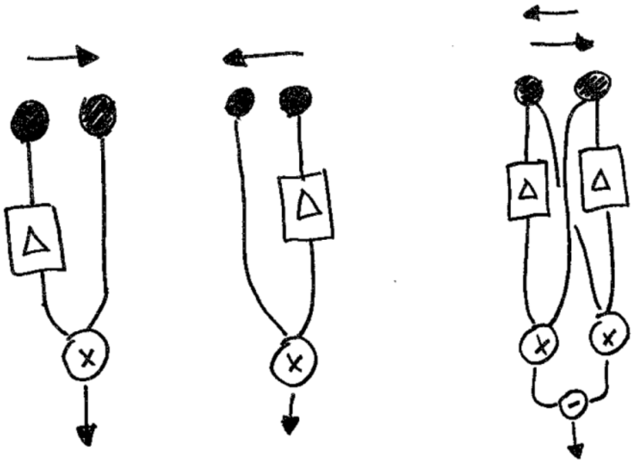
Computational Vision – Lecture 9

Visual Motion : 1D

Reichardt detector:



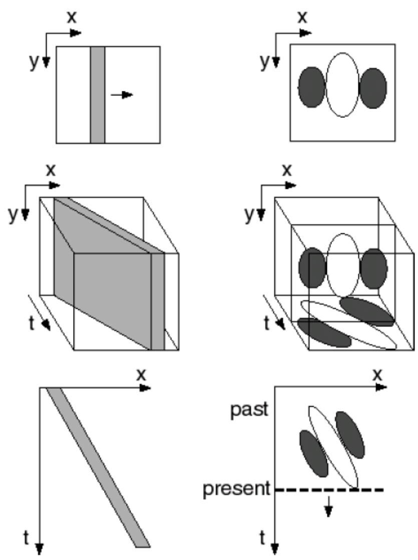
- Hypothetical neural circuits that can track motion
- A cell (x) will get two inputs, one from eye A and one from eye B
- Input from A is delayed and if the cell responds to that then it will fire
  - ➔ Cells respond only to one of the three example cases and then generates the motion perception
  - ➔ Can also combine reichardt detectors to higher level hierarchies
- Speed selectivity is very strong – so these types of neurons are tuned only to one speed, so for different speeds you need different neurons

New way of representation of receptive field of cell

→ takes into account the time aspect of the responses of the cell

- Logic to take this approach, because cells fire over longer timespan and patterns (e.g. biphasic responses) and not static
- Instead, dynamic and individual responses of cells

Space time representation → on the right



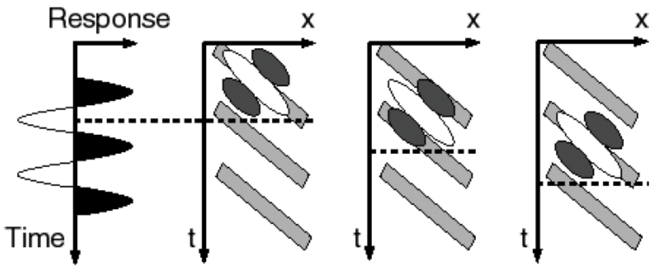
<u>Top left situation:</u>

- moving bar across field → could be shown as 3D representation (middle) = space time cube, but complex to draw for more complex stimuli
- alternative: represent the moving bar in an x/t diagram → slope of the line gives you the speed of the stimulus (lower)

