



Dynamic Density and its Application in Traffic Flow Management

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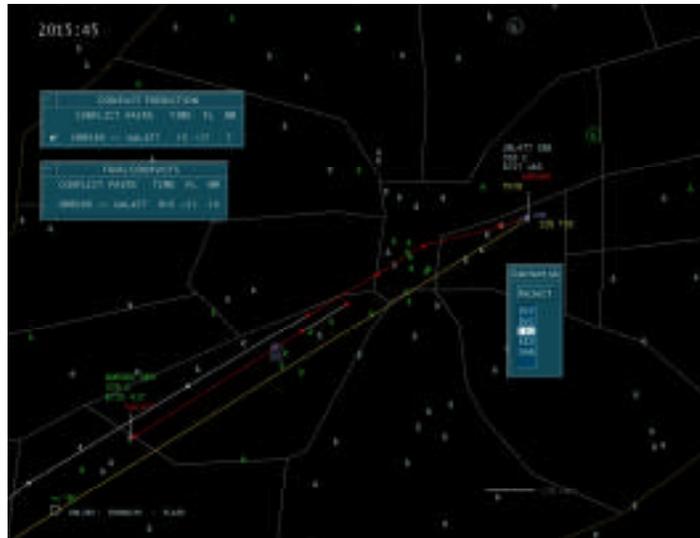
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Free Flight/DAG Workshop, May 22-24, 2000

