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COLLEGE ON NEUROPHYSICS:
"DEVELOPMENT AND ORGANIZATION OF THE BRAIN"
7 November - 2 December 1988

"Illusions of a Parallel Motion Algorithm"

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Illusions of a Parallel Motion Algorithm

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Overview

- A Parallel Motion Algorithm
  - based on voting for consistent motion
  - and winner-take-all
  - implemented on the Connection Machine
- Psychophysics
  - Barber Pole Illusion
  - Non-rigidity Illusion
  - Motion Capture Illusion
  - Aperture Illusion
- Physiology
  - Plaid Motion

Motion Detection Theory

Minimal Requirements

- two inputs
- non-linearity
- asymmetry

Many EMD Algorithms

- Correlation Model (Reichardt)
- Energy Model (Adelson-Bergen)
- Veto Model (Barlow-Levick)
- Shunting Inhibition (Torre-Poggio)

New Parallel Algorithm

- based on biology
- edge-based Alg. motivated by Veto-Scheme
- intensity-based Alg. motivated by Correlation Model

Voting for Motion

Our new parallel algorithm for computing the optical flow is based on the simple assumption, that the optical flow is locally uniform .

Physical constraints on motion limit the spatial variation of the optical flow field.

Constraints

- uniqueness, each image point has a unique velocity
- continuity, surface are locally smooth

This results in a partial solution to the aperture problem

The Aperture Problem

is an instance of the correspondence problem.

Without features, corresponding points can not be matched, eg. straight lines with constant intensity.

This is the aperture problem of the first kind.

For curved contours or lines with intensity variations the aperture problem can be solved.

This is the aperture problem of the second kind.

Voting for Motion

Our Parallel Motion Algorithm can solve the aperture problem of the second kind.

- all points in a neighborhood of a feature (edge or intensity) identify the correct motion
- lines with constant intensity are not disambiguated, since there are no features to match
- heuristic can select the motion of smallest magnitude in case of ambiguity

