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Fast Stereo Matching of Feature Links

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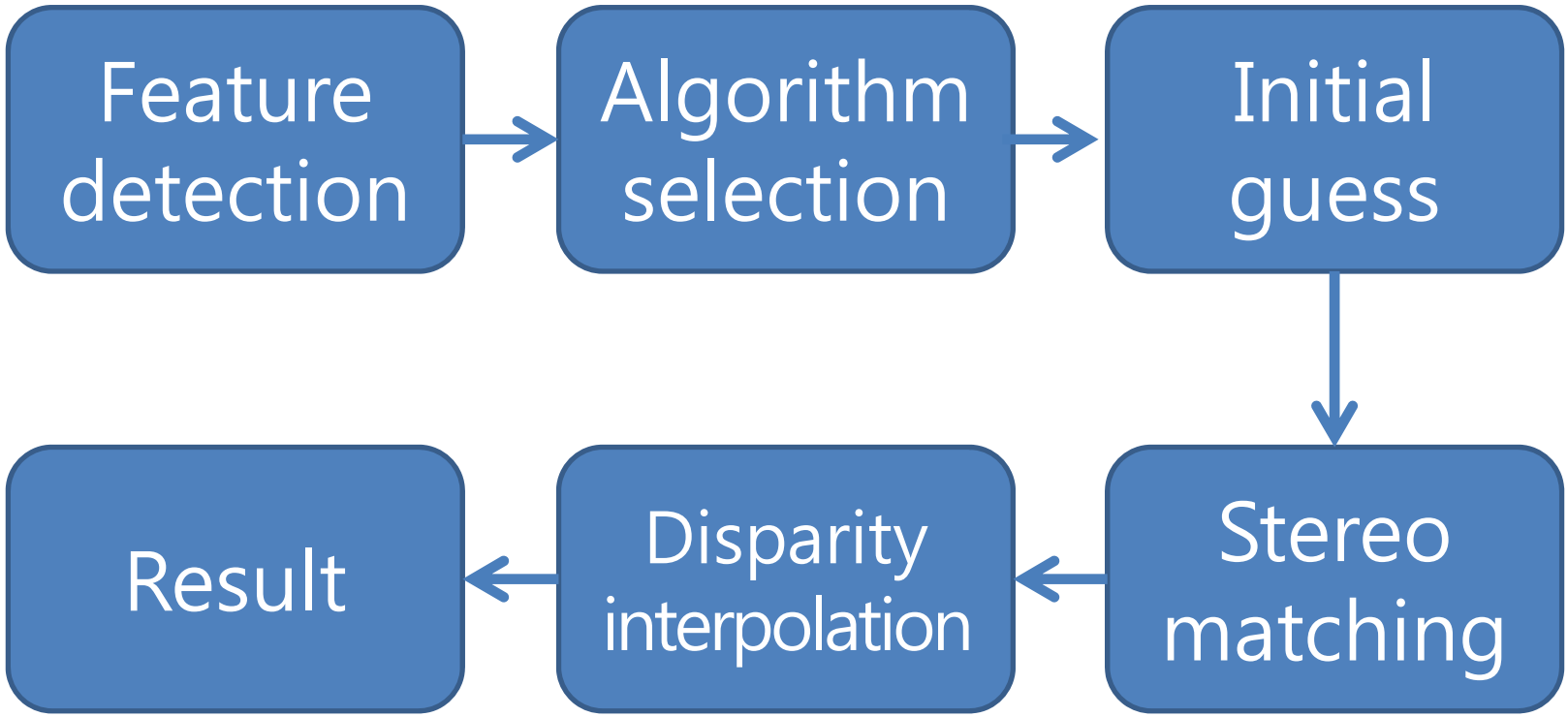
Introduction

