Using the symmetry of false matches to solve the correspondence problem

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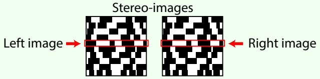
Conventional stereo-correspondence algorithms:
(1) Select true matches based on correlation and computational theory
(2) Reject false matches
(3) Work well with naturalistic, low noise images

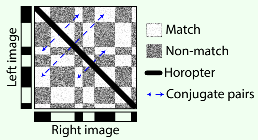
We propose to detect depth in camouflage, noise, and regions of multiple correspondences by visualizing stereograms in Keplerian arrays

1 Theory (Farell, 2013)

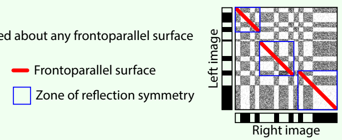
- Consider a pair of 1-D stereo-images where multiple matches are possible:



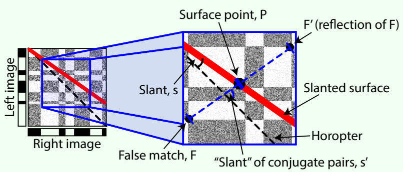
- When stereo-matches are plotted in a Keplerian array, false matches form "conjugate pairs" about the horopter (Tyler, 1977 & 1991)
- Conjugate pairs are formed by reflection symmetry



- False matches are reflected about any frontoparallel surface



- False matches are also reflected about any slanted surface. Each conjugate pair is:
(1) Joined by a line that is directionally opposite of the surface
(2) Equidistant on opposite sides of the line

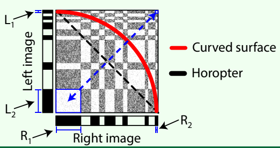


s' = 90-s

FP = F'P

- Curvature affine transforms reflection symmetry

Scale factor= (L_1 * R_2) / (L_2 * R_1)



2 Observations

- The area of the symmetrical region is correlated with the visible width of the surface
- The aspect ratio of the symmetrical region is correlated with the average surface slant

References:
Tyler C (1977) Am J Optom Physiol Opt 54:374-386.
Tyler C (1991) Vision and Visual Dysfunction: Cyclopean Vision pp. 43. Regan D. (ed). Macmillan Press.
Cumming B & DeAngelis G (2001) Annu Rev Neurosci 24:203-238.
Parker A (2007) Nature Rev 8:379-391.
Farell B (2013) J Vis 13:933.

Can symmetry help us identify true matches?

3 Method

(1) What is a match?

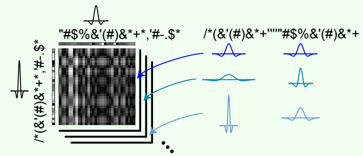
Most surfaces are non-Lambertian: corresponding image points would not have identical luminance

- Filtering images with Gabor kernels enables contextual rather than pixel-wise comparisons

(2) How much context to use?

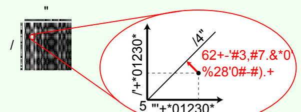
Kernel size dictates how much context is important.
The optimum amount of context depends on the extent of the symmetry (surface structure).

- Since we do not know a priori what the surface looks like, we filter the images with many kernel sizes
Filtered responses are compared in Keplerian arrays

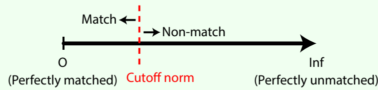


(3) How are the filtered responses compared in a Keplerian array?

- Norm from unity determines how similar a left response is to a right response:

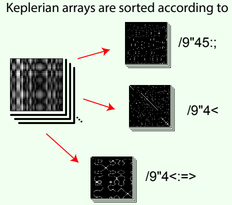


- Cutoff value determines match or non-match:



(4) How are matches used to recover surfaces?

- Keplerian arrays are sorted according to L:R kernel ratios and then averaged within sets:



Surface slant is correlated with the L:R kernel ratio with the highest signal

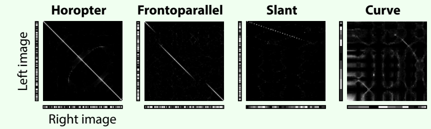
Width of the surface is correlated with the widest kernel that contributes to the signal

Curved surfaces:
Made up of many slants
Recovered by averaging signals over multiple ratios

4 Results

(1) Camouflaged surfaces

- Segmentation not possible: pixel values were randomly chosen from a standard uniform distribution
- Signal-to-noise ratio was iteratively increased by refining the kernel sizes and cutoff norms



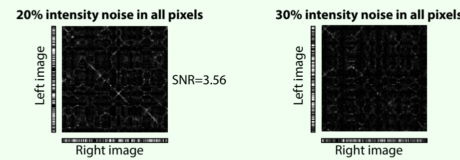
	Horopter	Frontoparallel	Slant	Curve
SNR	35.71	11.62	41.39	1.42
Kernel sizes (Gaussian envelope s.d)	0.1-19	0.1 - 6.5	2 - 19	0.5 - 15
Cutoff norm	0.0001	0.0001	0.0001	0.0003

(2) Multiple correspondences

- Maximum number of false matches: randomly assigned black (0) or white (1) pixels

(3) Noise

- Pixel intensities were varied by a random percentage



5 Observations

- Long and straight lines produced high SNR
- SNR was also high for stereograms with a large number of false matches
- Noise reduced SNR:
(1) Percentage intensity differences at corresponding pixels had a greater effect on the SNR than the number of pixels that harbored noise
(2) The signal was observable up to a noise level of 20% inherent in all pixels

Conclusion

False matches are reflected about the local curvature of a surface. We exploited this false match symmetry by optimizing two parameters (kernel size and cutoff norm) unsupervised, and then visualizing stereo correspndences in Keplerian arrays.

This procedure does not require object segmentation, computational theory, multi-camera calibration or knowledge of camera topology. Straight, contiguous surfaces that accord with the redundancy of natural images produce high SNR and hence would be naturally selected for. It it robust up to 20% noise level.

That retinal images are processed by Gabor-like receptive fields, and that false matches are propagated through the dorsal stream (Cumming and DeAngelis, 2001; Parker, 2007) also lend credence to this technique.

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