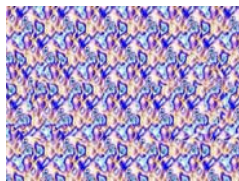


# Binocular Stereo Vision

Stereo viewing geometry and the stereo correspondence problem



**CS332 Visual Processing**  
Department of Computer Science  
Wellesley College

## Stereograms



Invented by Sir Charles Wheatstone, 1838

## Stereo disparity



left



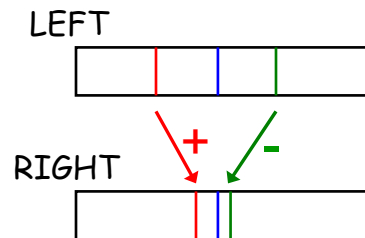
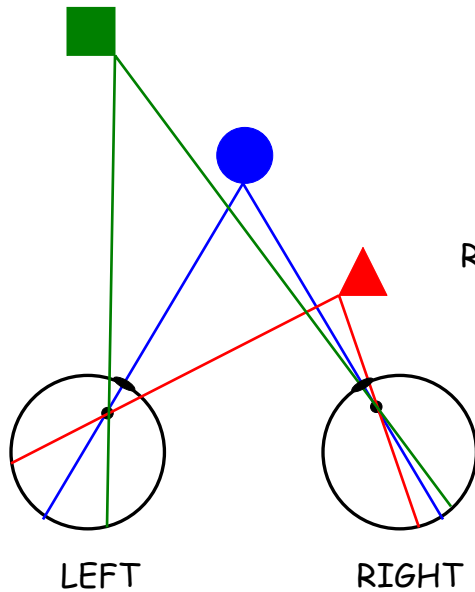
right



Magic-eye  
"autostereograms"  
stay tuned...

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## Stereo viewing geometry

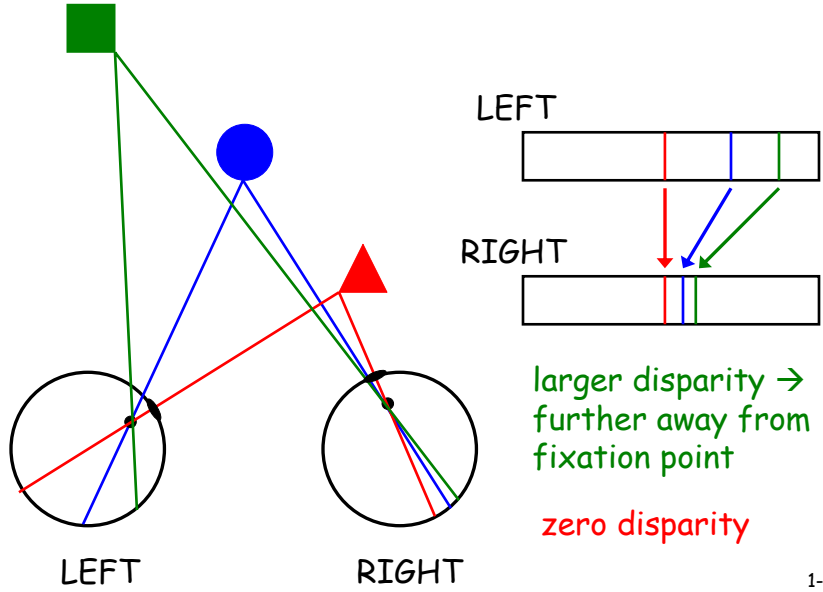


positive disparity  
→ in front of point of  
fixation

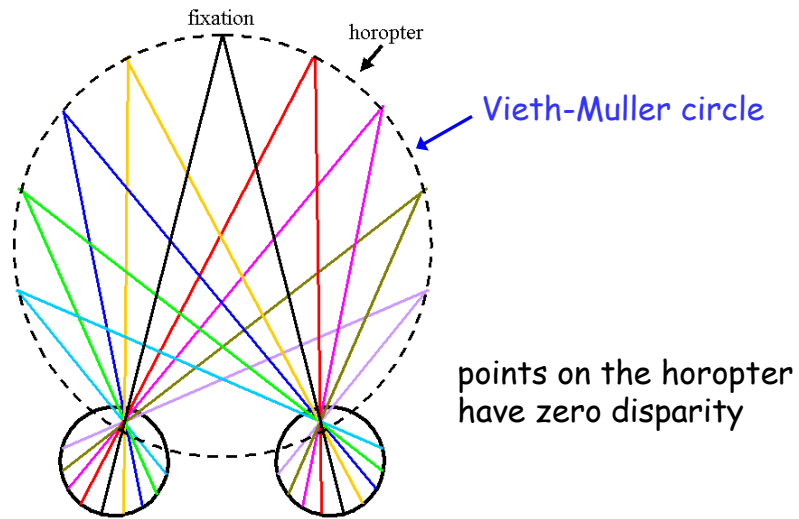
negative disparity  
→ behind fixation point

