SIMNET
COMPUTER
IMAGE
GENERATION
SYSTEM

1987

MICHAEL L. CYRUS
OVERVIEW

- SIMNET CIG SYSTEM
  - 6 U CHASSIS
    Central Processing Unit
    Active Area Memory
    Traversal Processor and DMA
  - 9 U CHASSIS
    Polygon Processor
    Tiling Process
    Pixel Processor Memory

- SIMNET OBJECT TYPES
- SIMNET SAMPLE IMAGERY
BBN Delta Graphics, Inc.
DELTA SimNet CIG System Performance Parameters

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CIG SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent Viewing Channels</td>
<td>Up to 8</td>
</tr>
<tr>
<td>Occulting Levels</td>
<td>524,288</td>
</tr>
<tr>
<td>Frame Update Rate</td>
<td>15 per second per channel</td>
</tr>
<tr>
<td></td>
<td>30 Hz optional with 4 channels</td>
</tr>
<tr>
<td>Computational Delay (at 15 Hz)</td>
<td>&lt;90 milliseconds</td>
</tr>
<tr>
<td>Computed Screen Resolution</td>
<td>320 x 128, 200 x 200</td>
</tr>
<tr>
<td>Displayed Screen Resolution</td>
<td>640 x 256, 400 x 400</td>
</tr>
<tr>
<td>Video Format</td>
<td>RS-170 RGB</td>
</tr>
<tr>
<td>Field-of-View (FOV)</td>
<td>Frame to frame Selectable</td>
</tr>
<tr>
<td>Potentially Visible Polygons per Frame</td>
<td>1000 polygons/channel</td>
</tr>
<tr>
<td></td>
<td>2000 optional</td>
</tr>
<tr>
<td>Online Database Storage Capacity</td>
<td>70 million bytes</td>
</tr>
<tr>
<td>Active Area Memory</td>
<td>1.5 million bytes</td>
</tr>
<tr>
<td>Terrain Grid Spacing</td>
<td>Selectable</td>
</tr>
<tr>
<td>Depth Complexity</td>
<td>3.8 at 15Hz.</td>
</tr>
<tr>
<td>Color Resolution</td>
<td>4096 colors</td>
</tr>
<tr>
<td>Anti-aliasing</td>
<td>Yes</td>
</tr>
<tr>
<td>Distance Fading</td>
<td>Yes</td>
</tr>
<tr>
<td>Texture Generation With Transparency</td>
<td>Yes, 16 transparency levels per color</td>
</tr>
<tr>
<td>Stamp and Perspective Texturing</td>
<td>Yes</td>
</tr>
<tr>
<td>Model Level-of-Detail Control</td>
<td>Yes</td>
</tr>
<tr>
<td>Moving Models Per Gaming Area</td>
<td>50</td>
</tr>
<tr>
<td>Texture Patterns</td>
<td>Up to 256</td>
</tr>
<tr>
<td>Laser Range Finding</td>
<td>Yes</td>
</tr>
<tr>
<td>Collision Detection</td>
<td>Yes</td>
</tr>
<tr>
<td>Database Size</td>
<td>Up to 3.75 million polygons</td>
</tr>
</tbody>
</table>
CENTRAL PROCESSING UNIT

FUNCTIONS

- Simulation Host Interface
- Moving Model and Special Effects Handling
- Vehicle Position Handling
- Local Terrain Message Assembly
- Active Area Memory Management
- Ballistic Calculations

IMPLEMENTATION

- MC68020 CPU.
- MC68881 Floating Point Coprocessor

SPECIFICATIONS

- 1 MByte RAM
- VME Bus Compatable.
ACTIVE AREA MEMORY

FUNCTIONS

- 8 KILOMETER SQUARE OF ACTIVE AREA MEMORY
- VEHICLE POSITION INFORMATION IN DOUBLE BUFFERED MEMORY
- GENERIC OBJECT DATA STORAGE

IMPLEMENTATION

- HALF MBYTE OF STATIC RAM PER BOARD (3 BOARDS)
- DUAL PORTED VME AND VMX BUS INTERFACE

SPECIFICATIONS

- 200 NANOSECOND ACCESS TIME
MY VEHICLE IS IN THE CENTER TERRAIN REGION
TRAVERSAL PROCESSOR AND DMA

FUNCTIONS

• TRAVERSE DATABASE FOR ALL CHANNELS PER FRAME
• PERFORM FIELD OF VIEW TESTING
• SEND PROPER DATA TO EACH CHANNEL
• PERFORM LOD PROCESSING
• DATA POINTER MANAGEMENT
• CONTROL DATA OUTPUT TO POLY PROCESSORS

IMPLEMENTATION

• MICRO CODED PROCESSOR
• FIXED POINT AND FLOATING POINT ALU'S

SPECIFICATIONS

• 8 MIPS FIXED POINT PROCESSING
• 2 MFLOPS FLOATING POINT PROCESSING
• 4K WORDS OF POINTER BUFFER
PRELIMINARY FIELD OF VIEW TEST

