Research on the Application of Video Frequency Correction Based On Sport Football Match

Hean LIU, Sainan XIAO
School of Information Science & Engineering, Hunan City University, Yiyang, 413000, CHINA

Abstract: In the traditional soccer video, it is difficult for the camera calibration technology to calibrate and provides the object's three-dimensional height information and other issues, so this paper puts forward camera's auto-calibration algorithm in soccer video. First of all, the two-dimensional model and three-dimensional model of the court are defined and the improved the detection algorithm of court lines obtains the feature points in the court plane to solve camera's isomorphic matrix, and then the solved isomorphic matrix is used to calibrate the goal and obtain the two feature points in the goal plan. Finally, the optimal internal and external parameters of camera are got from the method based on k-means clustering and Hough-like search. The court line detection and the detection experiment of the 3D – 2D camera are conducted, and the simulation experiments show that the improved court line detection algorithm can effectively improve the site regional classification in soccer video (> 98%), and the accuracy of court line detection (> 93%).

Keywords: Three-dimensional reconstruction; Mapping; Competition video; Edge pixels

1. Introduction

The brightness of each point on the image reflects some points' reflected light intensity on space surface, and the location of that point in the image is related to the geometry position on the object surface of space. These parameters must be determined by experiment and calculation, experiment and calculation process is called camera calibration[1-3]. Computer vision system involves the use of computer and CCD camera imaging device, so that it can automatically obtain the natural scenery in front of the camera, it provides a very simple method to record or observe the three-dimensional scene, but in terms of their characteristics, it will lose a lot of information by projecting 3 d scene to two-dimensional images, 3 d computer vision system should be able start from the image information got by the camera, reconstruct the location of the 3 d scene Shape geometry information, and thus recognized objects in the environment, here are a few standard of scene reconstruction based on different geometry, they respectively are projective reconstruction, affine reconstruction and metric reconstruction, different visual tasks need reconstruction of different types, however, to human observers, in order to be able to realistically reflect the original scene, most occasions need to get the 3 d metric reconstruction of the scene, to conduct metric reconstruction of scene using computer, it must be conducted prior to the camera calibration[4-8].

In the research field of Photogrammetry and computer vision, video camera calibration technology will increasingly play an important role. If you can find the feature points in soccer video image frame and its corresponding coordinates in the 3D world according to the geometric model of camera imaging, and work out the internal and external parameters of camera precisely, it will be good to promote further application research [9-11].

In order to solve the problems in the camera calibration, this paper first defines two course model, the two-dimensional model and three-dimensional model of the court, on this basis, this paper proposes a camera automatic calibration method based on pitch model to accurate solving the internal and external parameters of camera in broadcast soccer video, this method includes two steps, namely 2D - 2D camera calibration and 3D - 2D camera calibration (as shown in figure 1). In 2D - 2D camera calibration, this paper proposes an improved detection algorithm of pitch line to locate the court line of different area in soccer video, and use the detected pitch line's intersection as feature points to calculate 2D - 2D isomorphic matrix. In 3D - 2D camera calibration, first of all, using the isomorphic matrix which have been solved in step 1, combining with the algorithm of goalposts region growth to locate the goal posts of a video frame, and then, to get the 3D - 2D camera internal and external parameters' initial values by increasing the two feature points formed by the intersection of goalposts and beams, and finally, using a kind of algorithm based on k-means clustering and Hough - like search to obtain more accurate inside and outside parameters of camera.