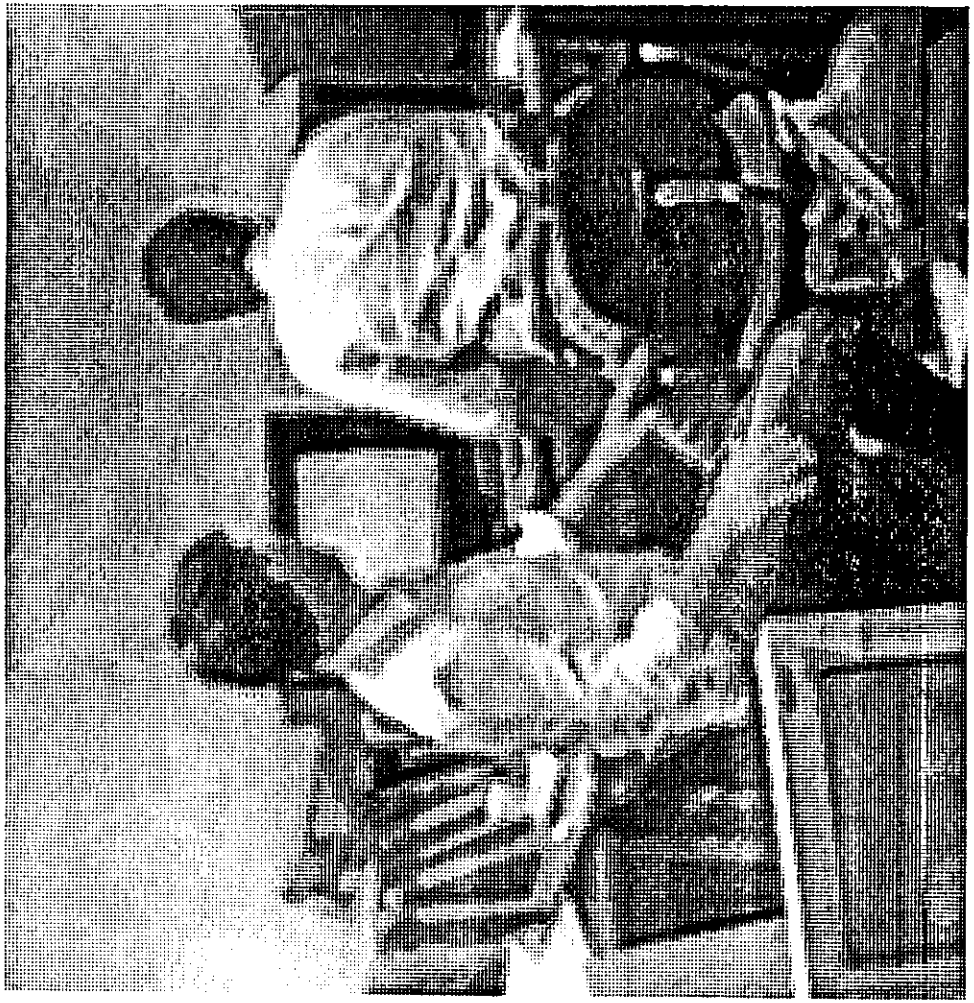
Edge-based VMA

- 1. find and label edges
- 2. match edges by shift and compare
- 3. find local support by counting the matches in a neighborhood of a pixel
- 4. vote by choosing the displacement which has maximum local support

Connection Machine Implementation

- maps easily into CM-architecture
- retinotopic mapping into CM-memory
- one processor per pixel
- parallel shift and match operation
- each processor keeps record of correct matches
- vote for maximum consistency in area

Fig. 2

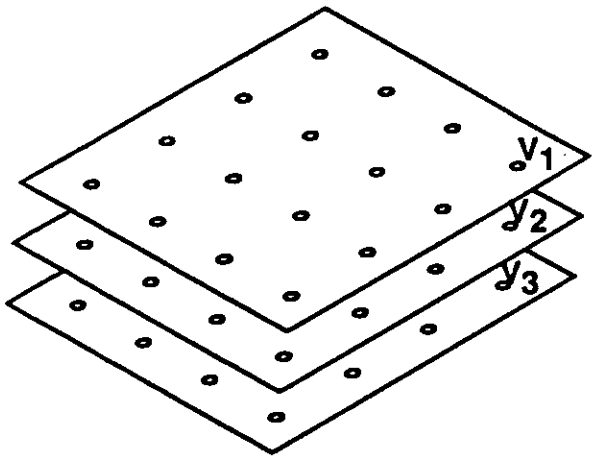


Advantages of VMA

- facilitates image segmentation
- segmentation not based on output
- segmentation internal to the computational mechanism
- non-iterative ⇨ faster
- not noise-sensitive due to patch integ.
- dense output for intensity-based VMA
- biological plausible (based on Veto- or Correlation Model)
- psychophysical plausible (shows Barber Pole, Motion Capture and other illusions)

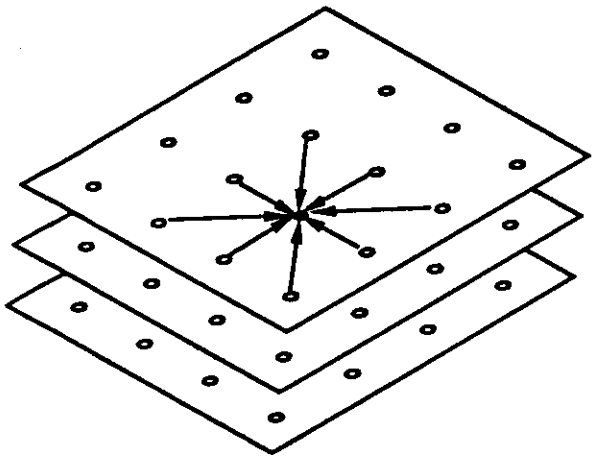
Neurophysiological Implementation ???

- based on a layered structure
- matching stage in V1 ?
- in different layers with progressively larger sampling basis
- summation stage (excitation)
- in mapping from V1 to MT ?
- larger receptive fields in MT summate output from V1
- consistent with psychophysical data (Adelson and Bergen, 1982)
- consistent with physiolagical data (Movshon et al., 1985)



