zabih. A Taxonomy and Evaluation of Dense Two-Frame Stereo Correspondence Algorithms. In IEEE Proceeding of the Workshop on Stereo and Multi-Baseline Vision, 2001, pp. 131-140

Sch2003 Scharstein D., and R. Szeliski. High-Accuracy Stereo Depth Maps Using Structure Light. In IEEE Computer Society Conference on Computer Vision and Patter Recognition, Vol. 1, 2003, pp. 195-202

Sch2003a Schreer O., N. Atzpadin, S. Askar, and P. Kauff. Advanced 3D Signal Processing for Virtual Team User Environments. In IEEE International Conference on Multimedia and Expo, Vol. 2 , 2003, pp. 61-64

Sem1963 Semple J. G. and Kneebone G. T. Algebraic projective geometry. Oxford at the Clarendon Press. London, 1963

Sha2002 Shao J. Generation of Temporally Consistent Multiple Virtual Camera Views from Stereoscopic Image Sequences. In International Journal of Computer Vision, Vol. 47, No. 1/2/3/, 2002, pp. 171-180

Si-J2004 Si-Jung K., J. Moon-Sung, K. Hong-Sic, and K. Tae-Yong. A development of interactive game "Ting Ting" using real and virtual objects. In IEEE International Conference on Systems, Man and Cybernetics, Vol. 2, 2004, pp. 1191 - 1197

Sim1999 Simshoni I., Basri R. and Rivlin E. A Geometric Interpretation of Week-Perspective Motion. IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 21, No. 3, 1999, pp. 252-257

Smo2005 Smolić A., P. Kauff. Interactive 3-D Video Representation and Coding Technologies. In Proceeding of the IEEE, Vol. 93, No. 1, 2005, pp. 98-110.

Sop1917 Soper H. E., A. W. Young, B. M. Cave, A. Lee, and K. Pearson. On The Distribution of the Correlation Coefficient in Small Samples. Appendix II to the Papers of Student and R. A. Fisher. In Biometrika, Vol. 11, No. 4, 1917, pp. 328-413

Spr2005 Sprljan N., Mrak M., Abhayaratne C., Izquierdo E., "A Scalable Coding Framework for Efficient Video Adaptation", 6th International Workshop on Image Analysis for Multimedia Interactive Services (WIAMIS 2005). Montreux, Switzerland, 2005, 13-15 April 2005, Pages 1-4

Teo2004 Teo P. C., D. J. Heeger. Perceptual image distortion. In Proceedings of SPIE Human Vision, Visual Processing and Digital Display, Vol. 2179, 1994, pp. pp. 127-141

Tom1998 Tomasi C., and R. Manduchi. Stereo Matching a Nearest-Neighbour Problem. In IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 20, No. 3, 1988, pp. 333-340

Tor1995a Torr P. H. S., A. Zisserman, and S. J. Maybank. Robust Detection of Degenerate Configuration for the Fundamental Matrix. In IEEE Proceedings Fifth International Conference on Computer Vision, 1995, pp. 1037-1042

Tor1995b Torr P. H. S. Motion Segmentation and Outlier Detection. PhD Thesis, Balliol College University of Oxford, 1995

Tor1996 Torr O. H. S., and D. W. Murray. The Development and Comparison of Robust Methods for Estimating the Fundamental Matrix. In Int. J. Computer Vision, 1996, pp. 1-33

Tor1998 Torr P. H. S., A. Zisserman, and S. J. Maybank. Robust Detection of Degenerate Configuration while Estimating the Fundamental Matrix. In Computer Vision and Image Understanding, Vol. 71, No. 3, 1998, pp. 312-333

Tru1999 Trucco E., A. Fusiello, and V. Roberto. Robust Motion and Correspondence of Noisy 3-D Point Sets with Missing Data. In ELSEVIER Pattern Recognition Letters, Vol. 20, 1999, pp. 889-898

Tru2003a M. Trujillo and E. Izquierdo. KLT-Based Linear Scaling for the Estimation of the Fundamental Matrix. In 4th European workshop on Image Analysis for Multimedia Interactive Services, London, 2003