![Diagram showing field of view test with lookup table and tank location]

- ORDERS TERRAIN REGIONS FRONT TO BACK
- REDUCES THE NUMBER OF DETAILED FIELD OF VIEW TESTS REQUIRED
DETAILED FIELD OF VIEW TEST

- CLASSIC CENTROID AND RADIUS DOT PRODUCT TEST

EXPAND RADIUS TO INCLUDE ALL OBJECTS ASSIGNED TO THE TERRAIN REGION
LEVEL OF DETAIL PROCESSING

- ALLOWS SCENE DETAIL TO BE CONCENTRATED CLOSE TO THE VIEWPOINT
POLYGON PROCESSOR

FUNCTIONS

• MATRIX MANIPULATIONS
• VIEWSPACE TRANSFORMATIONS
• ELIMINATE BACKFACING POLYGONS
• CLIP POLYGONS TO VIEWING PYRAMID
• SCREEN SPACE PERSPECTIVE PROJECTIONS
• PREPARE POLYGON FOR TILER BOARD
• SETUP TEXTURED AND FACE SHADED POLYGONS
• PROCESS TERRAIN GRIDS AND ROTATED STAMPS

IMPLEMENTATION

• PIPELINED FLOATING POINT MICROCODED ENGINES
• 4K OF 128 BIT WORDS OF MICROCODE SPACE
• CUSTOM CLIPPING HARDWARE
• ON BOARD DATA RAM.

SPECIFICATIONS

• 30,000 POTENTIALLY VISIBLE 4 SIDED TEXTURED POLYGONS PER SECOND
• 40 MFLOPS TOTAL PROCESSING POWER
$[X \ Y \ Z \ W] = [X \ Y \ Z \ 1]$
BACKFACE ELIMINATION &
VIEWPOINT TRANSFORMATION

VIEWPOINT COORDINATE SYSTEM

SCREEN

OBJECT

ELIMINATE BACKFACE
CLIPPING

PYRAMID OF VISION

VIEWPOINT

SCREEN

AFT PLANE

SCREEN
PROJECTION TO SCREEN COORDINATES

VIEWPOINT

SCREEN

POLYGON IN SCREEN SPACE

POLYGON IN VIEWPOINT SPACE

SCREEN COORDINATES
TILING PROCESS

Functions

- Polygon Fill
- Assign polygon color via texture lookup
- Anti-alias polygon edges
- Calculate true perspective depth at each pixel
- Add programmed distance fading
- Assign RGB or intensity texture maps with dynamic LOD control

Implementation

- 2 custom CMOS gate array designs (13 total arrays)
- MSI and LSI-TTL circuitry
- Programmable lookup tables for all color calculations

Specifications

- 160 Kbytes of texture map storage
- 5.5 million pixels per second
TILING & DEPTH LINEARITY

TOP VIEW OF OBJECT

CROSS SECTION OF THE OBJECT IN THE FIELD OF VIEW

OBJECT IN SCREEN SPACE
PERSPECTIVE TEXTURING

ADDRESS INTO TEXTURE MAP

A4,B4

A3,B3

TEXTURED POLYGON

A1,B1

A2,B2

PERSPECTIVE PROJECTION

SCREEN

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TEXTURE STORAGE & LEVEL OF DETAIL

- All textures are prefilttered to reduce aliasing effects
- Lower level of detail textures are formed by down filtering the highest level of detail texture
Pixel Processor Memory

Functions

- Hidden surface elimination via hybrid depth buffer
- Color blending for Antialiasing and Transparency
- Sky coloring
- Video output control

Implementation

- Double Buffered Frame Stores
- 672 KBytes of Static RAM memory

Specifications

- RS 170 compatible
ALIASING EFFECTS
DISCRETE SAMPLING

OBJECT WITHOUT ALIASING EFFECTS

OBJECT SHOWING THE DISCRETE SAMPLING EFFECT
ANTIALIASING

PIXEL AREA

ACTUAL EDGE CROSSING

EDGE WITH NO ANTIALIASING

EDGE WITH ANTIALIASING
SIMNET OBJECT TYPES

- REAL WORLD TERRAIN GRIDS.
- GENERIC STATIC OBJECTS.
- SINGULAR STATIC OBJECTS.
- TERRAIN OVERLAYS.
- MOVING OBJECTS.
- ROTATED STAMPS.
OBJECT DEFINITIONS