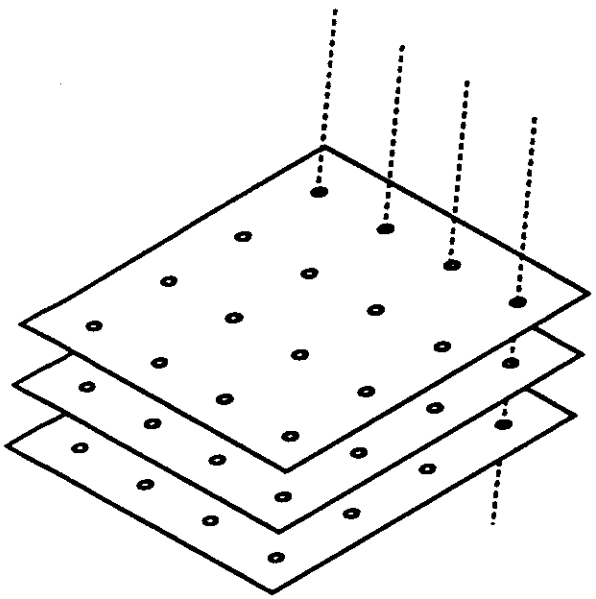
$$\tilde{E}_1(x) \circ \tilde{E}_2(x+\underline{v}\Delta t)$$

matching



$$\int_{\text{patch}} \tilde{E}_1 \circ \tilde{E}_2$$

voting



$$\max \int_{\text{patch}} \tilde{E}_1 \circ \tilde{E}_2$$

winner-take-all

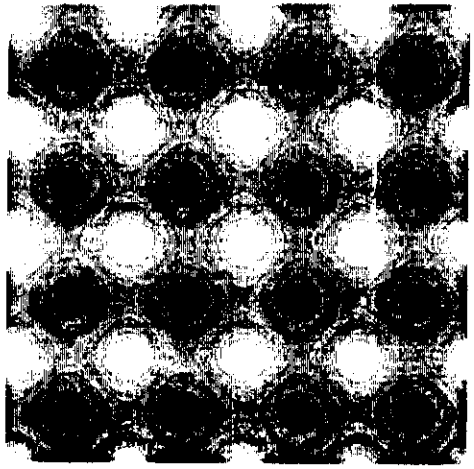
Fig. 1

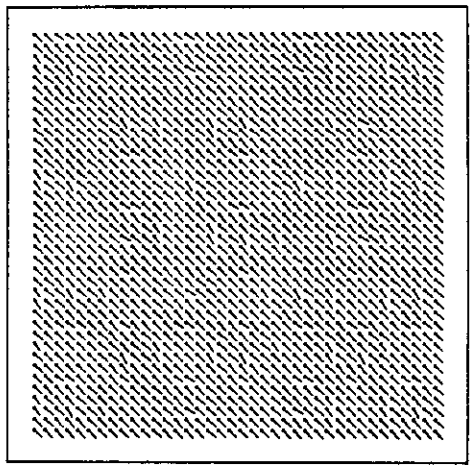
Plaid Motion

- superimposed sine-waves moving in different direction lead to perception of a coherent moving pattern (depending on relative contrast and frequency)
- V1 cells "see" component motion
- MT cells (about 20%) "see" pattern motion
- Algorithm "sees" pattern motion

Barber Pole Illusion

- true motion field for rotating Barber Pole is horizontal
- Perception is vertical
- but, horizontal motion field is also a possible physical interpretation of the flow field (curvature matching)
- therefore it is not surprising, that also many other motion algorithm show the socalled Barber Pole Illusion
- which is not really an illusion