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## Stereo viewing geometry



## The horopter



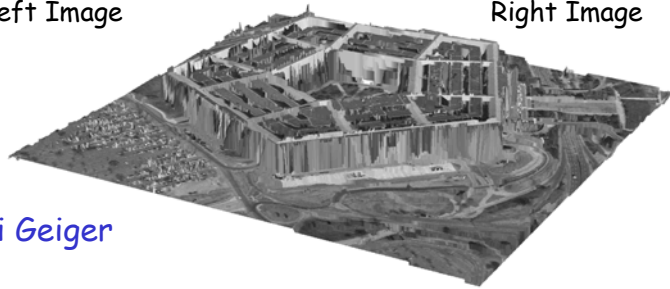
## Results of stereo processing



Left Image



Right Image



Davi Geiger

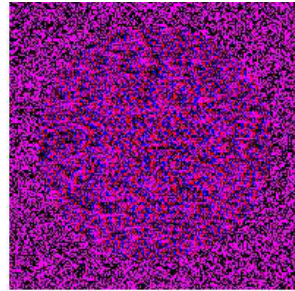
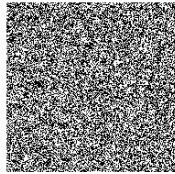
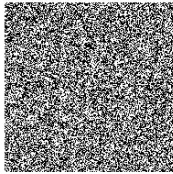
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## Stereo process:

- extract features from the left and right images, whose disparity we want to measure
- match the left and right image features and measure their disparity in position  
"stereo correspondence problem"
- use stereo disparity to compute depth

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## Random-dot stereograms



- Bela Julesz, 1971
- stereo system can function independently
- we can match "simple" features
- highlight the *ambiguity* of the matching process

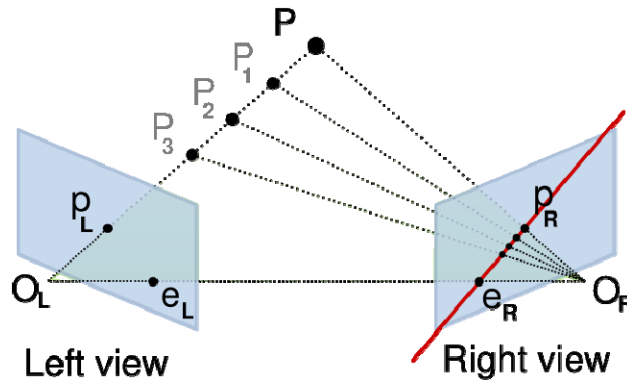
1-9

## Constraints on stereo correspondence

- **Uniqueness**  
each feature in the left image matches with only one feature in the right (and vice versa...)
- **Similarity**  
matching features appear "similar" in the two images
- **Continuity**  
nearby image features have similar disparities
- **Epipolar constraint**  
simple version: matching features have similar vertical positions, but...

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## Epipolar constraint

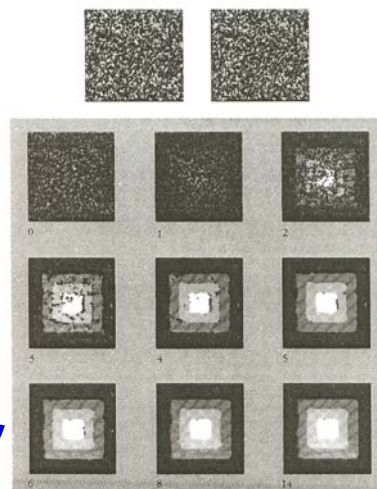


Possible matching candidates for  $p_L$  lie along a line in the right image (the epipolar line...)