Tru2003b M. Trujillo & E. Izquierdo, "Robust Estimation of the Fundamental Matrix by Exploiting Disparity Redundancies", 3rd IASTED International Conference on Visualization, Imaging and Image

Processing, VIIP, Benalmadena, Spain, 2003

Tru2004a M. Trujillo & E. Izquierdo, "Improving the Efficiency of a LMedS Schema for the Estimation of the Fundamental Matrix", International Journal of Pattern Recognition and Artificial Intelligence, 2004

Tru2004b M. Trujillo and E. Izquierdo, "A Robust Correlation Measure for the Correspondence Estimation", IEEE in cooperation with Eurographics and ACM SIGGRAPH, the second International Symposium on 3DPVT (3D Data Processing, Visualization, and Transmission) Greece, 2004

Tru2005a M. Trujillo & E. Izquierdo, "Combining K-Means and Semivariogram-Based Grid Clustering". In International Symposium on Video/Image Processing and Multimedia Communications, Zadar, Croatia, 2005

Tru2005b M. Trujillo and E. Izquierdo, "Sensitivity Analysis in Image Synthesis". In Proceedings Second International Conference on Vision, Video and Graphics –VVG05 – Edinburgh, UK, 2005

Tsa1982 Tsai R. Y., and T. S. Huang. Estimating three-dimensional motion parameters of a rigid planar patch. II: singular value decomposition. In IEEE Transaction on Acoustic, Speech and Signal Processing, Vol. 30, 1982.

Tsa1986 Tsai, R. Y. An efficient and accurate camera calibration technique for 3-D machine vision. In IEEE proceedings CVPR86, Miami Florida, 1986, pp. 364 -374

Tuk1977 Tukey, J. Exploratory Data Analysis. Addison-Wesley, 1977

Ull1991 Ullman S. and Basri R. Recognition by linear combination of models. IEEE Transaction on Pattern Analysis and Machine Intelligence, Vol. 13, No. 10, 1999, pp. 992-1006

Urs1980 Ursin, B. Asymptotic convergence properties of the extended Kalman filter using filtered state estimates. In IEEE Transactions on Automatic Control, Vol. 25, Issue 6, 1980, pp. 1207 – 1211

Van1996 van den Braden Ch. J., Farrel J. E. Perceptual quality metric for digitally coded color images. In Proceedings of the European Signal Processing Conference. Trieste, Italy, 1996, pp. 1175-1178

Wan2003 Wang Y., Izquierdo E., "High-Capacity Data Hiding in MPEG-2 Compressed Video", 9th International Workshop on Systems, Signals and Image Processing, World Scientific, Manchester, 7-8 November 2002, Pages 212-218

Wat1933 Watkins G. P. An Ordinal Index of Correlation. In Journal of the American Statistical Association, Vol. 28, No. 182, 1933, pp. 139-151

Wei1927 Weida F. M. On Various Conceptions of Correlation. In The Annals of Mathematics, 2nd series, Vol. 29, No. 1/4, 1927-1928, pp. 276-312

Wen1989 Weng J., T. S. Huang, and N. Ahula. Motion and Structure from Two Perspective Views: Algorithms, Error Analysis, and Error Estimation. In IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 11, No. 5, May 1989, pp 541-476

Wen1992 Weng J., N. Ahuja, and T. S. Huang. Matching Two Perspective Views. In IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 14, No. 8, 1992, pp. 806-825

Wer1995 Werner T., R. D. Hersch, and V. Slavá?. Rendering Real-World Objects Using View Interpolation. In IEEE International Conference in Computer Vision, 1995, pp. 957-962

Wex2000 Wexler, Y., A. Shashua. On the synthesis of dynamic scenes from reference views. In Proceedings IEEE Conference on Computer Vision and Pattern Recognition, Vol. 1, 2000, pp. 576 - 581