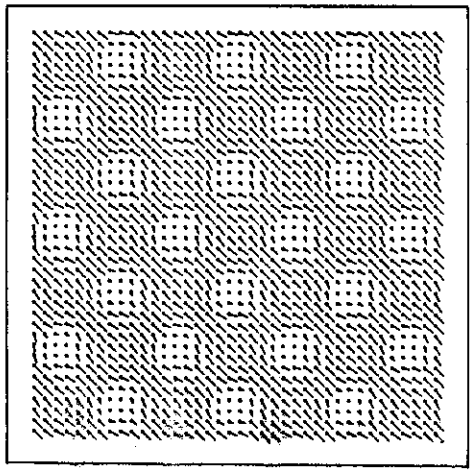
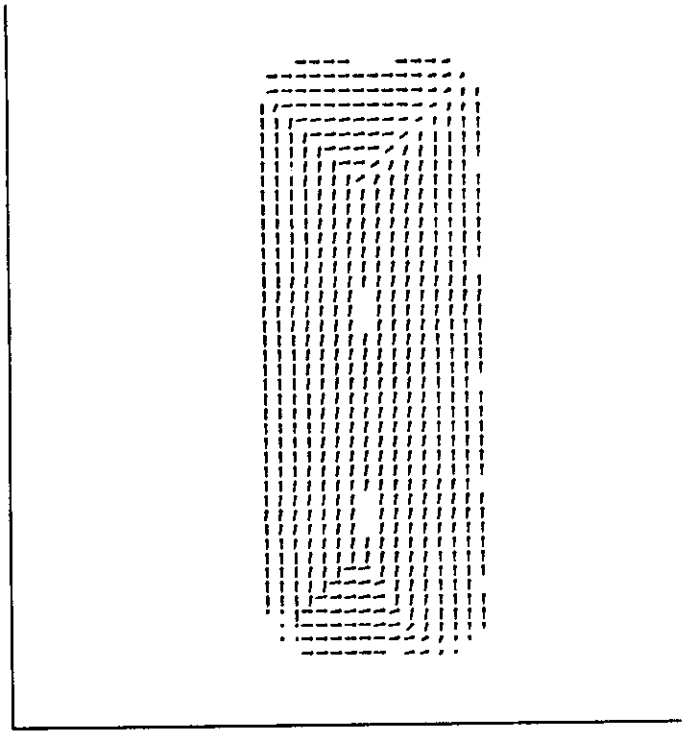
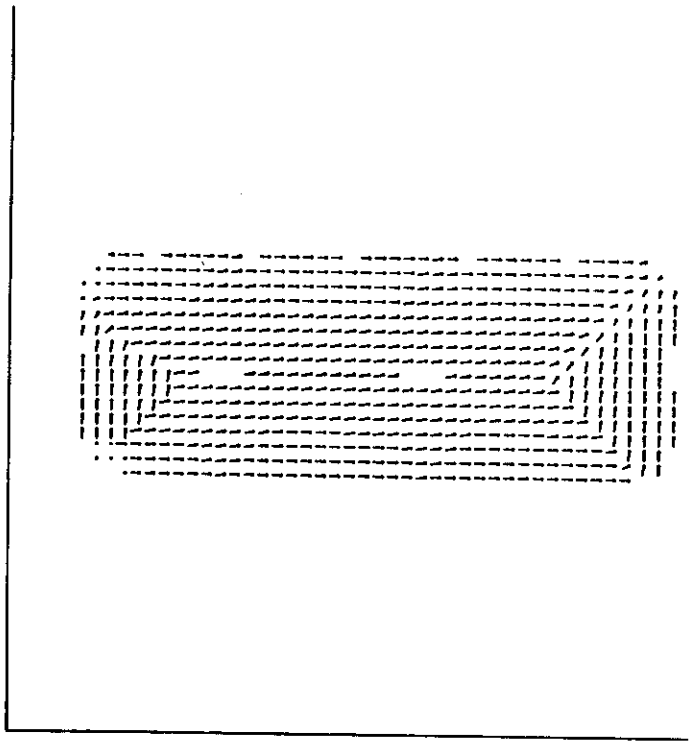
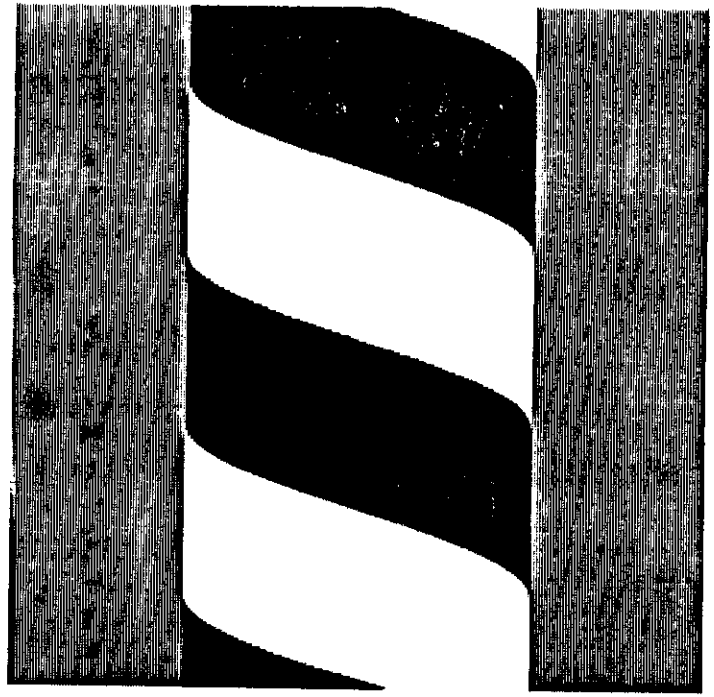