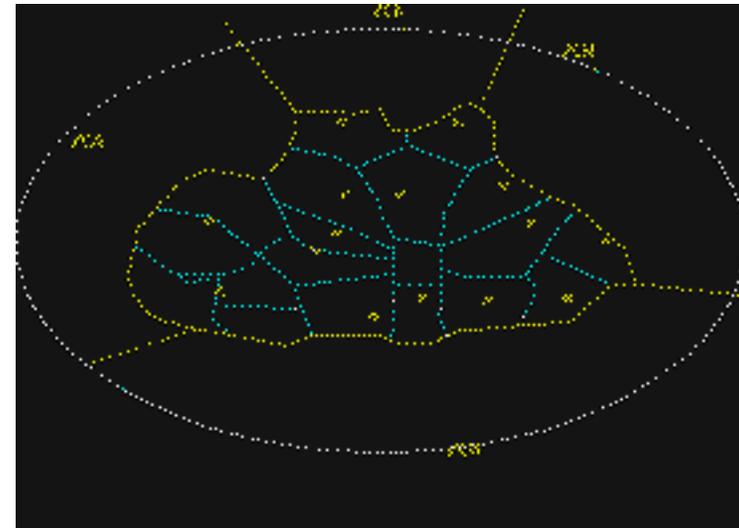


Airspace Complexity

Complex Traffic Flow



Airspace Design



Impact on the Controller

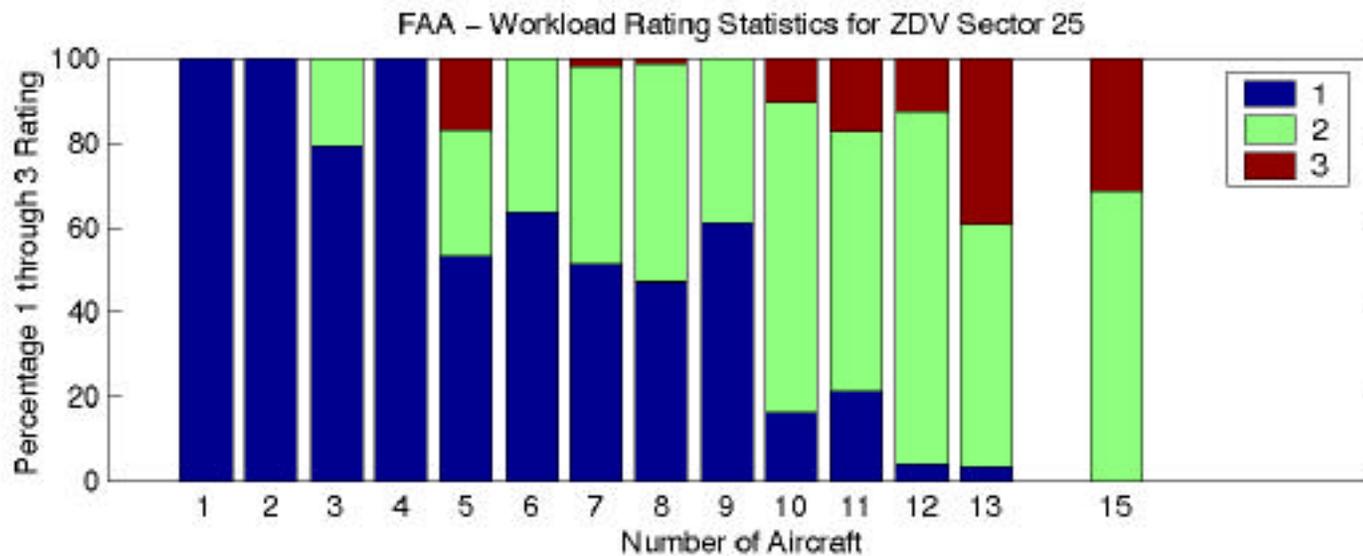
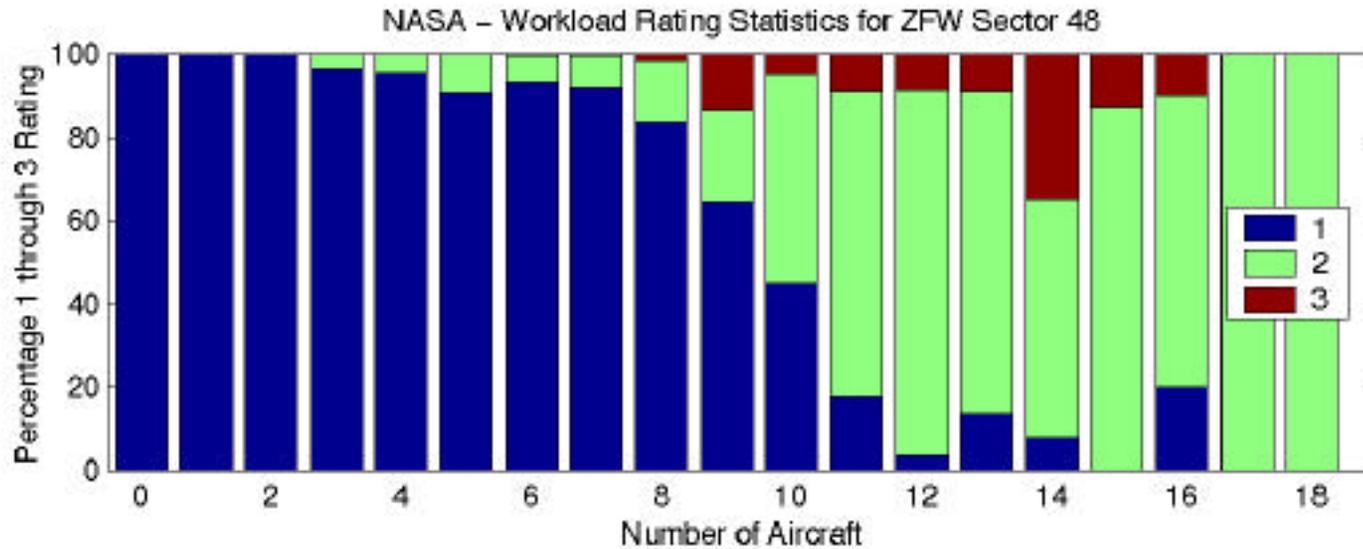


Airspace Complexity

- **Traffic Flow**
 - Growth in Air Traffic
 - New developments in Air Traffic Management such as User Preferences, Free Flight
- **Airspace Design**
 - Merging and Splitting of Sectors
 - Dynamic Resectorization
- **Models/Measures Needed**
 - To predict Air Traffic Controller Workload
 - Make Flow Management decisions like Re-routing
 - Current Measure: Traffic Density (Number of Aircraft in a Sector)



Current Measure: Traffic Density (Number of Aircraft in a Sector)





Air Traffic Controller Workload

- **How do you measure Workload?**
- **Physiological state - heart rate, ECG, blood pressure etc.**
- **Observed physical activity - key strokes, slew ball entries and communications**
- **Controller's rating**
- **Each approach has some drawbacks**