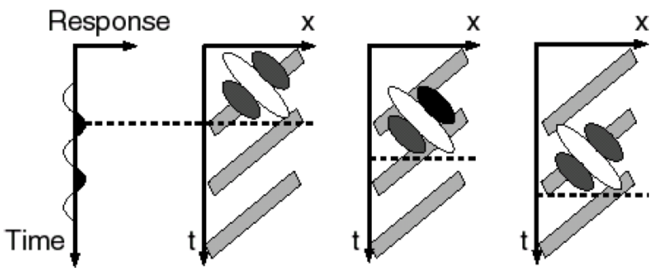
<u>Top right situation:</u>

- representation of receptive fields in the same scheme
- ON / OFF responses not static anymore, but dependent on the actual response → so e.g. above baseline = ON response, below baseline = OFF response
  - ➔ receptive field shape changes with time!
  - ➔ present line and receptive field above shows us that If we are at the present line and see a response at a certain location, then this will be due to a stimulation that has occurred in the timespan of the space receptive field. I.e. a response at the point of the arrow at present will be due to an ON response in the column of this x value up to the last point in the past.

Upper image:
- First peak: bar matches exactly the ON region of the cell
- Negative response after: bar does not match the ON region, so cell will not respond



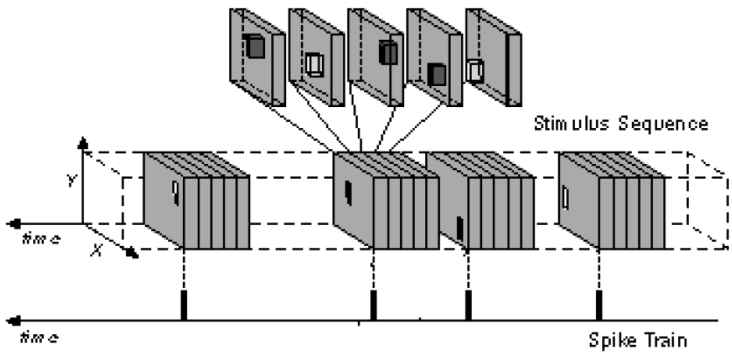
Lower image:
- Receptive field is also oriented in space time and that means that it is orientation selective
- That means that the same setup with bars that are in opposite orientation, the responses will be much smaller.



Measuring space-time receptive fields with reverse correlation

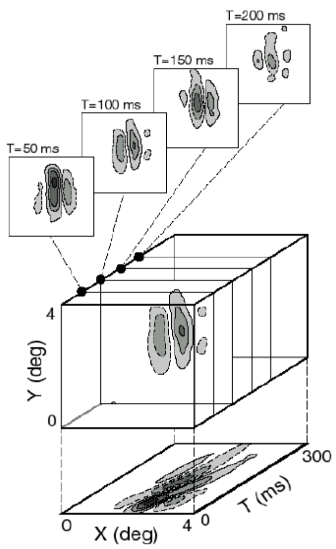
Time consuming, painful method to measure: for each location and each timepoint, measure response

BUT other method more efficient : **Reverse correlation**
- Want to record from simple cell, whose orientation you already know
- Present to cell a movie of a bar at different locations and different polarities (on/off)
- Then record spike train of the neurons and analyse



Analysis: Creation of spike recordings and you measure what was on the screen 5 ms before the spike → repeat for all spikes
- Then average all the images → result: on average, 5 ms before the image, there was an e.g. white bar
  → develop tendency, that everytime there is a white bar, you see a spike
- Repeat with 10 ms, 15 ms, 20 ms, 25 ms, etc. etc.
- Then you get series of pictures that represent the receptive field at different times
  → represent the receptive field

  ! if you go back **too far back**, then the information tendencies will be **uniformly grey** because of the averaging process



! at **point 0 ms or 1 ms before**, the picture will also be completely **grey**, because it has no relevance for the response.
! only works for linear receptive fields