Fig. 3d







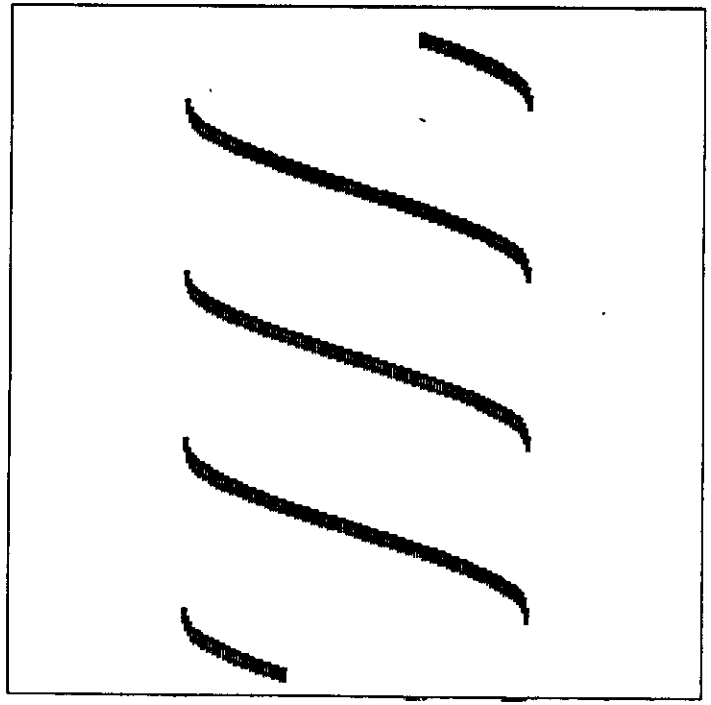


Fig 3a

Motion Capture Illusion

- described by Ramachandran & Inada

  Vis. Res. 1986
- Experiment: superimpose moving sinewave on uncorrelated random dot patterns
- Percept: dots move coherently with sinewav e
- Explanation: Votes for displacement vectors are biased by intensity (local summation)
- Note: works only with intensity-based algorithm
- Ramachandram Tricks: not necessary

Non-rigid Motion Illusion

- described by Nakayama & Silverman

  Vis. Res. 1988
- translating curved lines look non-rigid if curvature is small enough
- hard to simulate, because our algorithm is very sensitive to curvature matching
- we had to reduce the resolution of the summation stage
- observation: end-points are very critical

