FlightGear Flight Simulator

- A.R. Perry
  - alex.perry@ieee.org
  - Presenter and Developer

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UKUUG's Linux2001

- C. Olson
  - curt@flightgear.org
  - Project Leader

About the presenter

- Alexander Perry, a FlightGear developer:
  - Single engine pilot (commercial and instrument rated)
  - Advanced and instrument ground instructor
  - Aviation safety counselor (San Diego/Imperial counties, California)

The FlightGear project

- Project goals:
  - Do things 'right'
  - Minimize short cuts
  - Learn and advance knowledge
  - Build better toys to play with on ordinary computers
- Inspired by David Murr, April 1996
  - Open source GPL - Free as in speech and as in beer
  - Curt Olson made a multiplatform, OpenGL based release in July 1997
- Now more than just flight aerodynamics
  - Improving graphics, clouds, and fog, time of day
  - Shaded sky with sun, moon, stars, and planets correctly drawn
  - Automated world scenery generation tools based on real world data
  - Electronic navigation systems
  - Airports and runways
  - Head up display and instrument panel

Many simulation applications

- FlightGear is used in many different ways
  - Building a realistic home simulator from old airplane parts
  - Replacing the PC of an agricultural single engine simulator
  - Retrofitting older sim hardware with FGFS based software
  - A viable, modifiable alternative to commercial sims
  - A basis for icing research at the Smart Icing Systems Project
  - Training pilots to taxi safely at large airports
  - Demonstrating the dangers of mountain wave and turbulence
  - Remote user interface for an unmanned aerial vehicle
  - Generating visuals for aircraft carrier launch/recovery
  - Scenery and head up display for a Matlab-based flight model

This talk is only about visual scenery

- Among the dozens of simulator uses
  - Each has a different emphasis and technical needs
  - Unneeded features may be omitted to save resources
  - Compromises are usually made in the implementation
  - We prefer to offer run- and compile-time choices
  - One of the benefits of being an open source project
- Visual scenery is a huge resource hog
  - Application-specific optimization is critical
  - This talk reviews why scenery is necessary
  - Summarizes the standard FlightGear scenery
  - Discusses some of the easy customizations
- What is the simplest visual display we need ?

Cessna 172 in the clouds

(no visuals!)

Scenery is often unnecessary

- For instrument flight rules (IFR)
  - The pilots act the same inside as outside the clouds
  - They operate the aircraft by reference to the instruments
  - They navigate using electronic aids and radio instructions
- For dead reckoning trips
  - The pilots use time/heading/distance to navigate
  - The view outside is mostly optional during cruise
  - Only a few specific landmarks are needed to check progress
- For night flight
  - The world is black (except for towns and airports)
  - Need to only show a blob of light for each town
- For these cases, should we bother ?
  - Would it really just be eye candy ?

Visuals can be a distraction

- Popping in and out of sunny clouds
  - Dim grey featureless background when inside a cloud
  - Blinding white glare when emerging into sunlight
  - Makes the instruments very hard to read
- Occasional small patches of ground
  - Not big enough to identify any specific landmarks
  - Not long enough to match patterns to the charts
  - Distracts pilot from flying the plane
  - Encourages erroneous changes in route
- Mountains in the distance
  - A pretty background, static and easy to draw
  - Too far away to estimate the aircraft's position
  - Appears to confirm the pilot's opinions
- So, yes, even IFR benefits from scenery
  - It all makes flying harder and more realistic

On short final to land

Basic scenery is also necessary

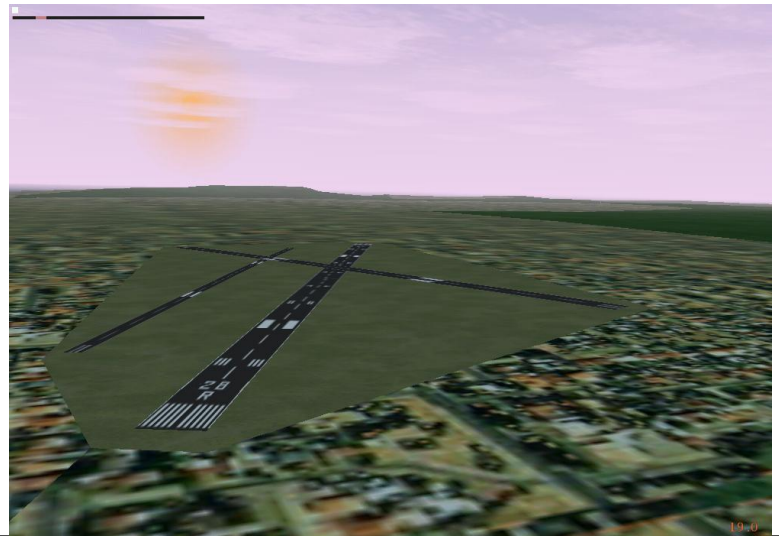
- To provide an airport area for takeoff and landing
  - For IFR flights that disappear into a cloud
  - When it isn't a conventional runway
- To show the specific landmarks and town outlines
  - For dead reckoning, pilotage, and similar
  - Doesn't take much; the occasional tower, lake, etc.
- To decide what should be seen between the clouds
  - Where the mountains are in the distance
  - And whether the plane will shortly hit one
- FlightGear has supported all that for years ...