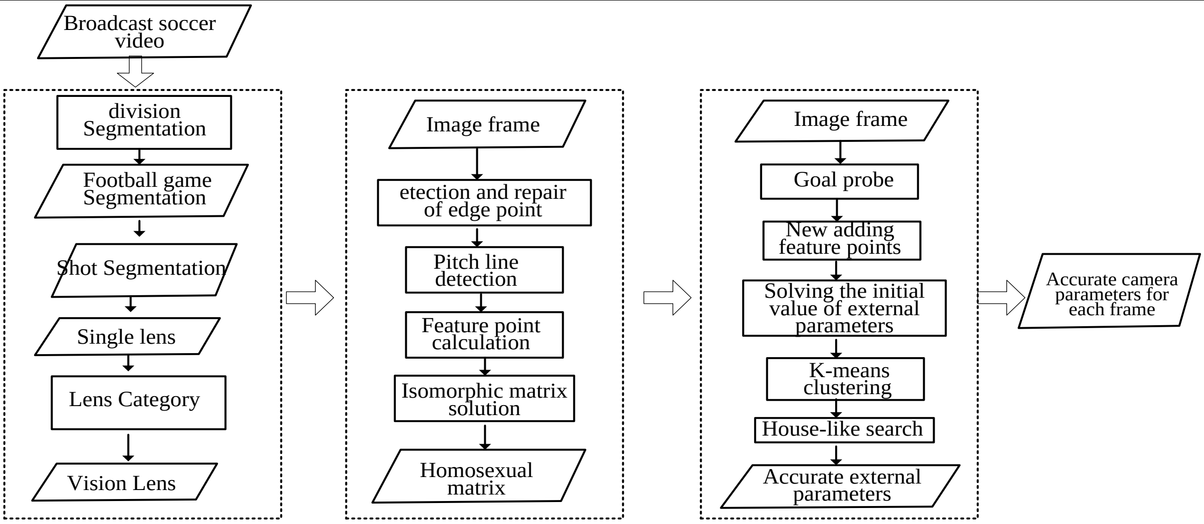


Figure 1. The technological progress chart of camera automatic calibration method

2. Mapping and Model

2.1. 3D–2D Camera Mapping

In 3D-2D camera calibration, the camera can be regarded as a mapping from 3D real world to 2D image space, in particular, in the video of broadcast football, from the point of 3D field, to soccer video image frames coordinates of Euclidean transformation is shown in figure 2. Among them, the world coordinate system is formed by three axes w_x, w_y, w_z , the camera coordinate system is formed by three axes c_x, c_y, c_z , the image coordinate system is formed by two axes i_x, i_y . The world coordinate system and the camera coordinate system can be transformed through the axis of rotation and translation. O point for camera light heart, starting from point O along the c_z axis is in the camera optical axis, o_0 for the camera focal length. If define any point of the world coordinate system T can be expressed by 4 d with conformal array (x, y, z, i) T, and any point of the image coordinates t can be created by 3D with array (x, y, z) (their corresponding Euclidean coordinates is $(x/z, y/z,)$, P is 3 X 4 camera projection matrix, then the mapping from the point T in 3D world to the point t in 2D image frame can be simply described as t = PT.

2.2. 3D Field Model and 2D Model of the Stadium

According to FIFA for the football match rules, we know the midcourt line of football stadium (in addition to the line and the bottom line) and the position of the goal and length are fixed, therefore, can be set according to the rules of court lines and the goal to build the stadium model. This paper defined the 2D field model (Figure 2) (a) for all pitch line in the pitch plane (mainly has foul line, bottom line, ban line ,midcourt line, and circle, etc.) in the penalty area formed by the area, among them, the location of the pitch line in accordance with the rules of the game set, its length is carried out in accordance with the rules set by the length of scaling, and we will make the pitch lines' intersection as the feature points of camera calibration. Unlike existing work, in addition to actual intersection of the pitch line (hollow white point of Figure 2), we also extended the field lines or increase the virtual line to get some virtual node (solid black spots of Figure 2), thereby increasing the feature points which can be used for camera calibration.2D football field model and the corresponding feature points in the image frames as shown in figure 3.

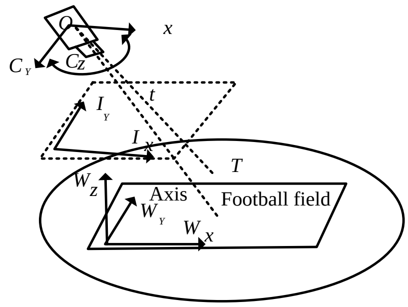


Figure 2. Transformation in soccer video from 3D world coordinates to 2D image coordinate

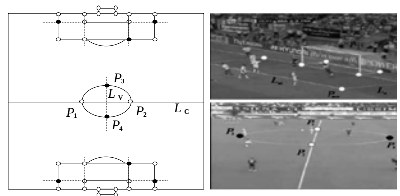
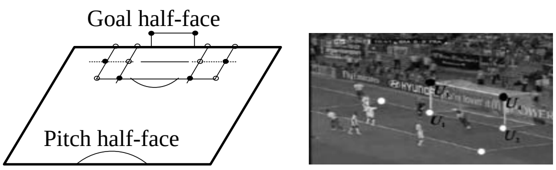


Figure 3. 2D football field model ((a)) and the corresponding feature points in the image frames ((b))

On this basis, this paper also defines the 3D field model (figure 4 (a)), it includes two perpendicular plane, namely the pitch plane and the goal plane, the pitch plane set is the same with 2D model, the goal plane is according to the football match rules set and corresponding reduction. With the need of not coplanar feature points in the process of 3D - 2D camera calibration, we can increase two points of intersection between the beam and post of goal plane (solid black spots in figure 4) as the feature points to achieve the extraction of 3D information. 3D football field model and the corresponding feature points in the image frames as shown in Figure 4.