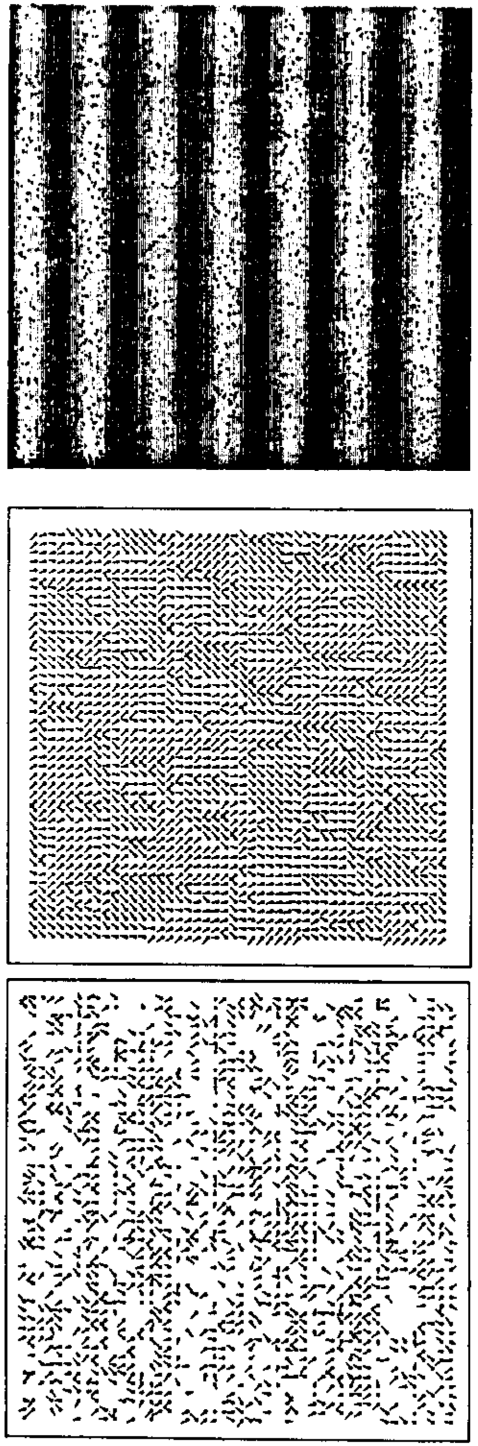


Fig. 3c

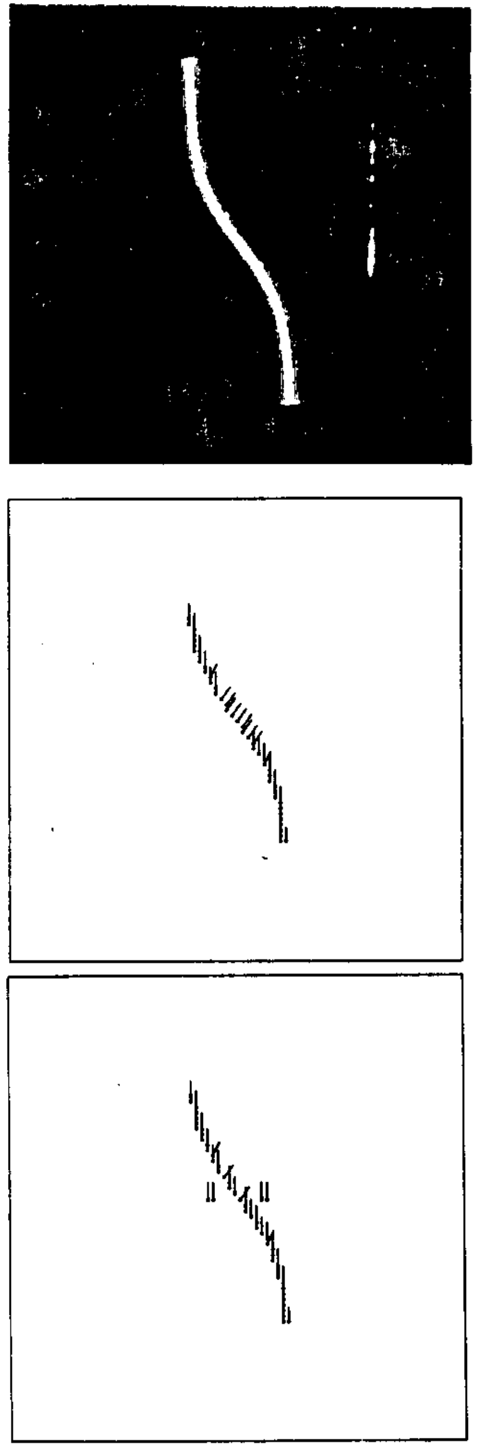
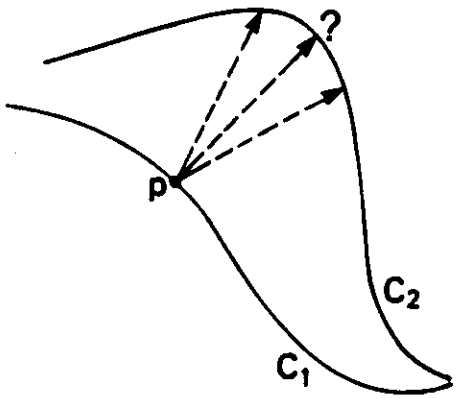
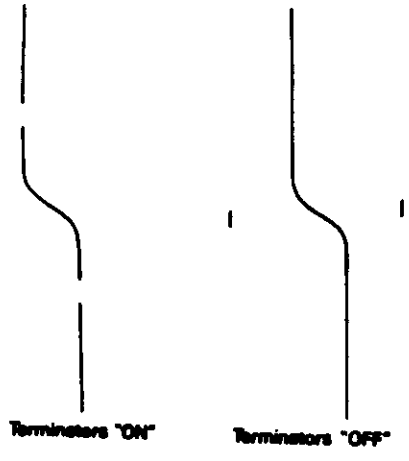


Fig 3b

Nakayama and Silverman
Vis. Res. 1988 in press





Nakayama and Silverman
Vis. Res. 1988 in press