Controller Workload Modeling

- **Controllers use spatial and temporal traffic patterns seen on the display along with their domain knowledge for Air Traffic Control.**
- **Describe the traffic pattern (relation among the aircraft within the airspace) using features/measures_ Number of aircraft in a sector, separation, speed difference,...**
- **Model controller workload by relating the traffic features to**
 - **Observed Controller activity(Denver Center, 97)**
 - **Workload assessment made by the controller (Ames Lab 98, Denver Center/FAATC 99)**



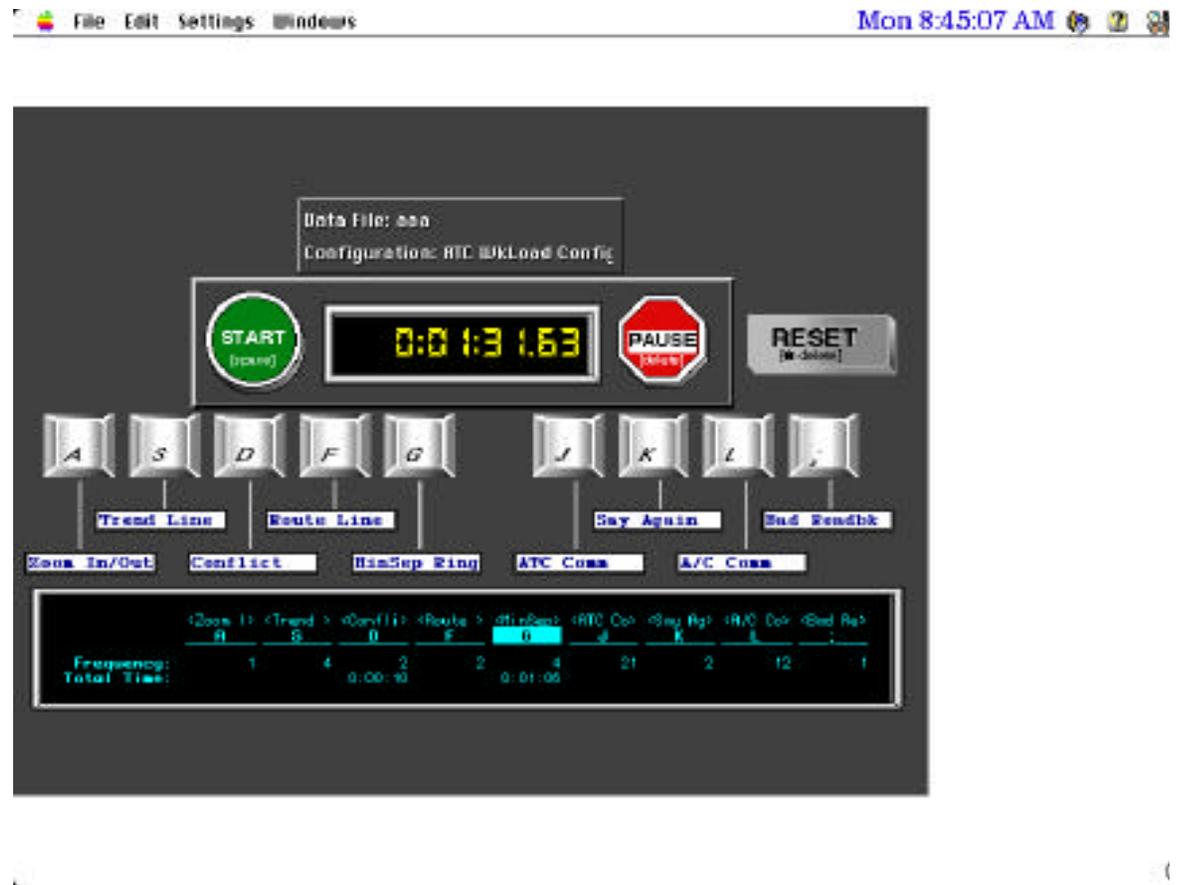
Activity Catalog Tool

Radar Scope

- Zoom
- Trend Lines
- Conflict Alert
- Route Line
- J-Ring

Communication

- ATC Comm
- ATC Missed Comm
- Pilot Comm
- Incorrect Readback





Dynamic Density

- A measure of controller workload, that is a function of traffic density & complexity of air traffic.
- Previous work developed and validated a Dynamic Density metric at Denver Center