(a) (b)

Figure 4. 3D football field model ((a)) and the corresponding feature points in the image frames ((b))

3. 2D - 2D Camera Calibration

Once you determine the field area of the current image frame, and using edge detection and repair algorithm to get the edge of the robust image, Hough transform can be applied to the left/right of the goal area to detect a straight line, in the midfield area using ellipse matching algorithm to match.

Because in the rebroadcast process of the football game, the camera position is fixed, this makes the pitch line of the left and right goal area will appear at a fixed Angle, therefore, can assume a range of stadium line's slope Angle in Hough straight line detection, in the experiment, we limit on both sides of the pitch line parameter θ meet their goal of $67^0 \prec \theta \prec 85^0 \prec \theta \prec -65^0$. In addition, this article also further improve the pitch line detection accuracy through introduced the parallel constraint and repeat line removal, the limit to detect at least two parallel $\left(|\theta_1 - \theta_2| \prec 10^0\right)$ pitch line, and the straight line $\left(|\theta_1 - \theta_2| \prec 10^0 \; and \; |d_1 - d_2| \prec 5_n\right)$ of the similar parameters is considered to be repeated, only one will be preserved.

In the midfield area, in order to remove the unrelated linear, the parameters restricted to the midline must meet |θ| < 10. In addition, because the ellipse matching algorithm is sensitive to noise, so only running ellipse matching algorithms when precise detection to the vertical Central Line, and, because the coil is symmetrical relative to the center line, you can also use the midline to filter the asymmetric edge points. The experimental results of the pitch line positioning are shown in Figure 5.

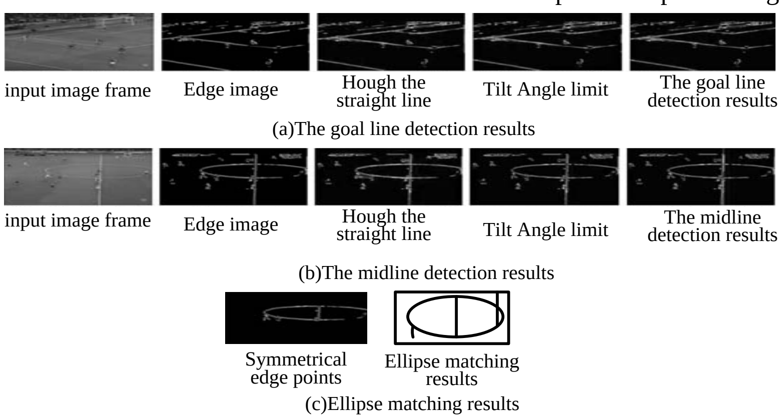


Figure 5. Experiment results diagram of the pitch line positioning

4. 3D - 2D Camera Calibration

4.1. Feature Point's Detection Algorithm of Goal Plane

In order to solve the position of the goalplane's feature points in the image frame, namely μ_3 and μ_4' in figure 4 (b), in this paper, a kind of ball post growth algorithm was proposed based on color to locate the node position between post and beam. Left goalposts' feature point's location as shown in algorithm 2, similarly, we'll be able to locate the right goalposts' feature point. In the experiments, in order to solve some of the non-white object (such as athletes) for goalposts shade problem, this algorithm allows the goalposts growth can be up to over 20 pixels. Figure 7 is the experimental results figure of the goalposts growth based on the color, which figure (a), to the left goalposts growth figure 8 (b) for the right goalposts growth, figure 7 (c) is for the situation which is sheltered by athletes.