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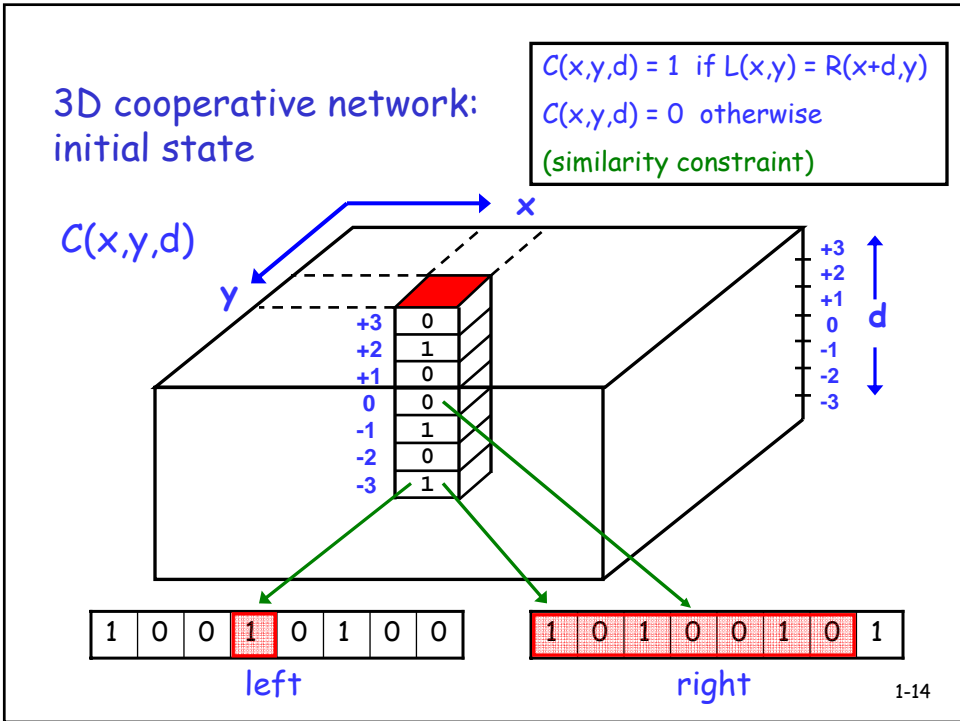
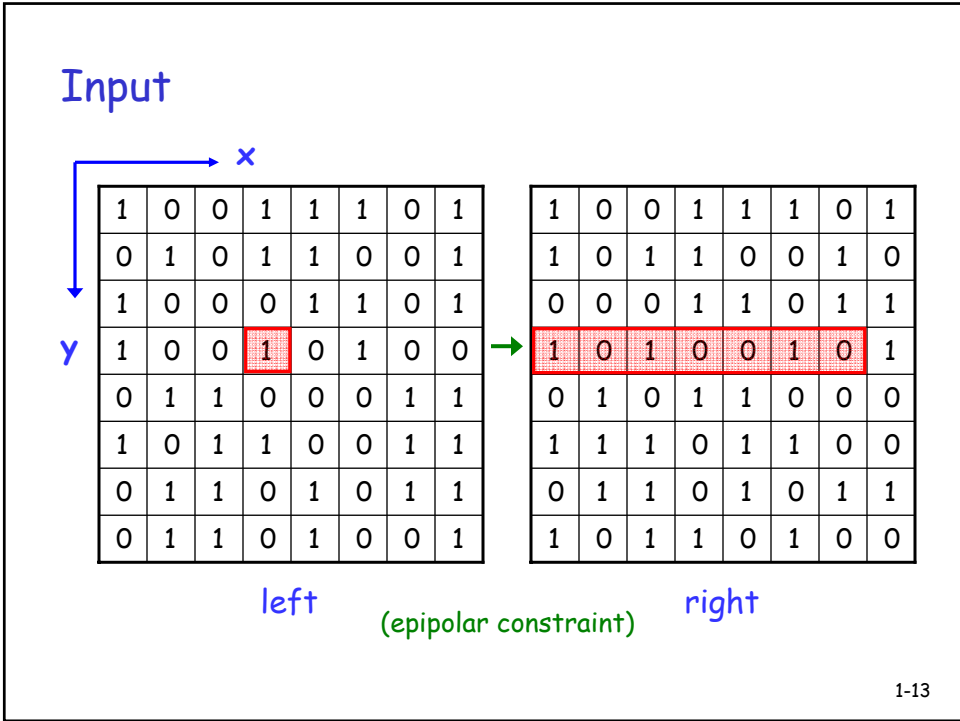
## Marr-Poggio cooperative stereo algorithm