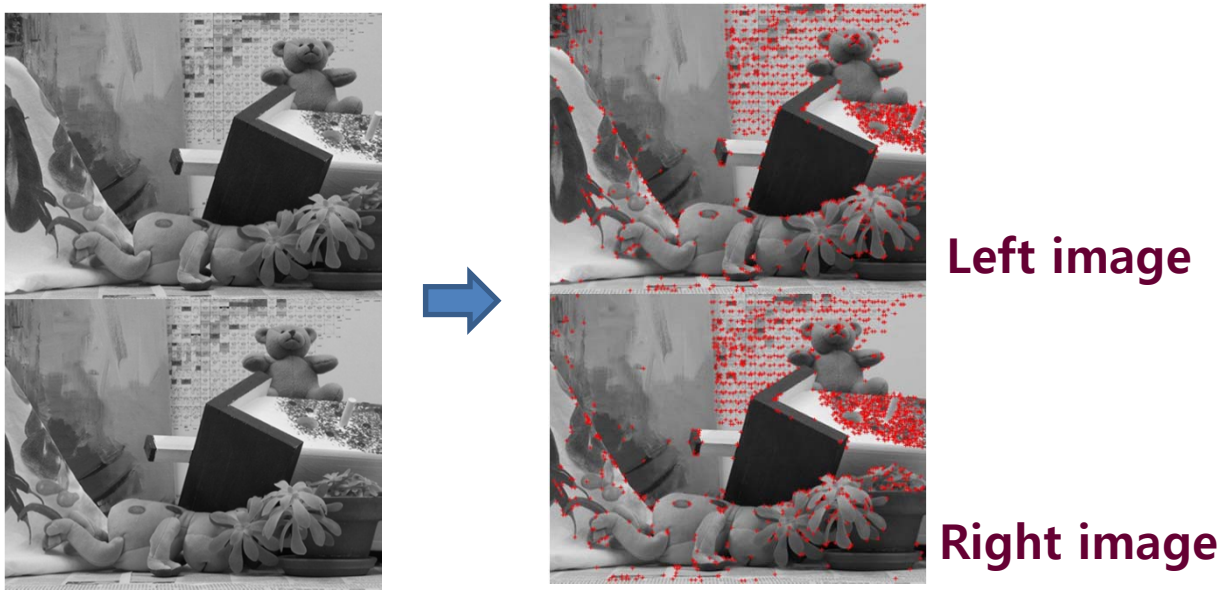
- Stereo matching?
  - interesting topics of computer vision researches
  - To determine a disparity between stereo images
  - A fundamental technique of 3D image processing or reconstruction
- Type of Stereo Matching
  - Area based method: to determine disparities at all image pixels
  - Feature based method: to determine disparities at some feature points
  - Computation time of feature based method is generally faster than the other method
- Purpose : Stereo matching technique for real-time application of mobile robot
- Approach: Feature based stereo matching

Stereo Matching Procedure



Step 1: Feature Detection

- Detect some feature points from stereo images
- FAST detector
  - Comparing the brightness with neighboring pixels
  - Faster than other feature detectors
  - Feature points sort by ascending order



Feature Detection

Simple Feature based Stereo Matching

- Problem of simple feature matching
  - Error of feature detector: the number of feature point and location are not equal between stereo images

Left image

Right image

Error of feature detector

  - Important to find the correct correspondence in order to reduce matching error
    - Image information
    - Geometric information between feature points

Feature based Stereo matching constraints

- Use three constraints: to increase the accuracy of stereo matching
- Epipolar constraint
  - Arrange corresponded characteristic points in the line between stereo images
  - To increase the accuracy of stereo matching and reduce computation time
- Ordering constraint
  - determines the order of neighboring correspondence between stereo images
  - To reduce the computation time
- Link length constraint
  - The length of corresponding two features is the same

Correlation Function

- Use the RGB color information and MSE(Mean Square Error) method
- When this function value is less than certain threshold, we regard as the correct correspondence between stereo images

$$MSE_{color}(x,y,d) = \frac{1}{n^2}\sum_{i=-k}^{k}\sum_{j=-k}^{k} dist_c(C_R(x+i,y+j), C_L(x+i+d,y+j)$$