Algorithm 1

Step 1 Set up the left goal posts' point set PSL, and $\mu_1 \in PSL$;

Step 2 At last the coordinates of a point from PSL goalposts growth up, if the adjacent pixels meet R > 150 and G > 150 and B > 150, it will join the PSL point and repeat step 3, otherwise it will be added to the left goalpost point at which a candidate point set CP SL and go to step 3;

Step 43 If Num(CPSL) ≤ 20, At last the coordinates of a point from CPSL goalposts growth up, if the adjacent pixels meet R > 150 & G > 150 & B >150, that point and all points in the CPSL will join the PSL, and then to empty CPSL and go to step 3, otherwise it will join the CPSL and repeat step 4; If Num(CPSL) > 20, the end of the algorithm, the last point's coordinate in PSL is the endpoint of left goalpost μ_3 coordinates.

(a) (b) (c)

Figure 6. Experimental results graph of the ball post growth based on the color figure ((a) left goalposts increase; (b) the goalposts increase; (c) the situation of being covered)

4.2. Precise Calculation of Camera's Internal and External Parameters

First, define two types of camera parameters, namely, the parameters of shot change and frame changes. The so-called shot change parameters (namely c, μ_0, v_0, γ, s) refers to this kind of camera parameter values only changes over the lens, that is to say, this the same lens image frames are the same in this kind of parameters; And frame change parameters ($i, e.., r, f$) suggests that this kind of camera parameter values will change with the change of image frames.

As it has been got 4 coordinates of feature points of the pitch plane (3), and locate two point's coordinates μ_3 and μ_4 of the goal plane (section 4.1), thus it can also use the method of the direct linear transformation to solve the initial values PI of camera matrix, then according to the type (2) for factoring p_i . Assume that a single lens $s_i\left(i=1,2,...,m\right)$ totally contains N image frames F $s_{ij}(j=1,2,...n)$, and the initial value of each image frame camera parameters is $\left\{CF\ S_{ij}, \mu_{of}\ s_{ij}, v_{of}\ s_{ij}, \gamma_f\ s_{ij}, RF\ s_{ij}, fe\, s_{ij}\right\}$.

In theory, the value of Camera parameter's change in a single lens is unchanged, but in practice, due to factors such as error in feature point calculation caused the fluctuation of camera lens change parameter values, In order to improve the accuracy of parameters of camera lens change, the lens Si shot change parameter of each image frames respectively for k-means clustering $CF\ S_{ij}$, $\mu_{of}\ s_{ij}$, $v_{of}\ s_{ij}, \gamma_f\ s_{ij}, s_e\ s_{ij}\left(j=1,2,...n\right)$, the lens changing parameters is respectively marked for $\bar{c}\,s_i$, $\bar{u}\,os_i$, $\bar{v}\,os_i$, $\bar{\gamma}\,s_i$, $\bar{s}\,s_i$, after classification, then, these similar center will instead lens Si change parameters of each image frames $F\ s_{ij}$, namely

CF $s_{ij}=\bar{c}\,s_i$, $\mu_{of}\ s_{ij}=\bar{\mu}o\,s_i$, $v_{of}\ s_{ij}=\bar{v}\,s_i$, $\gamma_e\ s_{ij}=\bar{r}\,s_i$, $s_f=\bar{s}\,s_i$, the camera parameters which got after being instead is called the improved camera parameters' initial value P0.

After got the camera parameter values P, three-dimensional pitch model M3D can be projected back to the source image IS, get the model projection IP RO(P, M3D). Due to the estimation error of camera matrix will lead to the difference between source image and the model projection, therefore, in order to improve the frame change parameters of camera, it can find the optimal values of frame changes based on a function of pitch matching, the optimal value can make the source image and projection model of maximum matching values.

5. Experiments and analysis

5.1. Calibration Experiment of 3D - 2D Camera

Table 3 is the experimental instances of clustering center of camera change parameters, among them, the coordinates of the camera center ($\bar{x}\,s_i, \bar{y}\,s_i, \bar{z}\,s_i$) is the world coordinate system 's coordinate(the world coordinate system's origin at the middle of the goal model), the unit is meters. You can see from table 3, broadcast football game's main cameras generally located in the midline extension cord ($\bar{x}\,s_i \approx 0$) near the podium, but the specific location will varies according to the site, such as the premier league games are in professional football (no runway near the soccer course), therefore, the main camera position closer to the center ($e,...g, \bar{y}\,s_i$ of camera 2 is smaller), and the Olympic football games are in comprehensive stadium (have runway near the soccer course), so the main camera position is further to the center ($\bar{y}\,s_i$ of camera 2 is bigger).