Whi2003 Whitehorn, M., T. Vincent, and C. H. Debrunner. Steele, J.;Stereo vision in LHD automation. In IEEE Transactions on Industry Applications, Vol. 39, Issue 1, 2003, pp. 21 – 29

Wu2002 Wu X., R. Shao, and Y. Zhu. New Interactive Improvement of a Solution for an Ill-Conditioned System of Linear Equations Based on a Linear Dynamic System. In PERGAMON Computer and Mathematics with Applications, Vol. 44, 2002, pp. 1109-1116

Wys1982 Wyszecki G., and W. S. Stiles. Color Science. John Wiley and Sons, 1982, pp. 567-570

Yic1999 Yicong L., T. Kirubarajan, Y. Bar-Shalom, and M. Yeddanapudi. Trajectory and launch point estimation for ballistic missiles from boost phase LOS measurements. In Proceedings IEEE Aerospace Conference, 1999 pp. 425 - 442

You2003 Young-Suk Sh. Virtual experiment environments design for science education. In Proceedings International Conference on Cyberworlds, 2003 pp. 388 - 395

Xu1996 Xu G., and Z. Zhang. Epipolar Geometry in Stereo, Motion and Object Recognition A Unified Approach. Kluwer, Netherlands, 1996

Yoh1987 Yohai V. J. High Breakdown Point and High Efficiency Robust Estimates for Regression. In The Annals of Statistics, Vol. 15, 1987, pp. 624-656

Yoh1997 Yohai V. J. and Zamar R.H. Optimal Locally Robust M-Estimate of Regression. In Journal of Statistics Planning and Inference, Vol. 64, 1997, pp. 309-323

Zab1994 Zabih R., and J. Woodfill. Non-parametric Local Transforms for Computing Visual Correspondence. In Third European Conference on Computer Vision, Stockholm, Sweden, 1994

Zga2005 Zgaljic T., Sprljan N., Izquierdo E., "Bitstream Syntax Description based Adaptation of Scalable Video", 2nd European Workshop on the Integration of Knowledge, Semantics and Digital Media Technology (EWIMT 2005). London, England, 30 November - 1 December 2005

Zha1994 Zhang Z., R. Deriche, O. Faugeras, and Q.-T. Luong. A Robust Techniques for Matching Two Uncalibrated Images Through the Recovery of Unknown Epipolar Geometry. INRIA Sophia-Antipolis RR-2273, 1994, 38 pages

Zha1996 Zhang A. Determining the Epipolar Geometry and its Uncertainty: A Review. INRIA Sophia-Antipolis RR-2927, 1996

Zha1997a Zhang Z. Parameter Estimation Techniques: A tutorial with application to conic fitting. In Image and Vision Comp. No. 15, 1997, pp. 59- 76

Zha1997b Zhang Z. and Xu G. A Unified Theory of Uncalibrated Stereo for Both Perspective and Affine Cameras. In Journal of Mathematical Imaging and Vision, 1997, pp. 1-17

Zha1998 Zhang Z. A Flexible New Technique for Camera Calibration. Microsoft Research Technical Report MSR-TR-98-71, December 2, 1998. Last Updated Aug. 10, 2002

Zha2001 Zhang Z., and C. Loop. Estimating the Fundamental Matrix by Transforming Image Points in Projective Space. In Computer Vision and Image Understanding, Vol. 82, No. 2, 2001, pp. 174-180

Zha2003 Zhang C., and T. Chen. A Survey on Image-Based Rendering - representation, sampling and compression. Carnegie Mellon University, Technical Report AMP 03-03, 2003, 45 pages

Zhu1992 Zhuang X., T. Wang, and P. Zhang. A highly robust estimation through partially likelihood function modelling and its application in computer vision. In IEEE Transaction on Pattern Analysis and Machine Intelligence, Vol. 14, No. 1, 1992, pp. 19-34

Zit2000 Zitnick, C. L., and T. Kanade. A Cooperative Algorithm for Stereo Matching and Occlusion Detection. In IEEE on Pattern Analysis and Machine Intelligence, Vol. 22, No. 7, 2000, pp. 675-684