$$dist_c(c^1,c^2) = (R^1-R^2)^2 + (G^1-G^2)^2 + (B^1-B^2)^2$$

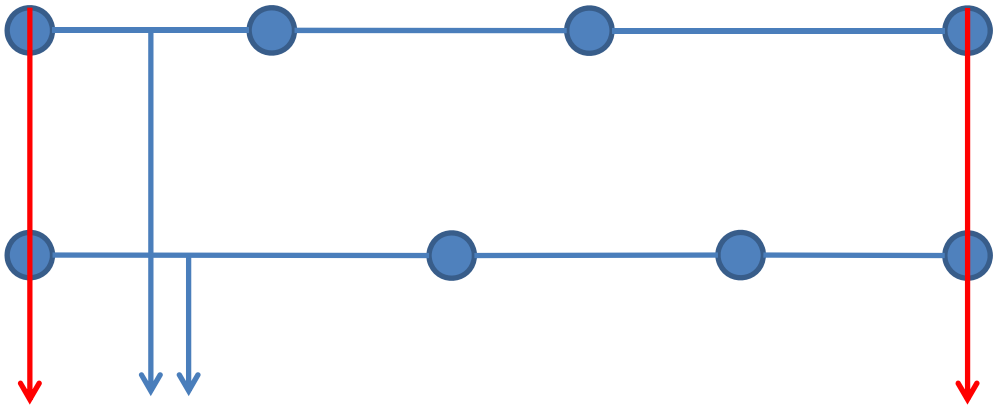
  - d is disparity
  - n is window size

Step 2&3: Feature Link Method

- Step 2: Algorithm selection
  - Check the number of feature points on the same line
  - The number of feature points is
    - One: simple feature matching
    - More than two: feature link matching
- Step 3: Initial guess
  - Initial feature point should be determined the correct corresponding feature point
  - Using the correlation function and combination of feature points, initial feature point set the correct corresponding feature point

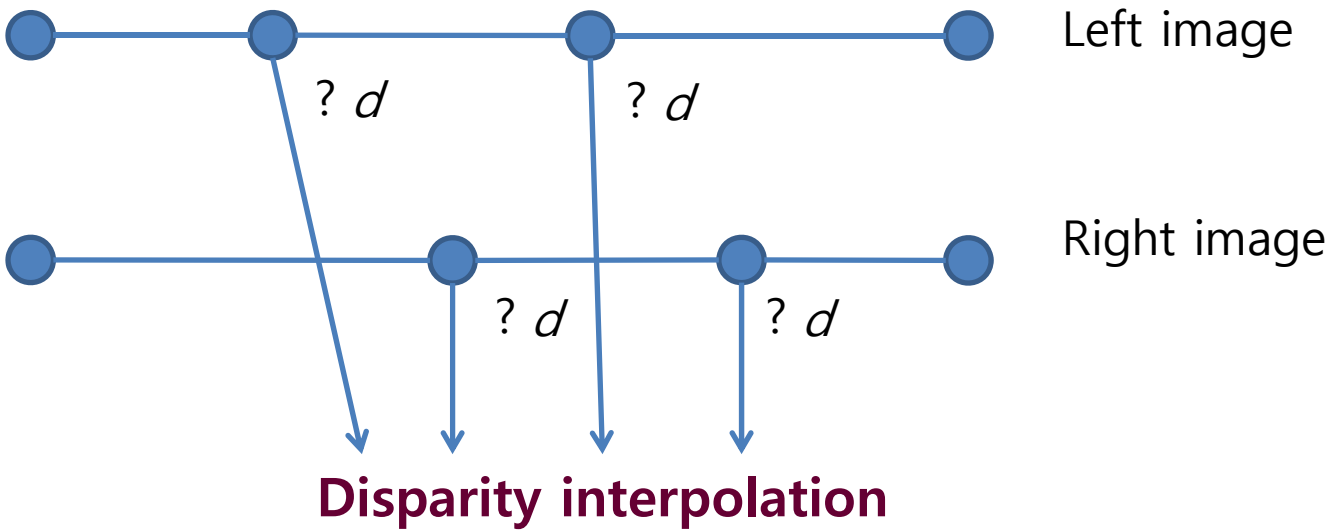
Step 4: Feature Link Method

- Feature link algorithm
  - Connect between two feature points
  - Connection of features is called ‘feature link’
  - On the same line, when two feature links have the same length, determine disparity values at first and last feature points



Step 5: Disparity Interpolation

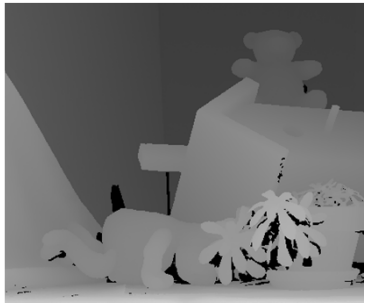
- If some inner feature points have not disparity value in corresponding feature link, inner feature points have disparity value using bilinear interpolation method
  - Using the distance between feature points that have a disparity value