Table 1. CLUSTERING CENTER INSTANCE OF CAMERAS CHANGE PARAMETER

lens	$\bar{c}s_{s_i}(\bar{x}s_i,\bar{y}s_i,\bar{z}s_i)$	$\bar{v}o_{s_i}$	$\bar{r}o_{s_i}$	$\bar{\mu}o_{s_i}$	$\bar{s}o_{s_i}$
Lens 1	(0.039,63.1,12.4)	269.01	-69.01	0.988	0.114
Lens 2	(0.087,57.3,9.8)	149.05	-73.59	0.953	0.105
Lens 3	(0.042,,73.2,12.4)	245.04	-65.02	0.918	0.140
Lens 4	(0.049,59.01,10.3)	170.02	-73.61	0.988	0.096
Lens 5	(0.0991,69.01,15.3)	256.35	-66.02	0.972	0.110

Table 2. COMPARISON OF CAMERA PROJECTION MATRIX INITIAL VALUE IMPROVED VALUE AND THE ACCURACY OF THE OPTIMAL VALUE

	1	2	3	4	5	6	7	8	9	10
$A_{PMp_{pt}}$	938	807.5	839	530	904	622	856	923	846	727.7
$A_{PMp_{po}}$	946.3	813.3	820.1	823.5	887	601.3	800.6	903	813.2	708
$A_{PMp_{opt}}$	978	829	893.1	893.4	892	699	836.7	958	897	768
$IP\%$	3.54	2.47	6.68	4.51	-1.01	-13.06	-2.07	3.78	6.07	5.47

The same as the section 5.2, it is hard to get real values of soccer video camera projection matrix P, therefore, in order to test the performance of the algorithm. 3, still measure the accuracy of the projection matrix P by calculating pitch matching function PMF (IS, IP RO (P, M3D)) (formula (8)).

Specific process is: first, using the method of section 4.1 and section 4.2 to get each image frames $FS_{ij}(j=1,2,...,n)$ in lens Si 's initial projection matrix p_{ij} and improve the initial value P0j of the camera parameters, and then calculate the corresponding matching pitch values of projection matrix and the notes for $PMF\ p_{ij}$ and $PMF\ p_{oj}$ respectively, finally, the algorithm 3 are used to get the optimal camera projection matrix P_{optj} and matching and calculating the corresponding field value $PMF\ pop_{tj}$. Make the AP MFPI for the average of $PMF\ p_{ij}$ in all the lens, the $AP\ MFPI = \sum_n^j P\,MFPI_j / n = 1$, the same can be got AP MFP0 and AP MFP_{opt} . Table 4 is compared to AP MFPI, AP MFP0 and AP MFP_{opt} in the ten lenses, among them, the last line is the increase percentage of field matching values, namely IP % = AP MFP_{opt} − AP MFPI/AP MFPI×100 %. Seen from table 4 that APMFPI and APMFP0 value has no significant difference, and even many times APMFP0 value is lower than APMFPI, therefore, It needs use algorithm 3 to get the optimal cameras matrix. Most of the lens in table 4 (except the lens 5, and 7), $APMFP_{opt}$ value is improved compared to APMFPI (average percentage increase 4.32%), through the further analysis to lens 7 and 5 found that the main reason is that the camera parameters' global optimal value is not contained the constructed Hough space which $\mu_{es}\ p_{oj}$ as the initial value, which leads to algorithm 3 can only find the local optimal value, this is a problem to be solved in the future work.

In addition, in addition to consider the size of the pitch matching values, we also compared the camera parameters' optimum value P_{optj} and initial value P0j stability in the consecutive frames, this is very important for some subsequent applications such as the superposition of virtual objects, because in the process of superposition of virtual objects, the instability of camera parameter values will result in volatility of object position, thus affecting the visual effect of stacking. Figure 7 said the changes of camera focal length's (mm) optimal value (solid line) and the initial value (dashed line) in successive frames. It is clear that the optimal value of the camera focal length is more stable than the initial value, and it also proves the camera calibration algorithm presented in this paper can effectively reduce the wave phenomenon of camera parameters, more conducive to the subsequent application.