GENERIC STATIC OBJECT

SINGULAR STATIC OBJECT

J O E ' S

GENERIC MOVING OBJECT

SINGULAR STATIC OBJECT

TERRAIN

TERRAIN OVERLAY

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STAMPS

- A TEXTURED SURFACE THAT ROTATES TO FACE THE VIEWPOINT

- REDUCES POLYGON COUNT

- ADDS REALISM TO THE SCENE
OBJECTIVES OF DATABASE CONSTRUCTION

- LOWER LIFE CYCLE COSTS

- PROVIDE BROAD UTILIZATION OF SIMULATION SYSTEM

- PROVIDE MAXIMUM IMAGE QUALITY, SCREEN COMPLEXITY AND REALISM ALLOWED BY THE CIG PROCESSOR
CHALLENGES IN DATABASE CONSTRUCTION

• COMBINING DATA OF VARIOUS TYPES AND FORMATS

• MATCHING GAMING AREA DATA TO REAL WORLD COORDINATES

• WORKING WITH LARGE QUANTITIES OF DIVERSE DATA

• MODIFICATION AND ENHANCEMENT OF GAMING AREAS

• COMpressing AND FORMATTING DATA TO BUIld COMPACT RUN-TIME DATABASES
KEY TASKS

MULTISOURCE DATA INPUT

GAMING AREA CONSTRUCTION

LOAD MODULE CONSTRUCTION
MULTISOURCE DATA INPUT

- INTERCOL
- STATISTICAL
- PHOTO
- INTEL
- 3-D MODELS
- MODEL LOCATION
- DMA ELEVATION
- MAP DATA

REFINED INPUT DATA
DATABASE CONSTRUCTION PHASE II

DATABASE ASSEMBLY

DATABASE ENTITY TESTING

DATABASE COMPILED

DATABASE PREVIEW

DATABASE DENSITY TESTING

VISUAL DATABASE
LOAD MODULE CONSTRUCTION

GAMING AREA REGION FILE

LOAD MODULE COMPILER

RUN-TIME DATABASE
EXAMPLE

DATAPATH - TERRAIN
TERRAIN GRID CREATION

STEP 1
READ DMA LEVEL 1 ELEVATION DATA BLOCKS FROM TAPE(S) TO DISK.

1° X 1° BLOCK (2.88 MByte)

LATITUDE (DEG)

35

34

33

LONGITUDE (DEG)

86 85 84

SUBSET BLOCK

STEP 2
GROUP ADJACENT DMA BLOCKS, AND EXTRACT A
1° X 1° SUBJECT BLOCK SURROUNDING A POTENTIAL GAMING AREA

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TERRAIN GRID CREATION

SUBSET BLOCK

LAT/LON (DMS)
34 20 0
84 30 0

RAW GAMING AREA

LAT/LON (DMS)
33 20 0
85 30 0

STEP 3

EXTRACT RAW GAMING AREA BLOCK OF ELEVATION VALUES, & CONVERT DATA POINTS: (LATITUDE, LONGITUDE, ELEVATION) TO (NORTHING, EASTING, ELEVATION) IN UTM COORDINATES

STEP 4

RESAMPLE CONVERTED DMA DATA TO FINAL GAMING AREA SIZE AT SELECTED GRID SPACING.
**TERRAIN GRID CREATION**

**Graph:**
- **Correlation Coefficient** vs **Grid Spacing**
  - Correlation Coefficient ranges from 0 to 1.
  - Grid Spacing is on the x-axis.

**Step 5**
**Data Testing**

**Data Correlation Coefficient**
- To match base terrain data

**Surface Roughness**
- To gage polygon relaxation potential

**Backface Percentages**
- To estimate model data densities
TERRAIN GRID CREATION

STEP 6

POLYGON RELAXATION
TERRAIN GRID CREATION

STEP 7
RESTRUCTURE GRID ARRAY INTO INDEPENDANT TERRAIN REGIONS (10,000 REGIONS)

STEP 8
STORE TERRAIN REGIONS INTO GAMING AREA REGION FILE (3.6 MBytes)
TERRAIN MODEL POLYGON COUNT VS VIEWING RANGE

30° FIELD OF VIEW ANGLE

POLYGON COUNT

LEGEND

- 100 M GRID
- 125 M GRID
- 166 M GRID

- 1000 Polygon throughput design envelope**
- 1500 Polygon throughput design envelope**
- 2000 Polygon throughput design envelope**

- 20% Polygon Relaxation
- 20% Backface Elimination

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TERRAIN MODEL POLYGON COUNT VS VIEWING RANGE

40° FIELD OF VIEW ANGLE

POLYGON COUNT

LEGEND

- 100 M GRID
- 125 M GRID
- 166 M GRID

1000 Polygon throughput design envelope**
1500 Polygon throughput design envelope**
2000 Polygon throughput design envelope**

20% Polygon Relaxation
20% Backface Elimination

Viewing Range (Meters)

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.5 KM TERRAIN PATCH

100 METER
TERRAIN DATA RESOLUTION

TRAINGULATED TERRAIN GEOMETRY MODEL
(POLYGON COUNT = 50 POLYGONS)

RELAXED TERRAIN GEOMETRY MODEL
(POLYGON COUNT = 34)

NOTE: 32% GROSS POLYGON REDUCTION