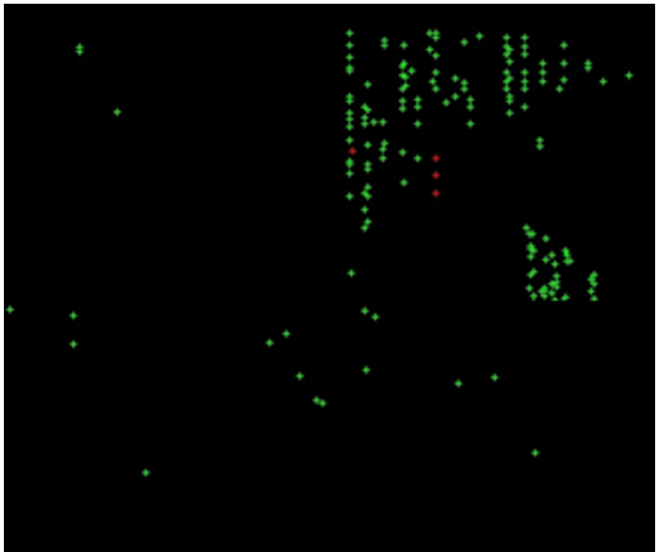
Experiment Result

- Accuracy
  - Comparing the disparity value at the feature point to result image and one of the ground truth image from Middlebury
  - Disparity difference at feature point is less than the error threshold value, we regard as correct correspondence

Ground truth image



Result image



Accuracy image

+ Correct

+ Incorrect

Experiment Result

- Compare to the simple feature method and the proposed method

Image Name	# of Left Features	# of Right Features	Simple Feature Matching			Feature Link without Interpolation			Feature Link with Interpolation		
			Error Threshold			Error Threshold			Error Threshold		
			0.5	0.75	1.0	0.5	0.75	1.0	0.5	0.75	1.0
Teddy	1071	1202	85.43%	90.07%	92.05%	90.08%	92.56%	94.21%	90.98%	93.23%	94.70%
Aloe2	995	1029	99.67%	99.67%	99.67%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Cloth1	928	875	99.25%	99.25%	99.62%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Lamp	1132	980	91.84%	91.84%	98.64%	95.27%	95.27%	99.32%	94.67%	94.67%	99.33%
Rocks2	1025	989	97.66%	97.66%	98.83%	97.93%	97.93%	99.31%	97.93%	97.93%	99.31%
Average	1030.2	1015	94.77%	95.70%	97.76%	96.66%	97.15%	98.57%	96.72%	97.17%	98.67%

Table of matching accuracy

Experiment Result

- Computation time

Image Name	Simple matching	Feature link before interpolation	Feature link after interpolation
Teddy	13.05	13.50	13.70
Aloe2	20.32	20.63	20.72
Cloth1	19.08	19.88	19.90
Lampshade	19.05	20.08	20.02
Rocks2	19.61	20.76	20.76
Average	18.22	18.97	19.02

Computation time

Unit: millisecond (ms)

