3D Image Generation
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What is Micro Nav?

- UK based specialist simulation company
- Delivering ATC simulators for 28 years
- Delivering 3D Tower simulators with Image Generators for more than 20 years
Who am I?

- Mike Male
- Ex Air Traffic Controller (Heathrow)
- Co-Founder of Micro Nav
- 30 plus years experience in ATC simulation
- Involved with many 3D tower systems (> 20 years)
- Not an Image Generator expert by training
- Have seen and experience of many
What is an Image Generator? - IG

- Way of presenting the simulated world in 3D
- Most development came from flight simulation - very expensive, highly complex
- First experience - 1994, E&S EP1000 - Cost >US$1m
- Now mostly PC based using gaming technology
- Flight simulation market
  - Some now PC based IGs
  - IGs have to be certified
  - Still expensive but less than before
- ATC currently not regulated
  - Much lower cost
  - Able to take advantage of ‘games’ development
Micro Nav and IGs

- Have been delivering ATC towers (up to 360 degrees) since early 90s
- Used several IG manufacturers (including E&S)
- Now use Imagine SARL
  - The leading edge company developing ATC specific features
- Part of the Quadrant Group
- Owns and operates full flight simulators
- Also moves flight simulators around the world
What Makes a Good IG?

- Several factors:
  - Image Quality
  - Image Frame Rate
  - Power (in ATC terms = the ability to show the required image with enough moving models)
  - No stuttering
  - Features
    - Effects that can be used
    - Flexibility of view

- All need to be viewed in the context of the scenario complexity

- Requirements will differ from use to use
Channels & Synchronisation

- A channel is normally the image for a single screen or projector
- Normally each simulator will include several channels
- Availability of low cost projector and display systems can result in significant numbers of channels
- IG must be able to support high numbers of channels
- All channels must have some form of synchronisation to ensure coherent image between channels
Image Quality

Dubai 3D Model – created by Micro Nav Fast Airport Builder – displayed using Imagine IG
No substitute for pixels
  - See the 4k image on the Micro Nav stand [542]!

Essentially, the more pixels there are, the better the image

Limited by the display system

Human eye said to be “equivalent to 8k x 8k”

Therefore no image as good as ‘reality’

The downside to pixels...
  - The more there are the harder the IG is working
  - Affects the frame rate
Frame Rate

- This refers to how often the screen image is updated
- Cinema standard is 24 frames per second (fps)
- IGs generally have variable rate – normally related to the display screen refresh.
  - For example for 60Hz, frame rates supported would be:
    - 60 fps - 1 screen update per frame
    - 30 fps - 2 screen updates per frame
    - 20 fps – 3 screen updates per frame...
- For ATC, 30 fps or higher considered ‘flicker free’
- Constant frame rate is important
- The more complex the scene (scene content, pixel count...) the harder the IG is working
Scene Content

- Scene consists of static and moving models (although the whole scene can move – as in flight simulator)
- 3D models normally defined by a mesh containing triangles of colour or texture
- Generally, the more triangles, the harder the IG works
- Textures are patterns that can be applied to a triangle rather than solid colour
Tower View

- Static model is the airport scene - triangle count is fixed for that element
- Not necessarily evenly spread over channels
- Moving model triangle count will vary with traffic count per channel
- Frame rate can be affected by dynamic scene content (number of models, number of triangles)
- Frame rate also affected by other effects (weather, fire, smoke, explosions...)
Aircraft or Vehicle View

- If the IG can show the view from the aircraft (a flight simulator or ATC simulator with pilot view):
  - Static model triangle count varies with location and direction
  - Moving models in view also affects triangle count
  - Visual effects also affects frame rate

- Dynamic terrain (static object terrain) where present helps
  - Shown as higher definition near aircraft or vehicle
  - Lower definition further away
  - Maximises view quality and frame rate
Frame Rate Control