 - Based on interviews and survey techniques
 - Activity Catalog Tool
 - Computed in real-time from air traffic data inputs
- Dynamic Density is a weighted sum of Traffic Density and number of aircraft undergoing Heading , Speed and Altitude Changes and Separation between aircraft
 - $DD = (1.00) \text{ Traffic Density} + (2.4) \text{ Heading Change} + (2.45) \text{ Speed Change} + (2.94) \text{ Altitude Change} + (3.72) \text{ Speed Differential} + (2.45) \text{ Minimum Distance } (0,5) + (1.83) \text{ Minimum Distance } (5,10) + (4.0) \text{ Conflict } (0,25) + (3.00) \text{ Conflict } (25,40) + (2.11) \text{ Conflict } (40,70)$
- Developed a Dynamic Density measure with a prediction capability



Lab Workload Experiment

WORKLOAD SETUP

Name:

Center:

Sector:

Number of Ratings:

Rating Direction:

Rating Timeout:

Interval (secs):

Current Time:

Start Time: -1 means start immediately

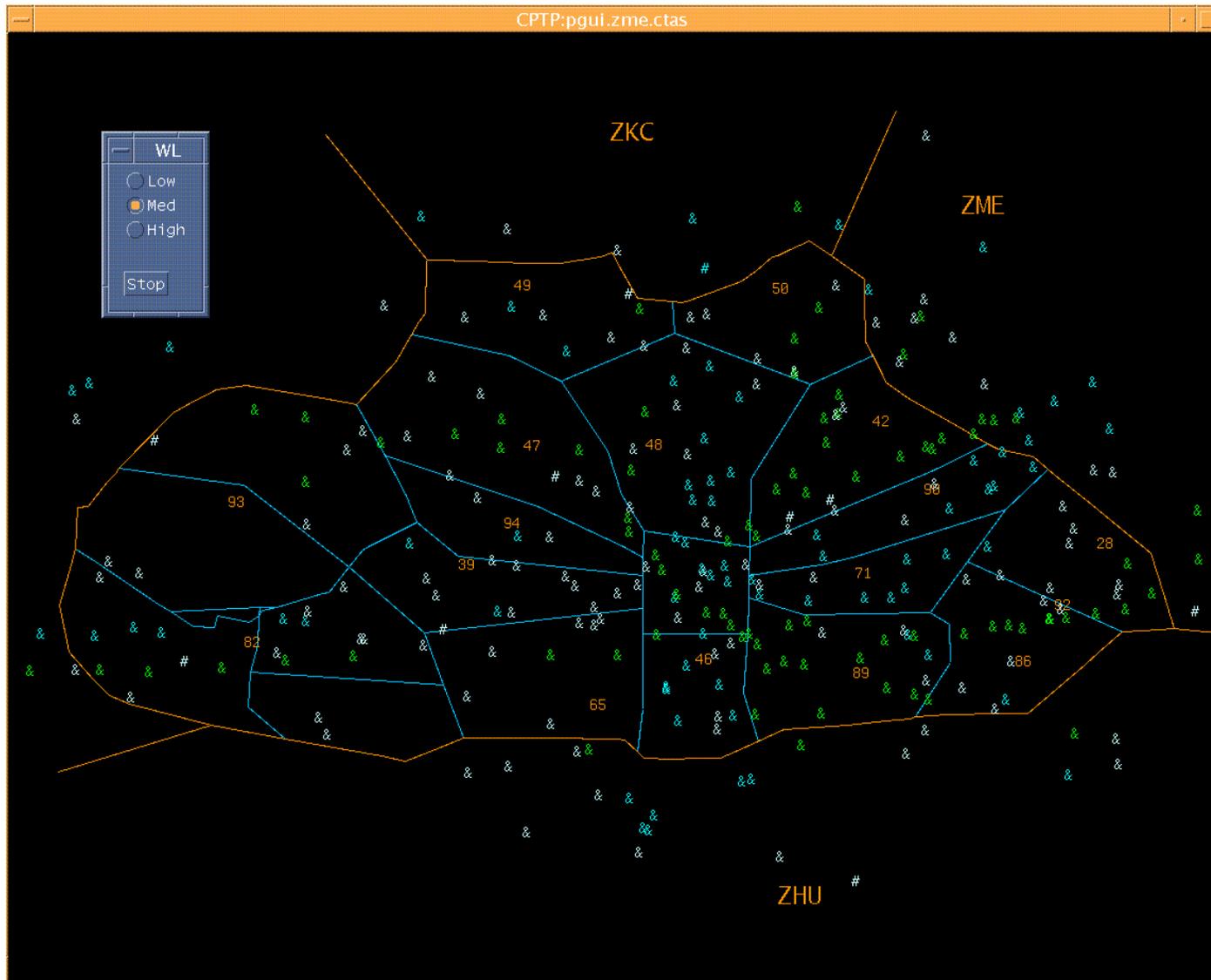
Stop Time: -1 means manual stop

Comments:

Error Messages:

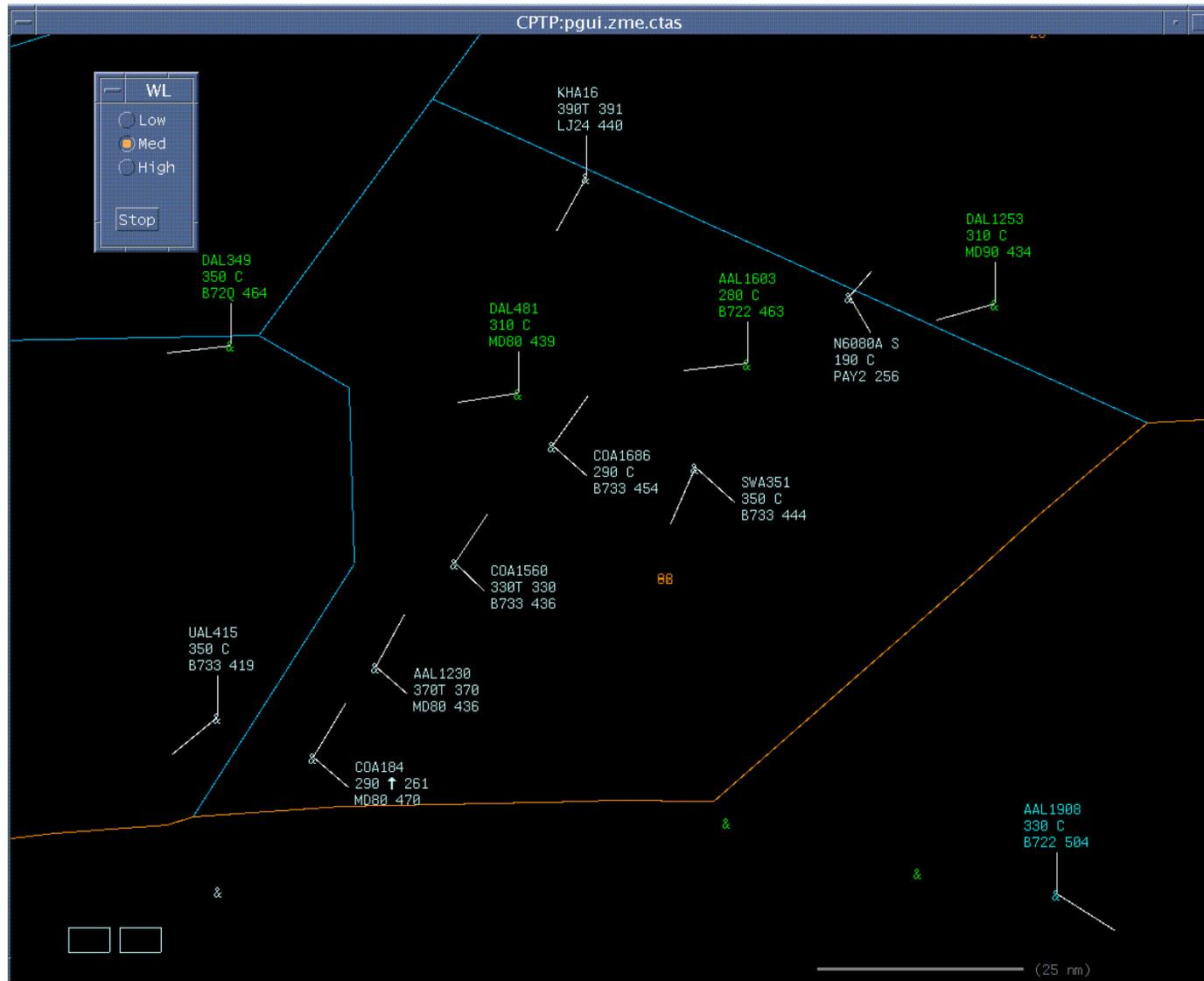


Data Collection



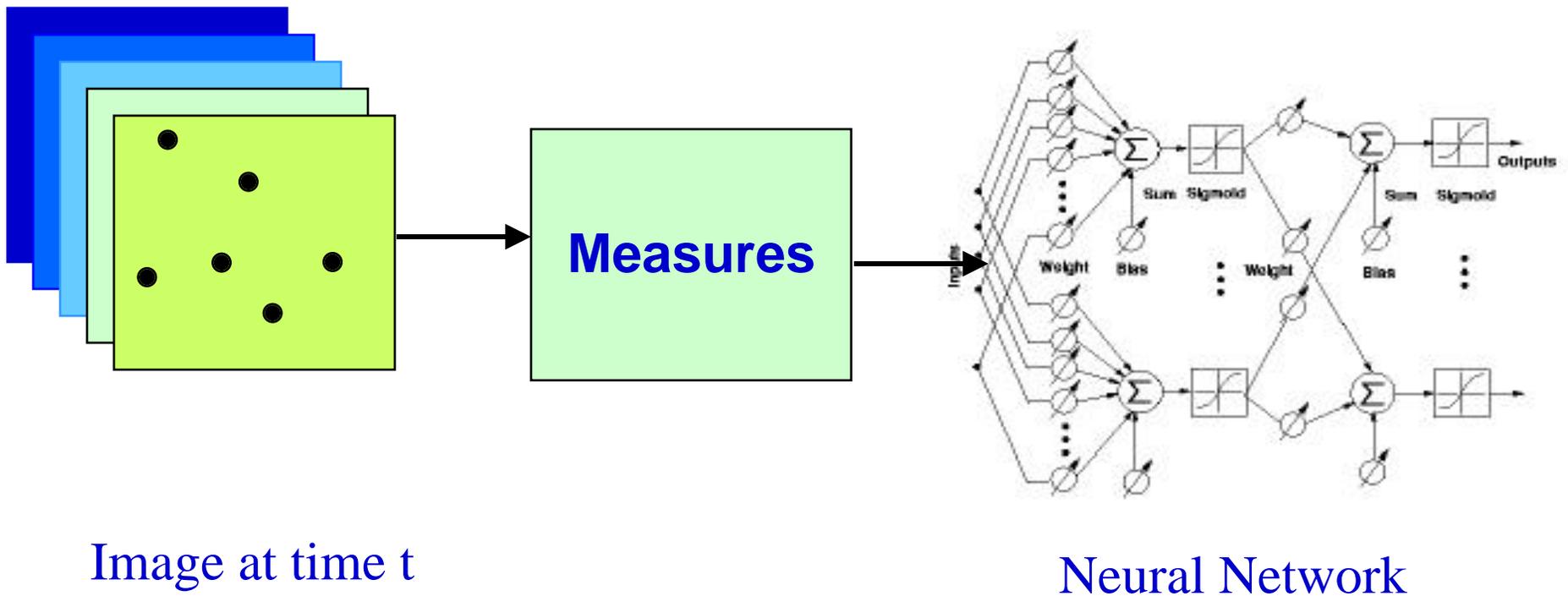


Data Collection





Relating Measures to Workload





Neural Network Training

- ◆ Training inputs: Low: $[-.1, .1, .9]$, Medium: $[-.1, .9, .1]$, High: $[-.9, .1, .1]$
- ◆ Standard back-propagation algorithm used for training.
- ◆ 2/3 data used for training and 1/3 for prediction.
- ◆ All training samples were correctly classified.



Classification Results

	Low	Medium
Low	95%	18%
Medium	5%	82%
High	0%	0%
Total	100%	100%



Count Threshold Versus NN

Count Threshold

	Low	Medium
Low	93.8%	50%
Medium	6.2%	50%
High	0%	0%
Total	100%	100%

Neural Network

	Low	Medium
Low	95%	18%
Medium	5%	82%
High	0%	0%
Total	100%	100%



Discussion

- **Use of Dynamic Density as a Planning Tool**
- **Alternate Complexity Measures**
- **Use of Airspace Complexity as a Design Tool**
 - **Change Space (Airspace Redesign, Resectorization)**
 - **Change Traffic (What If Tool)**