SPACE STATION WILL HAVE REQUIREMENTS FOR CONDUCTING SUCH MANIPULATION/OBSERVATION ACTIVITIES AS CONSTRUCTION, MAINTENANCE, MANUFACTURING, EXPERIMENTS, Rendezvous AND DOCKING, POINTING AND TRACKING, TARGET ACQUISITION/IDENTIFICATION, AND SOLAR SYSTEM OBSERVATIONS. INITIALLY, MOST OF THESE MANIPULATIONS/OBSERVATIONS WILL REQUIRE REAL-TIME PROCESSING OF DATA AND INFORMATION FOR VISUAL PRESENTATION, WHICH IN TURN WILL REQUIRE MAN'S OPERATIONAL CAPABILITIES IN-THE-LOOP WITH VIDEO DISPLAY, WHICH WILL CREATE AN ADDITIONAL NEED FOR REAL-TIME AUTONOMOUS WITH MAN MONITORING, WHICH WILL CREATE AN ADDITIONAL NEED FOR REAL-TIME PROCESSING AT DATA RATES EXCEEDING 100 MBITS/SEC. PROCESSING AT SUCH HIGH RATES WILL MOST LIKELY BE ACCOMPLISHED BY SPECIAL PURPOSE COMPUTING IMPLEMENTING COMPUTATIONALLY SIMPLE ALGORITHMS. CURRENT TECHNOLOGY PROJECTIONS INDICATE THE LACK OF AVAILABILITY OF SUCH SPECIAL PURPOSE COMPUTING IN THE EARLY 1990S, AND NASA NEEDS TO ACCELERATE THE TECHNOLOGY FOR APPLICATION TO SPACE STATION. POTENTIAL FUNCTIONS FOR VIDEO IMAGE Special-purpose Processing are being investigated, such as smoothing, enhancement, object detection and identification, and vision synthesis. Also, ARCHITECTURAL APPROACHES ARE BEING IDENTIFIED AND MENTIONED INTO AN OVERALL ARCHITECTURAL APPROACH THAT WILL PROVIDE IMAGE/VISION PROCESSING AT VIDEO RATES THAT ARE FLEXIBLE, SELECTABLE, AND PROGRAMMABLE.
IMAGE/VISION PROCESSOR

- AUGMENT MAN'S REMOTE WORK CAPABILITIES
- REVIEW AND EDIT OBSERVATIONS
SPACE STATION EVOLUTION

~1990
BUILDUP

~2010
MATURE OPERATIONS

MAN IN THE LOOP

NEAR AUTONOMOUS MANNERS

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

- MACHINEVISION 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/VISION SPECIAL PURPOSE PROCESSING, IDENTIFY ARCHITECTURAL APPROACH, AND GENERATE A CONCEPTUAL DESIGN. HONEYWELL

- RESEARCH COMPUTATIONALLY SIMPLE ALGORITHMS AND DETERMINE THEIR IMAGE/VISION EFFECTIVENESS.

- IMPLEMENT SELECTED ALGORITHMS IN SPECIAL HARDWARE DESIGNS AND EVALUATE.

- USING RESULTS OF PROCEEDING EFFORTS, IMPLEMENT AN OVERALL ARCHITECTURAL DESIGN THAT WILL PROVIDE IMAGE/VISION 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 DISTRIBUTION

INTERCONNECTION NETWORK

STORAGE

TO/FROM GROUND

MPAC MPAC MPAC

VIP VIP

C C C C C
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
NATURE OF PROCESSING

IMAGE:
ORDERED SETS OF NUMBERS

IMAGE FEATURES:
SYMBOLS ASSOCIATED WITH NUMERICAL VALUES
A : 37, 28
B : 30, 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

DATA STRUCTURES

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>
</tr>
<tr>
<td>CORRELATION</td>
<td>400</td>
<td></td>
</tr>
<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>
<td></td>
</tr>
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</table>
IMAGE-TO-IMAGE FUNCTIONS (CONTINUED)

- DATA DEPENDENCIES - VERY LOW
- WORD SIZE REQUIREMENTS - PIXEL RESOLUTION
- OPERATION DENSITY - $10-10^2$ OPS/PIXEL
- PROCESSING SUPPORT - SIMPLE ARITHMETIC OPERATIONS
- COMMUNICATION - FIXED, PREDETERMINED
- CONTROL STRATEGIES - SYNCHRONOUS, SIMD
<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>(EMPIRICAL)</td>
<td></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)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td><strong>Data Dependencies</strong></td>
<td>Tends to be high</td>
</tr>
<tr>
<td><strong>Word Size Requirements</strong></td>
<td>16 Bits</td>
</tr>
<tr>
<td><strong>Operation Density</strong></td>
<td>$10-10^3$ ops/feature</td>
</tr>
<tr>
<td><strong>Processing Support</strong></td>
<td>Arithmetic, some logical, limited floating point</td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td>Can be structured in a manner that can be predetermined</td>
</tr>
<tr>
<td><strong>Control Strategies</strong></td>
<td>Inclined toward MIMD</td>
</tr>
</tbody>
</table>
### 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>
</tr>
<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)

- DATA DEPENDENCIES - VERY HIGH
- WORD SIZE REQUIREMENTS - 32-64 BITS
- OPERATION DENSITY - $10^4$-$10^6$ OPS/FEATURE
- PROCESSING SUPPORT - SYMBOLIC OPERATIONS, DATA MANIPULATION, NON-NUMERIC OPERATIONS
- COMMUNICATION - DYNAMIC, VARIABLE
- CONTROL STRATEGIES - MIMD
## Functional Analysis Summary

<table>
<thead>
<tr>
<th></th>
<th>Image to Image</th>
<th>Data Structure to Data Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data Dependencies</strong></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>Pixel Resolution</td>
<td>16 Bits</td>
</tr>
<tr>
<td><strong>Operation Density</strong></td>
<td>$10^{-2}$ Ops/Pixel</td>
<td>$10^{-3}$ Ops/Feature</td>
</tr>
<tr>
<td><strong>Data Throughput</strong></td>
<td>8-500 MOPS</td>
<td>10-300 MOPS</td>
</tr>
<tr>
<td><strong>Processing Required</strong></td>
<td>Arithmetic, Simple</td>
<td>Arithmetic, Logical</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>Synchronous (SIMD)</td>
<td>Toward MIMD</td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td>Fixed</td>
<td>Can be structured and predetermined</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dynamic and Variable</td>
</tr>
</tbody>
</table>
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

OBJECTS

10^3 - 10^5 BITS/SEC.
≤ 10 - 10^3 FEATURES/SEC.

ARITHMETIC OPERATION (MOPS)
- PIXEL AND WINDOW OPERATIONS
- CONSTRUCTING DESCRIPTIONS
- SEARCHING MATCHING

OPERATION DENSITY
- 10 - 10^2 OPS/PIXEL

UNDERSTANDING

MATCHING

SYMBOLIC OPERATIONS (MLIPS)

INFERENCEx

10^4 - 10^6 OPS/FEATURE
CONCURRENT PROCESSING ARCHITECTURES

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