- Where IG cannot maintain desired frame rate, either:
  - Reduce frame rate
  - Reduce scene content (triangles)
- Flight simulators must maintain frame rate to remain fit for purpose – so must reduce scene
  - Referred to as a “deterministic” IG if it reduces scene content
  - Does this by progressively simplifying models (where models are created specifically for that purpose)
  - Reduces Level of Detail – things change/disappear
- ATC can tolerate some reduction in frame rate
  - Frame rate can be allowed to reduce as needed
  - Level of detail can be adjusted to keep frame rate – but things must not disappear
Level of Detail (LoD)

- Technique for minimising triangle count
- Detailed models required for ‘close up’ viewing
- Less detailed models required for distant viewing
- Primarily applied to moving models for ATC
- Often applied to static models for flight simulation (to allow frame rate to be maintained)
- System selects the appropriate model for the viewing distance
Level of Detail - Examples

- The images below are 3 of the 4 LoDs for the Boeing 737-900 model from the Micro Nav library – note decreasing quality
Level of Detail - Implementation

- Range for each LoD defined
- Appropriate image shown depending upon model distance from eye point
- Useful if LoD range can be adjusted by user
- LoD range can be automatically adjusted by IG to maintain frame rate (some IGs)
- Normally 3 or more LoDs available (Imagine uses 4)
Aliasing

- ‘Step’ effect of converting a straight line into ‘raster’ lines on a screen - observed at the edges of objects and triangles
- A horizontal straight line in pixels looks like this
  
  ![Horizontal line example](image)

- A non-horizontal straight line can look like this
  
  ![Non-horizontal line example](image)

- Or this
  
  ![Another non-horizontal line example](image)

- If not treated moving straight line image elements (such as wings) can appear to ‘flap’ or ‘creep’ as they move
Anti-Aliasing

- Technique to smooth the alias effect by adjusting the colour of adjacent pixels
- Takes power – not usually a problem with modern IGs
- Big subject – not enough time - but as an example...

Aliased

Anti-Aliased
Physically Based Rendering

- Allows differing smoothness and reflectivity to be applied to elements of moving models
- Gives varying reflectivity between the glossy and matt parts of each model - Adds significantly to realism
Image Reality v Training Reality

- IGs strive to give more and more realistic images
- Functions like Anti-Aliasing create improved looking images but have downsides
- Limited resolution also has downsides when compared with human eye
- Ranges of recognition and observation can be affected
- Need tools to help – for example aircraft models can be scaled to be progressively larger
- Thus ‘unrealistic’ scale can produce ‘realistic’ training benefit
- Important that this is controlled by the user
Johnson’s Criteria

- Commonly used to calculate the range at which an object can be:
  - Detected
  - Oriented (i.e. orientation can be determined)
  - Recognised
  - Identified

- Based upon the capabilities of the display system in terms of ‘optical line pairs’ (lines of pixels)

- Often used when describing display system capabilities

- Use carefully – all such factors do also depend upon the quality of the image and the display elements (such as contrast)
User Controls

- IG should allow user control over all elements including:
  - Scene – tools like Micro Nav’s Fast Airport Builder or Imagine Scene Editor allow users to create or edit airport scenes
  - Quality and content of moving models
    - user should be able to create models easily to ensure models ‘fit for purpose’ (not too detailed to add unnecessary triangles but good enough to be recognisable)
  - Control over LoDs
  - Control over visual effects (such as size of fire, size and colour of smoke) – must be ‘recognisable’ for the observer
  - Control over model scaling
  - Control over Anti-aliasing
Full 3D Scene v Photo Backdrop/Billboarding

- Static 3D scene elements can be created in two ways
- Full 3D model means that all objects are fully modelled
- Scene can also be modelled using a photo back drop – like a “movie set” – referred to a ‘billboarding’

- Photo taken of background then ‘applied’ to a billboard
Advantages and Disadvantages

- Full 3D model
  - Potentially more complex to model
  - This is resolved by tools like FAB which automatically creates ‘terrain’ from digital elevation data and satellite imagery
  - User eye point can move anywhere in the scene
  - Pilot eye point possible

- Billboardng
  - Reasonably simple to create (although needs some experience)
  - Aircraft will be ‘occluded’ only behind the flat image
  - User eye point is restricted – can move a little but not far from ‘centre’
  - Pilot eye point is restricted
  - Uses less IG power

