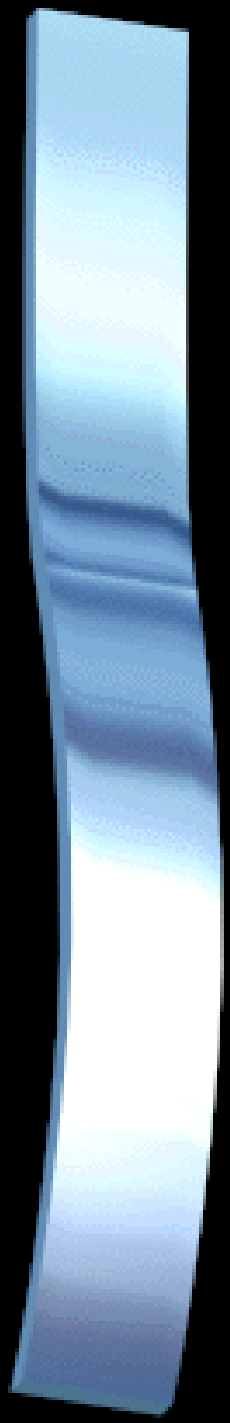

Camera Calibration for Large Rooms

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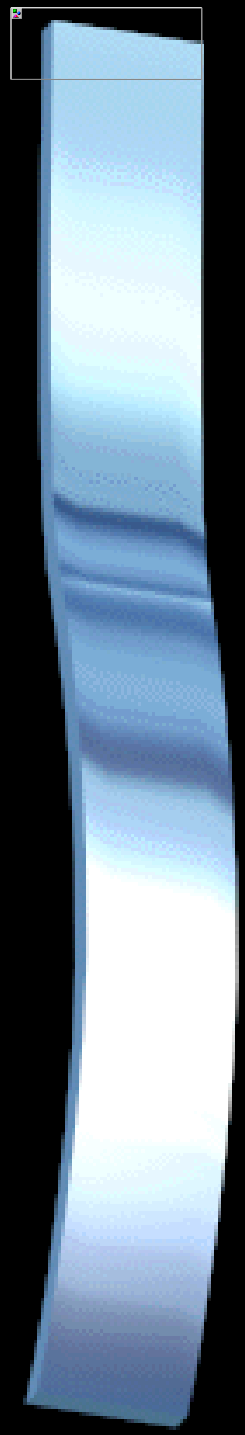
Outline

- Problem Description
- Camera Calibration
- Colour Calibration
- Object Tracking
- Conclusion

RoboCup Domain

- Autonomous agents playing soccer:
- Small League
  - 5 Players/team
  - Golf ball (Orange)
  - Table tennis field (Green)
  - Goal Box: Yellow and Blue
  - Team colors: Yellow and blue



Sample Image

Video Server

- General video server for Robotics applications
- Mono/Stereo Images
- Cheap, fast, accurate, portable, efficient. flexible
- Hardware:
  - Sequence P1S Framegrabber (Matrox Meteor clone)
  - Pentium 200 PC running Linux

Camera Calibration

- Mapping from 2D Pixel Coordinates to 3D World Coordinates
- Well researched problem in Computer Vision

$$\begin{bmatrix} kx \\ ky \\ ? \\ k \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

- Pinhole Camera Model

Gaussian Lens Model

- Pinhole camera model assumes 0 width lens: Pin cushion effect
- Gaussian lens model (assumes a small lens)
- Introduces 2 non−linear parameters
- 11 Parameter camera model
- 6 external: position and orientation
- 5 internal: optical centre, focal length, lens distortion

Camera Calibration Methods

- A lot of camera calibration methods
- Tsai RAC calibration
- Batista Iterative Multi−step calibration
- Input:
  - Set of known real world coordinates for a set of image points
  - Pin hole model: 12 unknowns => 6 points
  - Practice 12−20 points