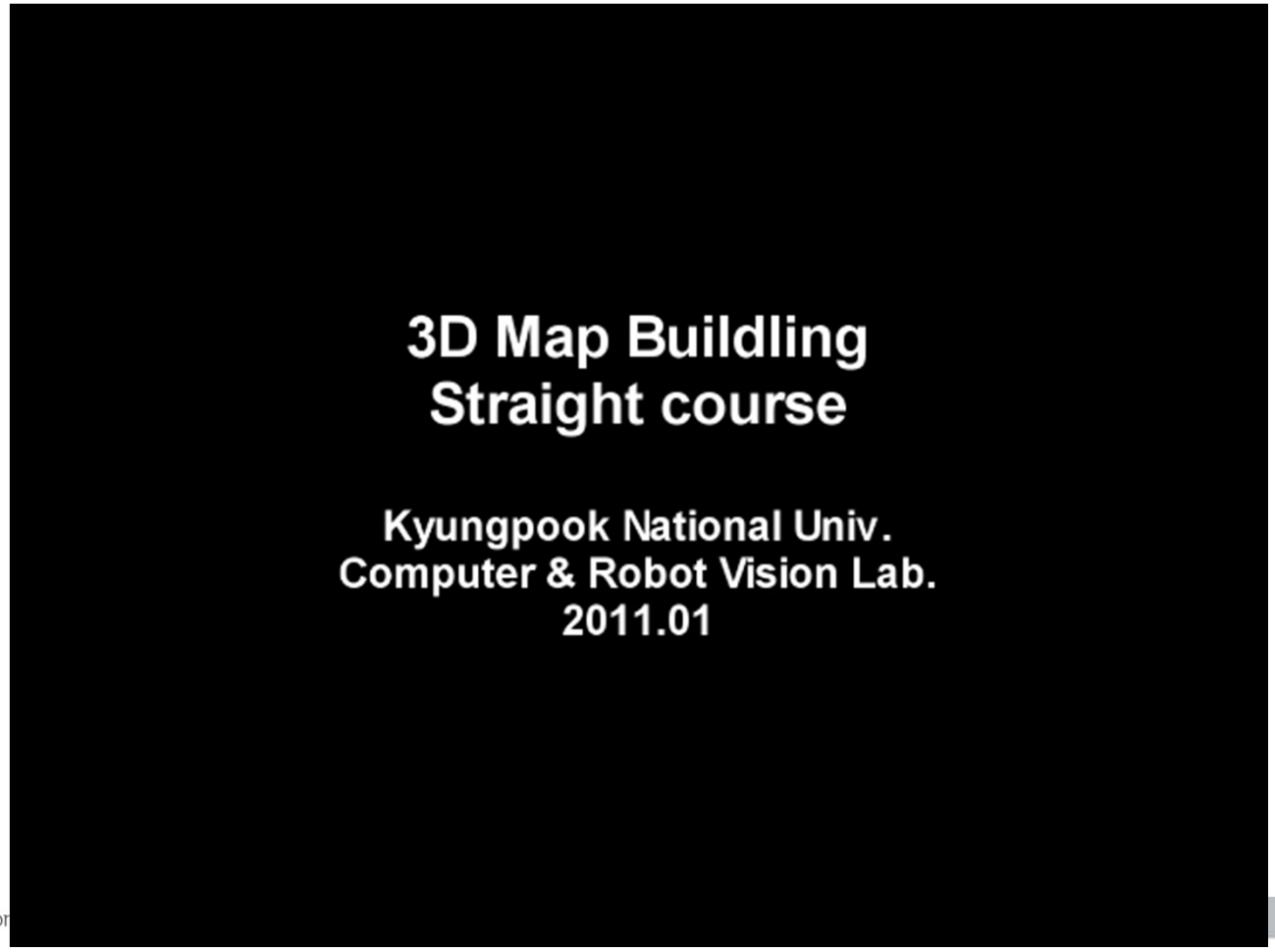
Application

- Localization of a mobile robot
  - To find current location in total 3D map
  - possible to compare current 3D feature points and total 3D map
- System
  - Bumblee-2 stereo camera
  - Mobile robot(NRLAB-02)
  - Laptop(Intel centrino 1.83GHz, RAM : 2.00GB)
  - 640x480 resolution

System

Application: Experiment Result

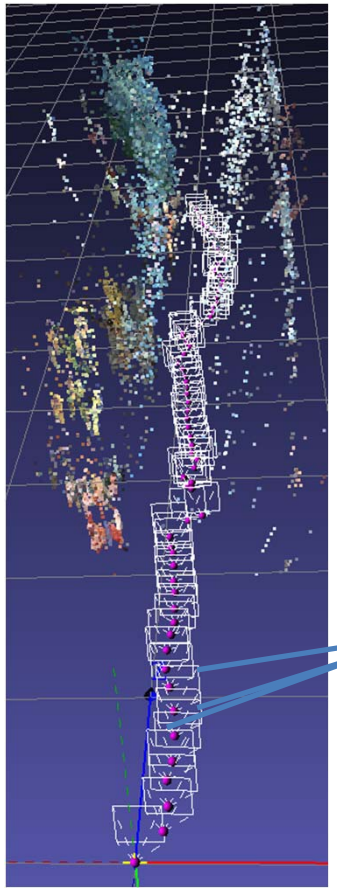
- Demo video – 3D map building at corridor for localization



Application: Experiment Result

- Corridor 3D map
- Average computation time: 21.13ms

A corridor



Moving point of robot

A 3D Map of a corridor

Conclusion

- Feature link stereo matching technique is introduced
- Feature link method has high accuracy and low computation time
- Feature link method is proper to real-time application system
  - localization of a mobile robot