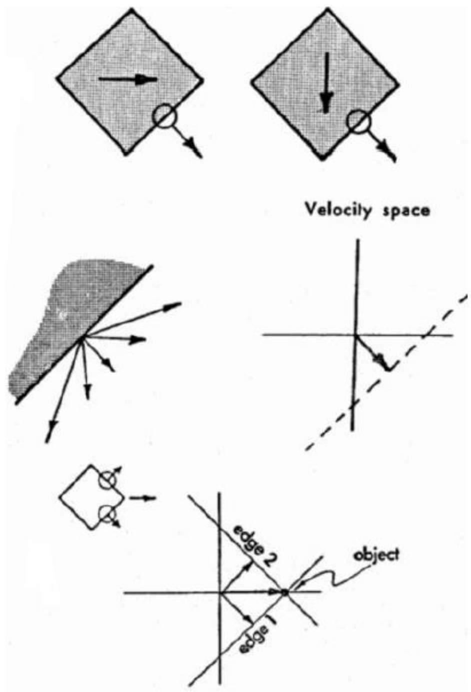
Video 1: Cat visual system → ON center cell (ganglion cell in retina / LGN) and non-direction selective

Video 2: biphasic response of a simple cell that is selective for vertical orientation → not changing much over time

Video 3: simple cell: ON/OFF regions that also move over time and oriented in space time and direction selective !

Video 4: stimulation of complex cells receptive field with reverse correlation technique only with a light emitting bar. If you were to measure with light/dark bars at the same time then they would cancel out → not so useful for complex cells because of nonlinear behavior and it cancels out!

Visual Motion: 2D



The Aperture Problem:

- E.g. square that is moving from left to right and one cell's receptive field is the circle. This receptive field will perceive the edge moving down
- If the square is moving down, it will see the same.
- That means that there are many possible movements of the square that all result in exactly the same expression in the receptive field → PROBLEM

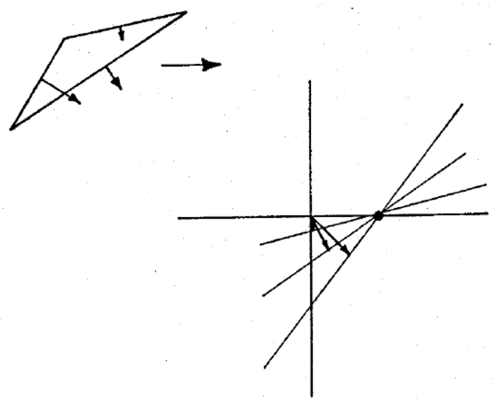
→ visual system can still solve this problem via:

Intersection of constraints:

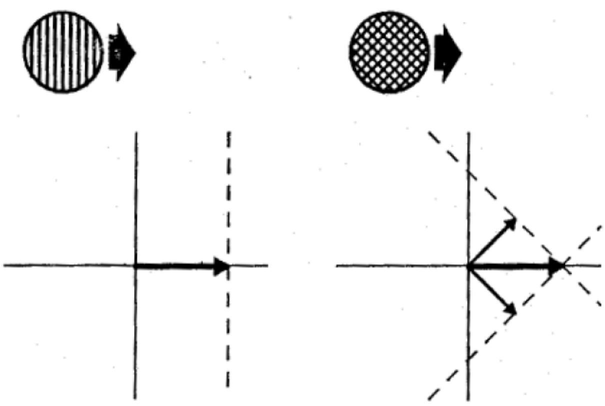
- combine outputs of two cells and then combine more and more to relieve the ambiguity (picture on the right)
- vector set creates complete impression
- line of constraints = line at which all these possible motion vectors end ➔ edge 1 and edge 2

➔ combining the lines of constraints at the intersection tells you the only possible motion of the square

- length of the vector = speed of the motion
- not just vector addition! See in the example on the right →



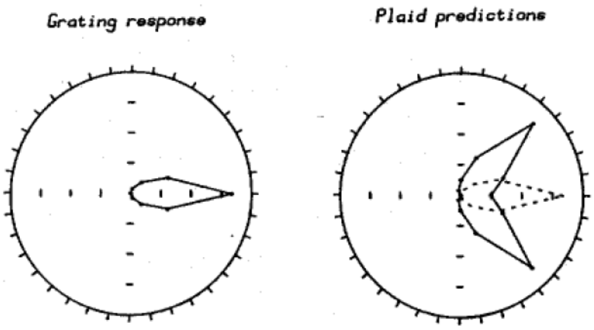
What happens if you look at more complex stimuli such as a grating?