Matching Points

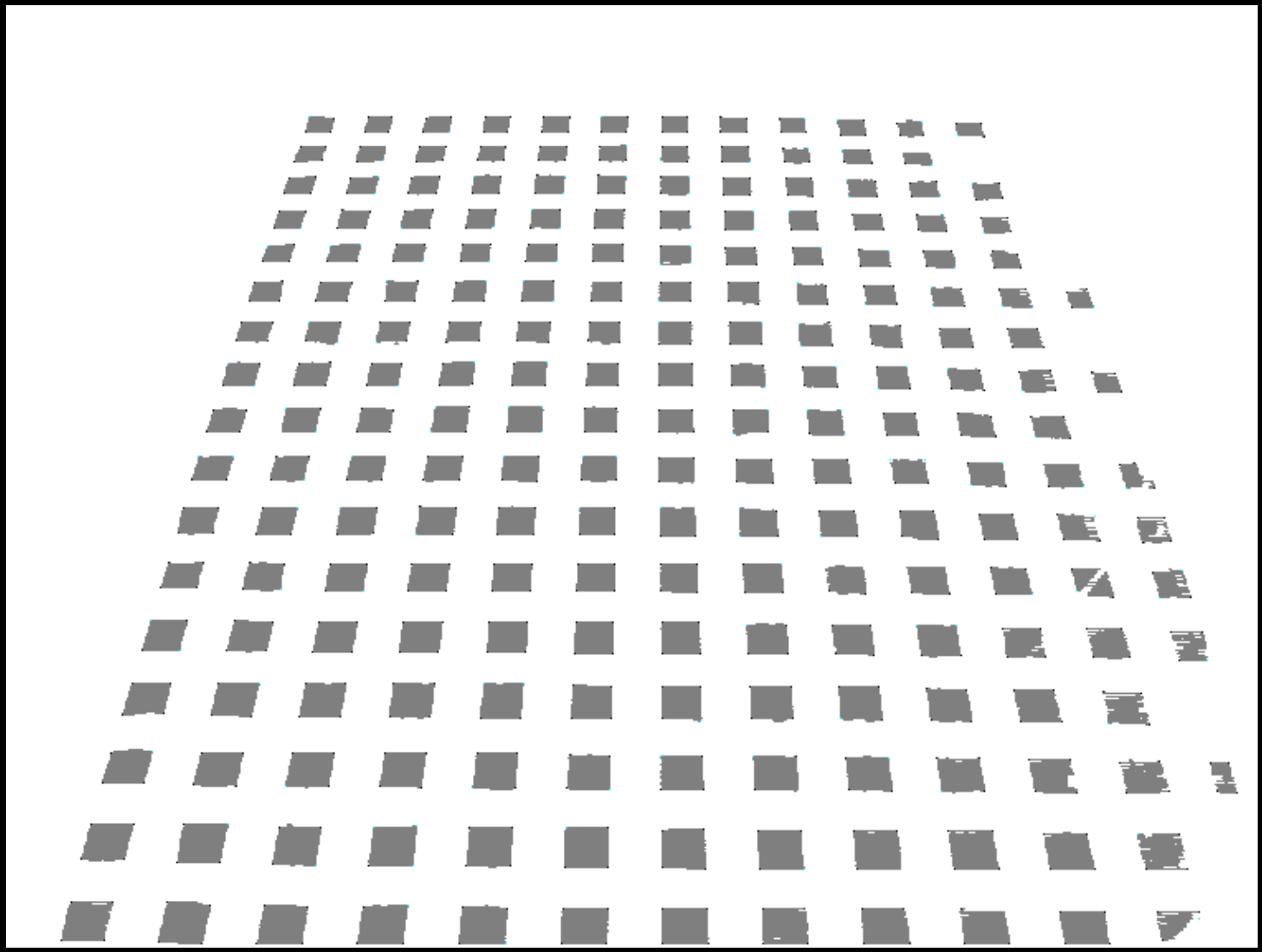
- How do we get this set of matching points?
  - Accurate,
  - portable (demos)
  - fast (every time the camera is moved)
  - cover whole playing area (5m * 5m)
  - cheap
- Environment or large calibration object
- Calibration cloth:
  - portable, cheap
  - Stretching, warping

Sample Input Image

Manual preprocessing

- Difficult to detect squares in any orientation only, e.g., tables, corner missing etc.
- User guided preprocessing (gimp)
  - remove artifacts: tables and surrounding area
  - select threshold red channel
  - convolution matrix to reduce line segments
  - threshold

