SPACE STATION EVOLUTION

MANIPULATIONS
- CONSTRUCTION
- MAINTENANCE
- MANUFACTURING
- EXPERIMENTS
- RENDEZVOUS AND DOCKING

OBSERVATIONS
- EARTH/SOLAR SYSTEM/DEEP SPACE
- MANUFACTURING
- EXPERIMENTS
- POINTING AND TRACKING
- TARGET ACQUISITION/IDENTIFICATION
SPACE STATION ACTIVITIES NEEDING VIDEO

- CONSTRUCTION
- SATELLITE SERVICING
- RENDEZVOUS
- PROXIMITY OPERATIONS
- COMMUNICATION AND TRACKING
- INSPECTION
- MAINTENANCE
- PAYLOAD DELIVERY/RETRIEVAL
- EXPERIMENT MONITORING
- DATA MANAGEMENT
- TRAINING
EXAMPLE SPACE STATION APPLICATIONS
OF VIDEO IMAGE PROCESSING

RENDEZVOUS
- TARGET IDENTIFICATION
- TARGET TRACKING FOR CROSS RANGE VELOCITY AND POSITION ESTIMATION
- POINT TARGET DETECTION

PROXIMITY OPERATIONS
- TARGET TRACKING FOR TARGET ORIENTATION, POSITION AND VELOCITY ESTIMATION

DATA MANAGEMENT
- BANDWIDTH COMPRESSION FOR DATA MOVEMENT AND ARCHIVING

INSPECTION
- MACHINE VISION TECHNIQUES FOR VERIFICATION OF SPACE STATION STRUCTURAL INTEGRITY AND DETECTION AND CLASSIFICATION OF DEFECTS

COMMUNICATION AND TRACKING
- BANDWIDTH COMPRESSION FOR DOWNLINK TRANSMISSION
- MULTI-TARGET TRACKING FOR AREA TRAFFIC CONTROL
- TARGET DETECTION AND IDENTIFICATION FOR AREA TRAFFIC CONTROL

CONSTRUCTION
- VERIFICATION OF CONSTRUCTION STEPS
VIDEO IMAGE PROCESSOR
506-58-13/N. D. MURRAY

OBJECTIVE

- Research and develop the real-time data and information processing of video image data for space station requirements.

APPROACH

- Investigate potential functions for video rate image/visual special purpose processing, identify architectural approach, and generate a conceptual design. Honeywell

- Research computationally simple algorithms and determine their image/visual effectiveness.

- Implement selected algorithms in special hardware designs and evaluate.

- Using results of proceeding efforts, implement an overall architectural design that will provide image/visual processing at video rates that are flexible, selectable, and programmable.
VIDEO SOURCES

- CAMERAS

  INTERNAL

  - MODULE CAMERAS
  - EXPERIMENT MONITORING

  EXTERNAL

  - MRMS
  - DOCKING PORTS
  - LOCAL AREA TRAFFIC MONITORING
  - SERVICING FACILITY
  - ON MMUS
  - OMV/OTV
  - FREE FLIERS

- VIDEO STORAGE DEVICES

- UPLINK VIDEO
VIDEO IMAGE PROCESSING IN SPACE STATION

- REAL TIME, 100 Mbps
ALGORITHMS

* PROCESSING
  REMOVAL OF NOISE
  HISTOGRAM
  THRESHOLDING

* ANALYSIS

   STRUCTURAL
   EDGES
   VERTICES
   REGIONS

   STATISTICAL
   DENSITY FUNCTION
   MOMENTS
   CO-OCCURENCE
   MATRICES

* RECOGNITION
  OBJECTS
  TEXTURES

* UNDERSTANDING
  SCENE DESCRIPTION
  SPATIAL RELATIONSHIP
  MOTION PARAMETERS
NATURAL OF PROCESSING

IMAGE:
ORDERED SETS OF NUMBERS

IMAGE FEATURES:
SYMBOLS ASSOCIATED WITH NUMERICAL VALUES
A : 37, 28
B : 29, 73

OBJECTS:
INTERRELATED SYMBOLS (GRAPH)

SCENE:
SEMANTIC NETS
FUNCTIONAL ANALYSIS

GOAL: FUNCTIONAL DECOMPOSITION OF SPACE STATION TASKS AND DETERMINATION OF COMPUTATIONAL REQUIREMENTS

FEATURES:

- OPERATION THROUGHPUT
- DATA THROUGHPUT
- POTENTIAL PARALLELISM
- DATA DEPENDENT BEHAVIOR
- WORD SIZE REQUIREMENTS
- OPERATION DENSITY, (OPS/PIXEL OR OPS/FEATURE)
- IMPLICATIONS FOR
  - PROCESSING SUPPORT
  - COMMUNICATION REQUIREMENTS
  - CONTROL STRATEGIES
IMAGE ANALYSIS COMPUTATIONAL MODEL

CLASS 1 (ENHANCEMENT)

CLASS 2 (EXTRACTION)

CLASS 3 (EVALUATION)

IMAGES

COMMANDS

FEATURES

DATA STRUCTURES

RESULTS

IMAGES

COMMANDS

LOW-LEVEL IMAGE PROCESSING

HIGH-LEVEL IMAGE UNDERSTANDING
IMAGE PROCESSING ENVIRONMENT

INPUT DATA STRUCTURES → TRANSFORMATIONS → OUTPUT DATA STRUCTURES

PARALLEL TASKS MAY BE FORMULATED BY EXPLOITING PARALLELISM IN THE TRANSFORMATIONS OR DATA STRUCTURES

TRANSFORMATIONS MAY BE CLASSIFIED AS

- IMAGE TO IMAGE (PREPROCESSING)
- IMAGE TO DATA STRUCTURE (DATA REDUCTION)
- DATA STRUCTURE TO DATA STRUCTURE (HIGH LEVEL)
## IMAGE-TO-IMAGE FUNCTIONS

<table>
<thead>
<tr>
<th>EXAMPLE</th>
<th>MOPS</th>
<th>DATA ACCESS PATTERN</th>
</tr>
</thead>
<tbody>
<tr>
<td>DETECTOR COMPENSATION</td>
<td>8-9</td>
<td>FIXED, HIGHLY PARALLEL</td>
</tr>
<tr>
<td>THRESHOLDING</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>FILTERING</td>
<td>400</td>
<td></td>
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<tr>
<td>CORRELATION</td>
<td>400</td>
<td></td>
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<tr>
<td>EDGE DETECTION</td>
<td>400-800</td>
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<tr>
<td>ENHANCEMENT</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>CHANGE DETECTION</td>
<td>8</td>
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</tr>
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</table>
IMAGE-TO-IMAGE FUNCTIONS (CONTINUED)

- DATA DEPENDENCIES - VERY LOW
- WORD SIZE REQUIREMENTS - PIXEL RESOLUTION
- OPERATION DENSITY - $10^{-2}$ OPS/PIXEL
- PROCESSING SUPPORT - SIMPLE ARITHMETIC OPERATIONS
- COMMUNICATION - FIXED, PREDETERMINED
- CONTROL STRATEGIES - SYNCHRONOUS, SIMD
### IMAGE-TO-DATA STRUCTURE FUNCTIONS

<table>
<thead>
<tr>
<th>EXAMPLES</th>
<th>MOPS</th>
<th>DATA ACCESS PATTERN</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGION GROWING</td>
<td>20-30</td>
<td>CONSTRAINED</td>
</tr>
<tr>
<td></td>
<td>(EMPIRICAL)</td>
<td></td>
</tr>
<tr>
<td>LINE AND SHAPE DETECTION</td>
<td>200-300</td>
<td>FIXED</td>
</tr>
<tr>
<td>(HOUGH TRANSFORM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENCODING VIA</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>- QUAD TREES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- RECTANGLE CODES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STATISTICS</td>
<td>30</td>
<td>PREDETERMINED</td>
</tr>
</tbody>
</table>
IMAGE-TO-DATA STRUCTURE FUNCTIONS
(CONTINUED)

- DATA DEPENDENCIES - TENDS TO BE HIGH
- WORD SIZE REQUIREMENTS - 16 BITS
- OPERATION DENSITY - 10-10^3 OPS/FEATURE
- PROCESSING SUPPORT - ARITHMETIC, SOME LOGICAL, LIMITED FLOATING POINT
- COMMUNICATION - CAN BE STRUCTURED IN A MANNER THAT CAN BE PREDETERMINED
- CONTROL STRATEGIES - INCLINED TOWARD MIMD
# Data Structure-to-Data Structure Functions