Experiments performed and recorded responses in area MT

- most cells in MT are selective for orientation

→ also for grids, you only perceive a fixed grid moving to the right and not the single lines



Polar plot that shows one cell's response first to grating and then to plaid

- angle = represents direction of motion
    - here cell responsive to orientation of motion and orientation in space
    - e.g. 0 deg. Grating is vertical and moving from left to right
    - 180 deg. Grating vertical and moving from right to left
    - 90 deg. Grating horizontal and moving from to bottom to top ? vice versa?

→ revisit the polar plots and readouts.. (check out the paper of the author Movshon)

- for a grating, the polar plot will just have a circle
- an orientation selective cell will have the grating response replicated on both side

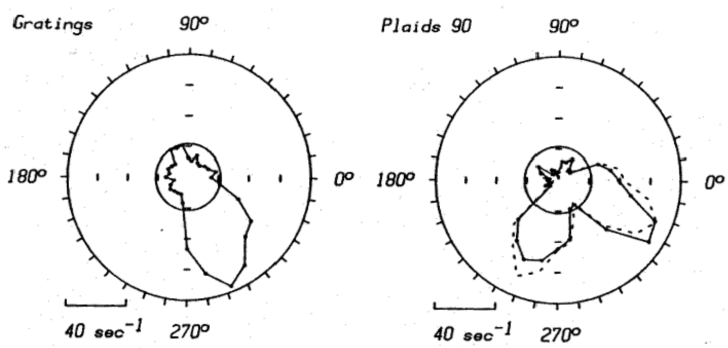
Plaid response:

- picture: response of plaid moving to the right
    - components are not vertical and that's why you see two directions on polar plot
    - but together the perception is that the plaid is moving to the right

Responses of a V1 cell:

- left: cell likes grating that moves to one direction
- right: same cell stimulated with a plaid and responds with a different polar plot

→ like one component going in one motion



Same experiment done in MT:
Found cells:

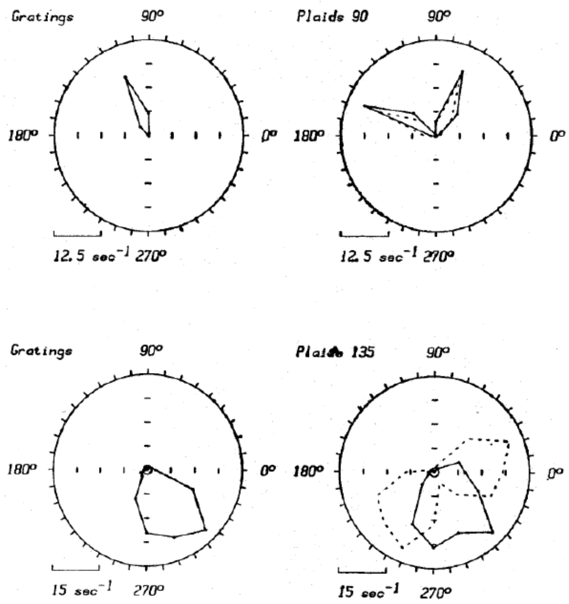
1) component selective cell → like cell responses above

2) pattern selective cells → response is like in the grating for the plaid ! cell has combined the motion of the two components to compute the overall direction pattern just like you perceive it like a human observer

→ shows that this pattern computation is not performed in primary visual cortex, but actually only in MT

A component selective cell

A pattern selective cell



Summary of experiment:
Population analysis:
- first stimulation with grating, then stimulation with plaid

Q: How much can you predict response to the plaid when you know the response to the grating?

Answer: in V1, the correlation is much higher towards the component cell model than to pattern model
In MT, correlation more spread → must have both types of cells