- Have used IGs with both - Billboardng too restrictive
3D Features and Visual Effects

- All IGs support effects that modify the displayed image
- Some have more effects than others
- Some effects should be common to all
- Others vary from IG to IG
- Essential effects will vary according to the requirements of the user
- All effects listed and shown supported by Micro Nav and Imagine
Basic/Essential Effects

- All IGs **must** support the following for ATC simulation:
  - Tower Viewpoint
  - Day, Dusk, Night, Dawn (with smooth transitions)
  - Reduced Visibility (mist, fog)
  - Airfield Lighting (approach, taxiway)
  - Volumetric Cloud (with varying types)
  - Precipitation (rain, snow, sleet, hail)
  - Shadows
  - Aircraft Landing gear (up, down)
  - Aircraft Lighting (navigation, strobe, logo, cabin, taxi, landing)
  - Fire and Smoke associated with aircraft
  - Representation of moving propeller or rotor
  - Binocular view
Shadows

- Shadows are essential for ‘fixing’ the aircraft in the scene
- Without shadows aircraft appear to float
- Ideally shadows should work with a ‘sun and sky’ model to allow shadows to be realistically shown
- Examples below show midday and late afternoon shadows
Other Effects - Lighting

- Essential airfield lighting elements include approach, runway and taxiway lights
- True pool lighting adds realism to airfield and moving models
Follow the Greens Capability

- Taxiway lighting can be defined as individually controlled groups and sections
- Required for Follow the Greens level functionality
- Needs intelligence between simulator, IG and lighting control
Trees – Minimum

- Trees are commonly modelled as ‘stamps’ (flat images similar to billboards)
- These can ‘turn’ to remain perpendicular to the viewer
Realistic Trees

- More ‘modern’ trees are true 3D trees
- With multiple levels of detail
- User can ‘zoom in’ on the detail
- Even affected by wind!
Fire & Smoke

Shown in Imagine Aircraft Editor – allows control over location, size, colour, speed etc. of fire, smoke, explosion, gear...
More Advanced Effects

- Examples of some of the other features that could add to simulation
- All are available using Imagine
Flocks of Birds

- Ideally with animation
- Should be controllable, on ground and in the air
Flaps
Explosions

Shown in Imagine Aircraft Editor – allows control over location, size, colour, speed etc. of explosion and other effects (fire, smoke, gear...)
Thunder Clouds

- Individual Cumulo Nimbus (cb) cloud
  - With associated lightning (sheet or fork)
  - With associated sound
Escape Chutes
Snow Accumulation and Clearance

- Snow accumulates as precipitation observed - can be cleared with snow clearance vehicle – note realistic pool lighting

- Snow re-accumulates after vehicle has passed
Dispensing Fire Appliance

- With cannon controlled from simulator
Water Effects – Ripples & Reflections
Remote Tower Simulation

- In order to simulate a remote tower, an IG needs some additional functionality:
  - Infra Red simulation
  - Presentation of labels
Other Effects General - 1

- Dynamic Viewpoint – ability to move the eye point or put eye point within target aircraft or vehicle
- Sun and Sky model
- Ground Fog (low level fog, in addition to general visibility)
- Fog Bank (with defined volume and movement)
- Sandstorm (also with defined volume and movement)
Other Effects General - 2

- Windsocks and wind blown objects
- Flares (from tower or vehicle)
- Animated Air Bridges
- Animated arrester nets, jet barriers, arrester cables
Other Effects  General - 3

- Fire and Smoke – from static source
- Characters
- Aircraft and vehicle labels
- Aircraft tracks
- Visual representation of glide slopes
Advanced Effects – Aircraft and Vehicles

- Animated aircraft landing gear
- Animated traffic on roads (animated splines)
- Collision detection
- Arrester Hook, Drag Chute
Conclusion

- IGs vary in quality and performance
- IG requirements must be appropriate for scenario
- Features required also specified appropriately
- IG and display system must be considered together

- Thank you

Questions?

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