- matches corresponding black & white dots in the left & right images
- stereo disparities computed by a parallel network of simple computing elements
- **iterative**: state of network changes with each iteration, to resolve matching ambiguity



disparity map emerges over time

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## Updating the network

For each iteration, the state of every element in the 3D network is updated:

$$(1) S(x,y,d) = C_t(x,y,d) + E - \epsilon I$$

support for disparity  $d$  at location  $(x,y)$       current state of network (0 or 1)      "excitation" neighborhood support for disparity  $d$  at location  $(x,y)$       "inhibition" evidence for *other* disparities at location  $(x,y)$

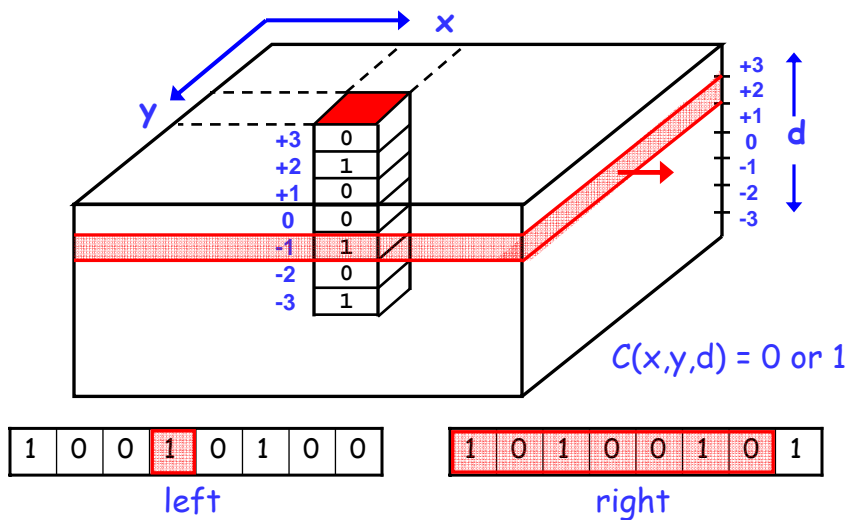
$$(2) C_{t+1}(x,y,d) = 1 \text{ if } S(x,y,d) \geq \tau$$

new, updated state at time  $t+1$       threshold

$$= 0 \text{ if } S(x,y,d) < \tau$$

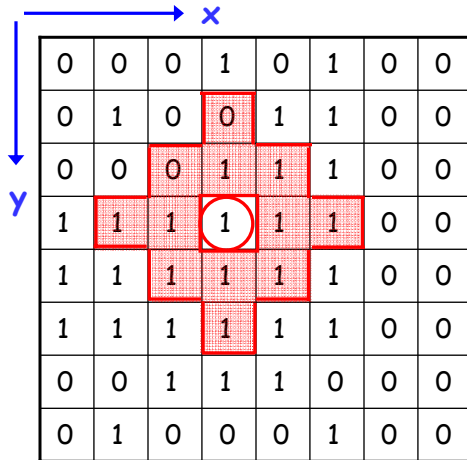
1-15

## 3D cooperative network



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## Enforcing the continuity constraint



disparity = +2

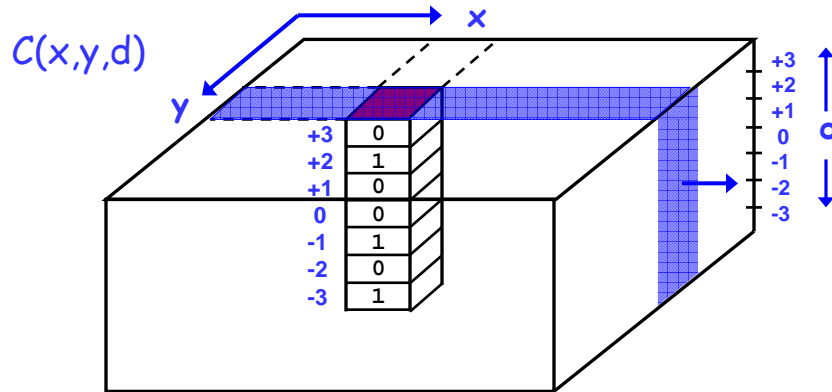
$E$  = sum of 1's in a neighborhood around  $(x,y)$