Cessna 172 on landing approach

Software implementation

- Graphics are drawn using the OpenGL API
  - Using accelerated renderer such as Utah or XF4
  - Through GLX calls on Linux; Mesa/X11 is too slow
- The scene graph is managed by the PLIB library
  - FlightGear's loader passes file names to SimGear
  - Visibility and clouds are specified by weather model
- Separate XML-derived objects are also used
  - The Head Up Display is drawn in front of scenery
  - The Instrument Panel is drawn beneath the scenery
  - A big improvement over the C++ method a year ago
- What creates the many files that SimGear can load ?
  - All those gigabytes of synthetic scenery ...

Montgomery field, San Diego California



Simulating the World - TerraGear

- Open-source tools and rendering libraries
  - We collect free data for building 3D representations
  - The whole earth is usable in real time rendering
- Much freely available GIS data on the internet
  - Core data for FlightGear has to be unrestricted
  - Many sources of raw data cannot be incorporated
- Four categories of data are in use
  - Digital Elevation Model (DEM), 1 km grid worldwide
  - Polygon outlines for coasts, lakes, islands, and towns
  - Land use / land cover 'raster' data
  - Landmarks such as lighthouses, radio and water towers
- Individual users and groups can rebuild it
  - Generate larger, slower files for faster computers
  - Use locally available, restricted, data sources
  - Optimize scenery quality for a specific application

TerraGear - Screen dump

TerraGear - Storage size

- It's clearly a synthetic image
  - But sufficient to understand and interpret
  - Allows cross-country navigation by pilotage
  - Where the pilot is comparing the view to a chart
- It's compact, about one kilobyte per square kilometer
  - Necessary, since about 10000 sq km may be in view
- A four level hierarchy with 10-100 ratios ...
  - One planet, currently only the Earth, then
  - 10 deg x 10 deg rectangle, then
  - 1 deg x 1 deg, approx 100 km x 60 km, then
  - A rectangular tile of 100 sq km approximately
- These tiles are demand loaded and unloaded
  - So it runs slower when the visibility is higher
  - Needs more memory to store the additional tiles too

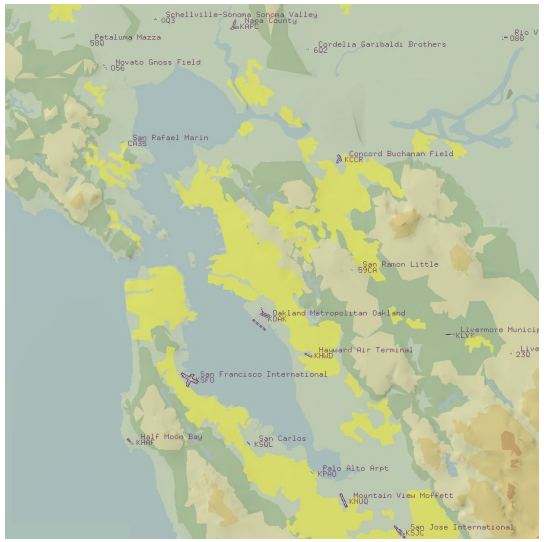
National data limitations

- Poor worldwide elevation data is already being used
- Good data is often country specific
  - Need special code to read and process file format
  - A lot of effort to do this for every country
  - Rapidly reaches the point of diminishing returns
- Many organizations collect and transform the data
  - Creating a standardized format, for their customers
  - There is a huge amount of effort involved
  - So their prices are extremely high to fund it
  - They cannot give the data away for us to use
- Maybe those organization will sell scenery
  - Run their data through TerraGear and burn some CDs
  - You can expect a high price tag for such reliable data

Mismatch of scenery and charts

- Public domain data is generally of reduced quality
  - Or out of date, or selective, or local coverage, etc.
- The scenery generated from that data may be incorrect
  - Compared to the real world out there
  - But generally only in visually unobtrusive ways
- These errors are more visible in electronic navigation
  - Such as needed for instrument flight (IFR)
  - Since the route tolerances are extremely tight
- Navigating the simulated aircraft around
  - With current Jeppesen (or NOS, etc) charts
  - Can be extremely frustrating, or impossible
  - When a piece of scenery is incorrectly in the way