<table>
<thead>
<tr>
<th>EXAMPLES</th>
<th>MOPS</th>
<th>DATE ACCESS PATTERN</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATCHING DESCRIPTIONS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- GRAPHS</td>
<td>1-3</td>
<td>PREDETERMINED</td>
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<tr>
<td>- CONTOURS</td>
<td>20-30</td>
<td>PREDETERMINED</td>
</tr>
<tr>
<td>MATCHING FEATURE VECTORS</td>
<td>1-2</td>
<td>FIXED</td>
</tr>
<tr>
<td>3-D STRUCTURE</td>
<td>?</td>
<td>UNKNOWN</td>
</tr>
<tr>
<td>INFEERENCE RULE EVALUATION</td>
<td>?</td>
<td>UNKNOWN</td>
</tr>
<tr>
<td>POSITION ESTIMATION, TRACKING</td>
<td>?</td>
<td>UNKNOWN</td>
</tr>
</tbody>
</table>
DATA STRUCTURE-TO-DATA STRUCTURE
FUNCTIONS (CONTINUED)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Requirement</th>
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<tbody>
<tr>
<td>DATA DEPENDENCIES</td>
<td>VERY HIGH</td>
</tr>
<tr>
<td>WORD SIZE REQUIREMENTS</td>
<td>32-64 BITS</td>
</tr>
<tr>
<td>OPERATION DENSITY</td>
<td>$10^4$-$10^6$ OPS/FEATURE</td>
</tr>
<tr>
<td>PROCESSING SUPPORT</td>
<td>SYMBOLIC OPERATIONS, DATA MANIPULATION, NON-NUMERIC OPERATIONS</td>
</tr>
<tr>
<td>COMMUNICATION</td>
<td>DYNAMIC, VARIABLE</td>
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<tr>
<td>CONTROL STRATEGIES</td>
<td>MIMD</td>
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# Functional Analysis Summary

<table>
<thead>
<tr>
<th>Data Dependencies</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
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<tbody>
<tr>
<td>Accuracy</td>
<td>Pixel Resolution</td>
<td>16 Bits</td>
<td>32-64 Bits</td>
</tr>
<tr>
<td>Operation Density</td>
<td>10-10^2 OPS/PIXEL</td>
<td>10-10^3 OPS/FEATURE</td>
<td>10^4-10^6 OPS/FEATURE</td>
</tr>
<tr>
<td>Data Throughput</td>
<td>8-500 MOPS</td>
<td>10-300 MOPS</td>
<td>1-5 MOPS, MLIPS</td>
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<tr>
<td>Processing Required</td>
<td>Arithmetic, Simple</td>
<td>Arithmetic, Logical</td>
<td>Floating Point</td>
</tr>
<tr>
<td>Control</td>
<td>Synchronous (SIMD)</td>
<td>Toward MIMD</td>
<td>Symbolic Non-Numeric</td>
</tr>
<tr>
<td>Communication</td>
<td>Fixed</td>
<td>CAN BE STRUCTURED AND PREDETERMINED</td>
<td>Asynchronous, MIMD</td>
</tr>
</tbody>
</table>
|                     |     | DYNAMIC AND VARIABLE | }
FUNCTIONAL ANALYSIS SUMMARY
(CONTINUED)

- MIX OF COMPUTATIONS AND CONTROL STRATEGIES

- INCREASING NON-DETERMINISTIC BEHAVIOR

- SHIFT IN POTENTIAL PARALLELISM FROM DATA TO ALGORITHMS

- PERHAPS CONFLICTING ARCHITECTURAL SOLUTIONS?

- ROLE OF COLOR NEEDS TO BE DETERMINED

- IMPACT OF DYNAMIC AND STATIC NATURE OF DATA STRUCTURES
  TO BE EVALUATED
**Computational Characteristics**

$10^8 - 10^9$ bits/sec.

- Enhancement
- Edge detection
- Vertices
- Filtering
- Histogram
- Statistics

$10^{-2}$

Objects

$10^3 - 10^5$ bits/sec.

$\approx 10 - 10^3$ features/sec.

Matching

Understanding

$10^3 - 10^5$ bits/sec.

Symbolic operations (MLIPS)

$10^4 - 10^6$ ops/feature

Inference

Operation density

$10 - 10^2$ ops/pixel

Pixel and window operations

Constructing descriptions

Searching matching
CONCURRENT PROCESSING ARCHITECTURES

- SPECIAL-PURPOSE PROCESSORS
- WORD-SEQUENTIAL PROCESSORS
- ASSOCIATIVE PROCESSORS
- ARRAY PROCESSORS
- PIPELINE PROCESSORS
- RECONFIGURABLE PROCESSORS
- MULTIPROCESSORS
- DATA FLOW PROCESSORS
- OBJECT-ORIENTED PROCESSORS
- INERENCE PROCESSORS