Output of preprocessing

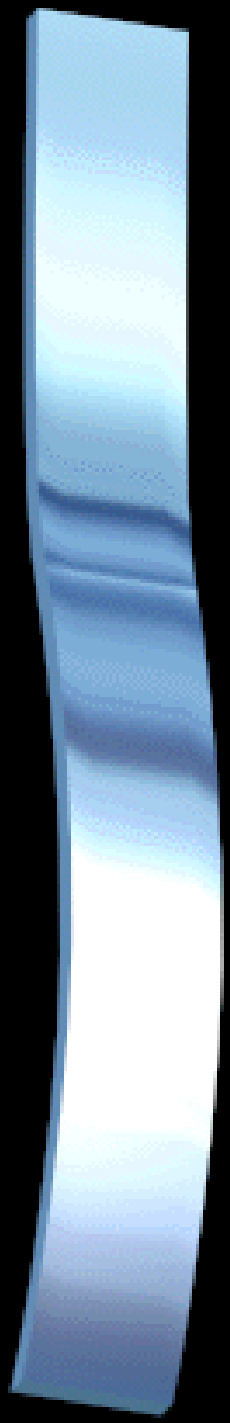


Automatic Sorting and Assignment of Real World Coordinates

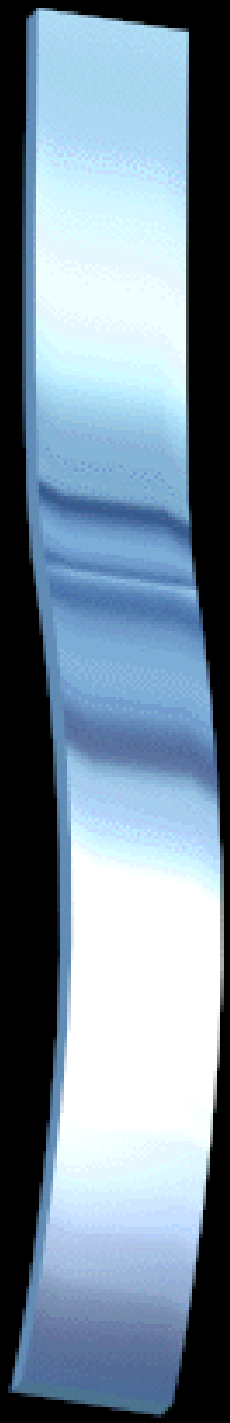
- Previous Image shows potential problems:
  - Missing squares
  - Some squares are distorted
  - Alignment not orthogonal
- Sorting of points
- Missing squares
- Hundreds of points

Matching points

- Sort square centres (detect missing squares)
- Perspective distortion makes it difficult to detect exact centres
- Corner points
  - more accuracy
  - less stable



```
1  find_real_world_coors(unsorted_squares) {
2
3    y_sort_squares=sort(unsorted_squares,y−direction);
4    guess_y=0; prev_avg_y=0;
5    Wy=0;
6
7   while (row=extract_row(y_sort_square,eps)!=empty) {
8     avg_y = aProcedureverage_y_coor(row);
9     if (guess_y != 0)
10       factor = round((avg_y−prev_avg_y)/guess_y);
11    else
12       factor = 0;
13    Wy=Wy+factor*SQUARE_Y_DIMENSION;
14    guess_y=avg_y−prev_avg_y;
15
16    x_sort_squares=sort(row,x−direction);
17    guess_x=0; prev_square=null;
18    Wx = 0;
19    foreach square in x_sort_square {
20       if (guess_x != 0)
21          factor=round((square.x−prev_square.x)/guess_x);
22       else
23          factor=0;
24       Wx=Wx+factor*SQUARE_X_DIMENSION;
25       square.realworld_x = Wx;
26       square.realworld_y = Wy;
27       guess_x = square.x − prev_square.x;
28       prev_square = square;
29    }
30    prev_avg_y = avg_y;
31 }
```



Evaluation

N	Synthetic Picture			Real Picture		
	Avg. Error	Stddev	Max. Error	Avg. Error	Std Dev	Max. Error
50	0.9936	0.0653	0.7291	15.2802	7.6748	85.0945
100	0.0964	0.0553	0.3307	17.2455	7.9873	50.0908
150	0.0931	0.0511	0.3068	13.0654	3.8769	37.0576
200	0.0939	0.0557	0.5121	13.8500	5.0923	55.2477
300	0.0904	0.0498	0.3186	13.6753	4.3130	43.3685
400	0.0901	0.0504	0.3207	13.6320	4.2632	56.5799
500	0.0899	0.0497	0.3152	13.5105	3.6942	34.5634

Evaluation of Accuracy

- Calibration points < 1 mm
- Test points < 1cm
- Practice < 3cm
- More points improve the accuracy
- Sometime points lead to overfitting
- Cross validation technique to estimate quality of calibration