Synthetic chart - example



Synthetic charts - Atlas project

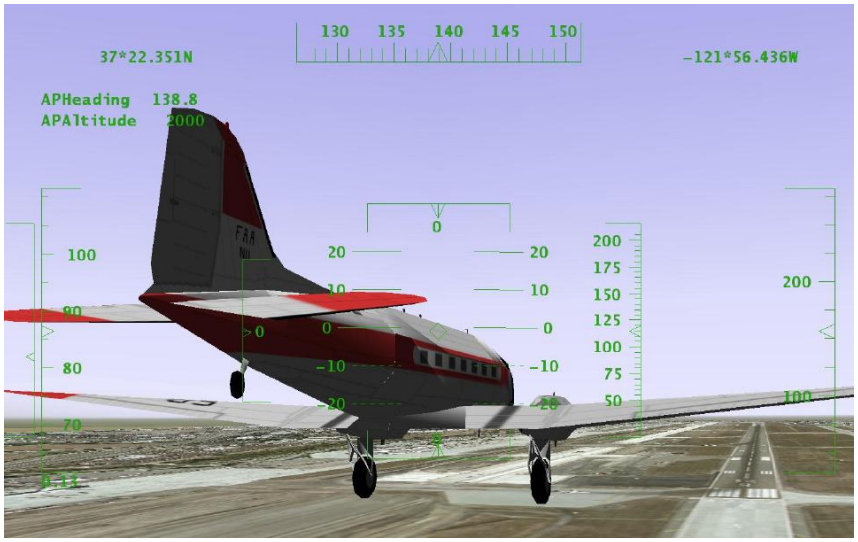
- Automatic translation of TerraGear files
  - Generates usable aviation style charts
- These charts are inaccurate to the real world
  - Therefore useless for flight in an aircraft
- Extremely accurate for the simulated world
  - When operating the FlightGear aircraft
  - Often easier to make and use printouts
- The Atlas application is for browsing
  - Can connect directly to FlightGear
  - Displays aircraft current location on moving map
  - Best used selectively by the simulator pilot
  - Most small aircraft do not contain such GPS units
  - ... with integrated moving map displays ... yet
- Invaluable to the flight instructor

Colorized satellite overlay for Ramona

Context cues around airport

- That insert was a quick few hours work
  - It shows the taxiway and buildings around the runway
  - The runway is no different, does it really help ?
- The default textures are intentionally fairly featureless
  - Pilots tend to fly low, similar to black hole effect
  - The other stuff helps to provide a sense of scale
  - The simulator was located at the red blob
  - This helps users to interpret the landscape
- Are these additional cues sufficient ?

Short final at San Jose



Do we want photorealism ?

- Is the TerraGear scenery sufficient ?
- Eye candy has no functional benefit
  - Looks nice, for spectacular screen dumps and demos
  - Helps sell the package to potential users
  - Doesn't help with usual usage of the simulator
- Can only be done for specific small areas
  - Storage need is many thousands of times larger
  - Unrealistically distinctive from a distance
- Sometimes, the aircraft stays in a small area
  - Balloons, acrobatics, model aircraft, hang gliders, etc
  - Landing practice, traversing mountain canyons, etc
- So, is photorealism just eye candy ?

Joining downwind at San Jose

Practicing visual decisions

- Making an incorrect choice of a runway
  - Dragstrips can look like runways
  - Airports can appear to be another parking lot
  - Parking lot lights look like an approach
  - A large airport can hide a smaller one
  - A large taxiway might look like a small runway
- Operating in poor visual conditions
  - Trying to distinguish things in fog
  - Lightning flashes, heavy rain showers
  - Navigating below a low cloud layer
- It's easy to make a wrong decision at 150 mph
  - And worth practicing to avoid it

How many runways at San Jose ?

Design of airports

- Can airport design influence the amount of pilot mistakes?
- Arrangment and size of parallel runways
  - Runway 29 to the far left can easily be overlooked
    - Starts later
    - Lighter coloured surface
- Color and contrast of runways/taxiways
  - Taxiway 'Y' has same color as runway 30L
    - Pilot knows there are two active runways
    - 30L is clearly a runway
    - At a glance, taxiway 'Y' looks like the other runway
- Can simulators be used to study and evaluate airport design problems?
- What can be done if a problem is discovered?

