Computer Vision is an Unsolved Problem

• Many (more or less mature) algorithms for many sub-problems
  - finding or estimation of edges, motion, structure, albedo, texture, surface properties, material, illumination, form, type (scene, object or activity type), affordances (manipulation, navigation), ...

• None of these problems can be solved in isolation
The Frankfurt Vision Initiative
(Bernstein Focus Neurotechnology, Frankfurt)

“Construct a functional vision system by integration of known vision algorithms, using the brain as model”
Problems

Computer Vision:

• Integration of Many Subsystems
• Coherent Architecture
• Learning from Examples

Neural Vision:

• Neural Tissue as Data Structure
The Computer Graphics Revolution as Model

• More and more realistic-looking imagery
• Our eye is very critical of the level of realism
• Our visual system must have a superb generative model
Cognition: The Reality in my Head

- What I see I take as reality
- This is a construction, on the basis of
  - Memory
  - Selection by visual input
- Sensory input is incomplete and ambiguous
- Perception is an inverse process
- How can we be sure the construction is “real”?
The Neural Basis of Cognition

- Collective states: states with holistic properties!
- Parts are connected into a whole
- Collective states can be dormant or active
- Collective states are generated by self-organization and learning
Nets as Collective States

- Nets: neural elements linked into a whole (Gestalt)
- Nets are dynamic attractors in configuration space
- Nets are generated by self-organization and learning
- Nets can be rapidly activated and de-activated
- Nets are capable of global operations
- In particular: object recognition by graph matching
  (checking for features and their arrangement)
Visual Sub-Modalities

• Texture, color, depth (distance), motion, reflectivity, material, illumination, ...

• Sensory input generates ambiguous hypotheses

• Constraints between modalities reduce uncertainty
  - E.g., kinematic relations betw. point motion, shape, global motion

• Consistency of converging signals is the sign of reality
A Visual Architecture

- Fixed Mapping
- Dynamic Mapping
- Sub-Modality Manifold with Segment
- Sub-Modality Memory Models
- Constraint Relation
Neural Elements of the Architecture

- Neural 2D manifolds with internal feature spaces
- Storage of many 2D patterns in memory
- Dynamic Neural Mappings
Neural Manifolds

• Neural Fields, 2D locally connected
e.g., Primary vis. Cortex

• Internal feature spaces
  - texture
  - color
  - depth
  - in-plane motion
  - reflectance
Combinatorial Representation of 2D Nets

Feature Types

Hyper-columns

WTA Dynamics

Selection by Input Image
Topological Mappints

• Example: Retinotectal map
Dynamic Mappings
Dynamic Mappings

Control Units sense pattern similarity and control projection fibres

Ch. Anderson, D. VanEssen, B. Olshausen, J.-M. Zhu, J. Lücke
Controlled Dynamic Mappings
The Visual Architecture

Fixed Mapping

Dynamic Mapping

Sub-Modality Manifold with Segment

Sub-Modality Memory Models

Constraint Relation
The Bernstein Focus Neurotechnology, Frankfurt

- Financed by the German Ministry for Technology
- Full Budget: 9.5 Million Euros
- Three new Professorships
- Leader: V. Ramesh, formerly head of real-time vision at Siemens Lab. Princeton
- A merger of software engineering and neuroscience
- Development of an integrated software environment
Panel Discussion Statement

• Vision as enabling technology
  - Surveillance (public, private security, battlefield management)
  - Autonomous cars
  - Robots (service, rescue, battlefield)

• Vision has high demands in terms of processing and data

• Mature vision expected to be demonstrated within a decade on mainframe computers
Mobile Vision
Requirements

• Reduction of cost, volume, power by factors of $10^5$

• Slow switching of components

• Massively parallel implementation

• Hybrid analog-digital action

• Attractor dynamics
  - Slow: learning, self-organization
  - Fast: perceptual collapse