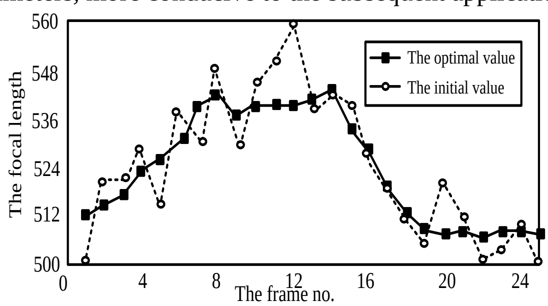


Figure 7. Comparison of camera parameter values stability in the consecutive frames

6. Conclusion

Camera automatic calibration algorithm proposed in this paper. The algorithm is established on the basis of the two-dimensional model and a three-dimensional model of the court, first of all, feature points of the pitch plane is obtained by improved pitch line detection algorithm, and solve the camera isomorphic matrix, then using the isomorphic matrix to fix goal position, get two feature points of the goal plane, in the end, to get the optimal internal and external parameters of camera based on k-means clustering and Hough - like search method. The experimental results show that the improved pitch line detection algorithm can effectively improve the soccer video site area classification (> 96%), and the accuracy of pitch line detection (> 92%), and camera automatic calibration algorithm can not only get the camera isomorphic matrix, but also can get inside and outside parameters of the camera, so as to make the extraction of three-dimensional information in soccer video become possible. In addition, optimal value precision of camera parameter is higher compared to the initial value by using the method (field value increased by an average 4.32%), and it also more stable in the consecutive frames.

References

[1] J. Lee, T. Chung, S. Gundavelli, "A Comparative Signaling Cost Analysis of Hierarchical Mobile IPv6 and Proxy Mobile IPv6, " In Proc. of IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC) 2008, pages 1–6, September 2008.

[2] Kasman Suhairi, Ford Lumban Gaol, The Measurement of Optimization Performance of Managed Service Division with ITIL Framework using Statistical Process Control. Journal of Networks, Vol 8, No 3 (2013), 518-529

[3] J. Lee, S. Gundavelli, T. Chung, "A performance analysis on Route Optimization for Proxy Mobile IPv6, " Telecommunication Systems, Vol.41, No.4, August, 2009, pp.279-292.

http://dx.doi.org/10.1007/s11235-009-9163-z

[4] Zhao Liangduan, Zhiyong Yuan, Xiangyun Liao, Weixin Si, Jianhui Zhao.3D Tracking and Positioning of Surgical Instruments in Virtual Surgery Simulation. Journal of Multimedia, Vol 6, No 6 (2011), 502-509

[5] M. Moayedi, Y. K. Foo, and Y. C. Soh, "Optimal and suboptimal minimum-variance filtering in networked systems with mixed uncertainties of random sensor delays, packet dropouts and missing measurements," Int. J. Contr. Autom. Syst., vol. 8, pp. 1179-1188, 2010.

http://dx.doi.org/10.1007/s12555-010-0603-z

[6] C.Y. Lin, T. C. Wu, and J. J. Hwang, "Multi-proxy Signature Schemes for Partial Delegation with Cheater Identification," The Second Int. Workshop for Asia Public Key Infrastructure, Netherlands: IOS Press, 2002, pp.147-152.

[7] J. Albowitz, A. Chen, and L. Zhang. Recursive position estimation in sensor networks. In Proceedings of IEEE ICNP, pages 35–41, 2007.D. Moore, J. Leonard, D. Rus, S. Teller. "Robust distributed network localization with noisy range measurements." In Proceedings of the Second ACM Conference on Embedded Networked Sensor Systems (SenSys '04). Baltimore, MD. November 3-5, 2004. pp. 50–61. Winner of the Best Paper Award.

[8] Muhammad J. Mirza, Nadeem Anjum,Association of Moving Objects across Visual Sensor Networks. Journal of Multimedia, Vol 7, No 1 (2012), 2-8

[9] M. Mambo, K. Usuda, and E. Okamoto, " Proxy signatures: delegation of the power to sign messages, " IEICE Trans. Fundam. Electron. Commun. Comput. Sci., vol.E79-A(9), pp.1338-1354,1996.

[10] G. L. Wang, F. Bao, J. Y. Zhou, and R. H. Deng, "Security Analysis of Some Proxy Signatures," Information Security and Cryptology, Berlin Heidelberg: Springer-Verlag, 2003, pp. 305-319.

[11] V. Chandrasekhar, W. K. Seah, Y. S. Choo, and H. V. Ee, "Localization in underwater sensor networks - survey and challenges," in Proceedings of ACM WUWNet'06, Los angeles, CA.