Airport navigation training

- Steering a taxiing aircraft is easy, but
  - The vehicle is ungainly, 40 ft wide
  - You cannot back up, or usually turn around
  - Small signs are mounted low to the ground
  - One junction may have six exits to choose
  - The paved surface may be 100 ft wide
  - Nothing indicates corners in the distance
  - A Cessna 172 has a much lower vantage point that a 747
- A lot of practice is needed to deal with this
  - A map doesn't always help enough
- Turn a wrong corner, you might end up on a runway
  - Can be bad if someone is trying to use it ...
- Airport service vehicles could also benefit

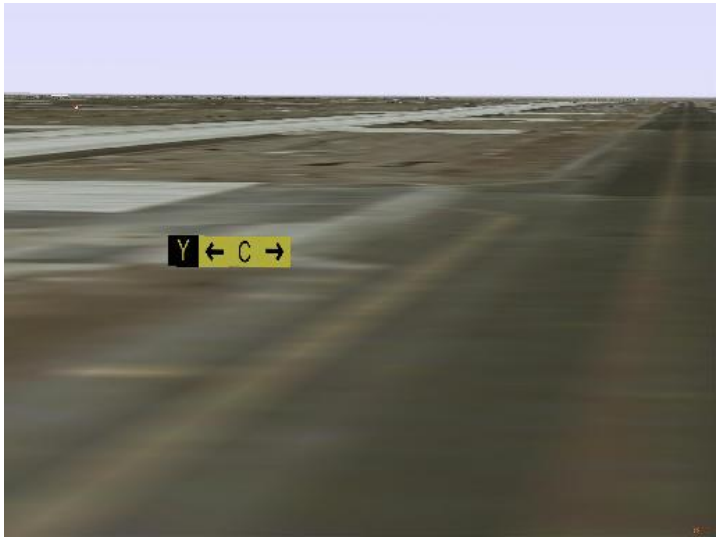
The runway incursion problem

- Any occurrence at an airport that
  - Results in loss of separation with an aircraft
  - Taking off, landing, or intending to do so
- Runway incursions are made up of
  - Pilot deviations (eg pilot took a wrong turn),
  - Operational errors (eg controller made a mistake),
  - Vehicle or pedestrian deviations (went the wrong way), and
  - Operational deviations (facility coordination error).
- Average rate is 230 per year in the 1990's
  - Rising 72% from 1993 to 1997, and to 547 in 1999
  - Accidents in Atlanta, Detroit, Los Angeles, St. Louis, etc
- The FAA strategic goal: reduce accidents
  - Eliminate 80% of the 1996 fatal rate by 2007
  - Curt is extending FlightGear to support them

Photo scenery, buildings, signage

- Replace the airport surroundings with photos
  - A directory with megabytes of photo texture data
  - Renders to be a bit fuzzy, but usable for taxiing
  - But rapidly overloads video capability in flight
- Add buildings and obstructions to vision
  - Drawn manually using the open source Pretty Poly Editor
  - Created by proprietary 3d image processing techniques and imported
  - Dropped into place using a file of airport objects
  - These mostly serve as navigation landmarks and distractions
  - The pilot can misidentify them from controller clearance
- Place the little signs in appropriate places
  - Their textures are computer generated on the fly
  - Locations are measured from airport engineering maps

San Jose California



Immersion and field of view

- Humans can see 90 degrees on each side
  - And a large angle of up and down too
  - Without moving your head, even
- Light aircraft have wrap-around windows
  - The brain processes that whole field of view
  - If view is partly missing, system is not immersive
  - Unrealistic, especially for visual navigation tasks
- A single monitor display is a poor substitute
  - FlightGear permits unlimited number of display channels
  - Each channel is a separate process on a network socket
  - Permits efficient SMP and clustering implementations
  - Limited by your number of video cards, monitors, etc

Testing triple display hardware

What's in the future?

- There's a lot out there ... some examples:
- FDMs are not (yet) accurate enough
  - Only suitable for conservative flights
  - Don't reflect the challenges of acrobatic maneuvering
- New consumer technologies for immersion
  - Surround projectors, head mounted displays
  - Directional sound and cockpit motion effects
  - Users will fly safe, forgetting they're not in danger
- Recent radar and visual satellite surveys
  - Enough detail to be used as photorealistic scenery
  - First, we must manipulate terabytes in real time
  - Data volume is about a million times larger than now

Conclusions

- FlightGear is a simple Open Source project
  - Builds on many other projects
- Due to the subject it addresses
  - It has many issues and unusual concerns
  - Most rarely inconvenience other projects
- These elements are providing the exciting challenges
  - And variety of associated activities enjoyed by the developers
- Thank you for your interest

www.flightgear.org