$E = 10$

$$S(x,y,d) = C_+(x,y,d) + \underbrace{E}_{\text{circled}} \varepsilon I$$

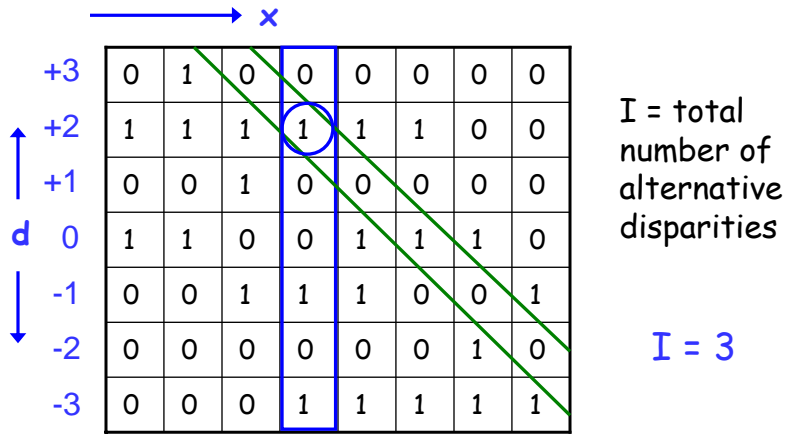
1-17

## 3D cooperative network



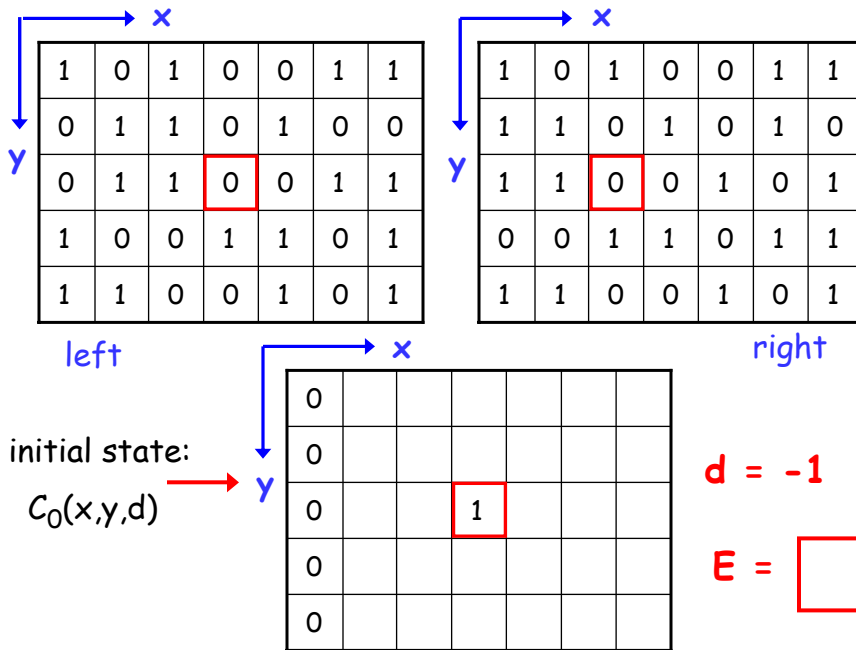
1-18

## Enforcing the uniqueness constraint



$$S(x,y,d) = C_+(x,y,d) + E - \epsilon I$$

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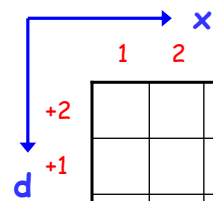
row 3:

1	2	3	4	5	6	7
0	1	1	0	0	1	1

left

1	2	3	4	5	6	7
1	1	0	0	1	0	1

right



initial state:  
 $C_0(x,y,d)$

	1	2	3	4	5	6	7
+2						0	0
+1							0
0							
-1	0			1			
-2	0	0					

$Y = 3$

$I =$

$S(x,y,d) = C_t(x,y,d) + E - \epsilon I$   
  $(\epsilon = 2)$

$C_{t+1}(x,y,d) =$