Flight Gear - from History to Future

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a FORUM presentation

for LinuxTag

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on Saturday at

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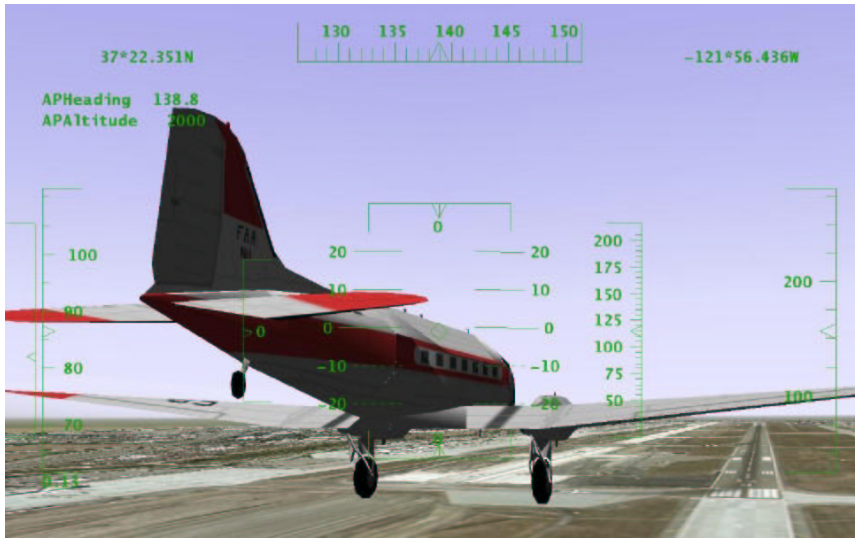
Project focus

- To create high quality simulation that
  - minimises short cuts and runs on ordinary computers
  - extensible and encourages local modifications
- Started April 1996 by David Murr
  - Open source (GPL) - No commercial backing as yet
  - Curt Olson made a multiplatform release in July 1997
- Since then, it expanded beyond flight aerodynamics
  - improving graphics, clouds and fog,
  - a shaded sky with sun, moon and stars correctly drawn,
  - automated worldwide scenery, network play,
  - electronic navigation systems, airports and runways,
  - head up display and instrument panel and much more ...
- Scales up from commodity computers
  - For commercial and research applications

Custom airport 2000

Custom airport 2001



Portability between Operating Systems

- Portable across operating systems (Mac, IRIX, etc)
  - For sound, 3D graphics, menus, joystick and keyboard
  - Implementation may be equivalent, yet very different
  - The PLIB project offers a simple API
  - http://plib.sourceforge.net
- Generally, the Windows binaries are portable
  - This is critical for most Win32 users
  - Few of them have developer tools installed
- Linux-based operating systems are very similar
  - Compared to Windows, MacOS and Irix, etc
  - Most problems affect PLIB first
  - When PLIB runs, FlightGear is generally ok
- With joysticks, for example:

Simulator Execution

- FlightGear can be running in less than an hour ...
- 1. Install Linux normally
  - Ensure zlib and its headers are present
- 2. Install and test 3D support
  - On video card, maximum of 25% of memory for 2D display
  - Then enable hardware accel (may need XFree86 3 and Utah)
  - Verify at least 100fps using gears (or play glTron)
- 3. Install PLIB 1.2 or later with headers
  - Already packaged in many distributions
  - Test with the supplied examples to ensure working
- 4. Install SimGear and FlightGear
  - Prepackaged in SuSE, Mandrake and Debian unstable
  - Or download SimGear, FlightGear source and base
  - Compile and install SimGear, then FlightGear, then
  - Finish installing the base and added scenery

Features beyond minimal install

- It's lonely being alone in the sky
  - Network play support is built-in
  - Each aircraft has to be reported to all others
  - Considerable network load, can degrade performance
  - The FlightGear Daemon is a standalone program
  - Runs on separate computer to do coordination
- View is more like passenger portholes on airlines
  - Not the wraparound windows of general aviation aircraft
  - Especially when the simulated aircraft has an open cockpit
  - Use multiple displays, as shown on next slide
- Base package only has a small area
  - San Francisco and adjacent Bay area, California
  - New pilots soon want to go somewhere else
  - The scenery server has the whole world, see later

Multiple displays for the pilot

Multiple displays implementation

- Multiple cards in one computer is slow
  - They compete for the limited bus bandwidth
- Use network socket communications
  - One machine runs FDM, and exports FDM data
  - Others use dummy FDM and import that data
  - No intrinsic limit to number of displays
- runfgfs --fov=45.0 --view-offset=0
  - --native=socket,out,60,s1,5500,udp
  - --native=socket,out,60,s2,5500,udp
- runfgfs --fov=45.0 --view-offset=-50
  - --native=socket,in,60,,5500,udp --fdm=external
- runfgfs --fov=45.0 --view-offset=50
  - --native=socket,in,60,,5500,udp --fdm=external

Simulating the Aircraft

- The aerodynamic simulation is only one part
  - Of the whole environment being simulated
  - Its performance is critical to the user's experience
  - Errors in Flight Dynamics Model (FDM) are distracting
- Other simulator components such as the autopilot
  - Are designed to expect a realistic aircraft
  - May respond incorrectly as a result of FDM errors
  - Provide additional pilot distractions
- Can ruin the user's immersive experience
- The FDM is created as an object abstraction
  - Allows multiple FDMs to be installed
  - Permits R&D use and future expansion

Simulating - Flight Dynamics Model

- LaRCsim, models a Cessna 172 or Navion
  - Dedicated C source with coefficients hard coded
  - Supports all normal flight maneuvers
- University of Illinois, parametric derivative
  - Simplified the models for cruise flight regimes
  - A configuration file is loaded at simulation start
  - Supports many different light aircraft choices
- JSBSim, completely parametric FDM
  - All the information is retrieved from XML format files
  - Can run independently of a full environmental sim
  - As of this year, supports the Cessna 172 fairly well and
  - The X-15 (a hypersonic rocket propelled research vehicle)

XML appearing everywhere ?

- This year, most configuration files are XML
  - The engine models,
  - The instrument panel layouts, instrument designs,
  - The head up display layout,
  - The user preferences and the saved state
- The real benefit of using XML here ?
  - For people with no software development background
  - Pilots, instructors, maintenance techs, researchers
  - They can easily and effectively contribute
  - All have in-depth technical knowledge of value
  - How an aircraft and hence the simulator should behave
- Previously, Windows binary users were excluded
  - Much system configuration was done at compile-time

Simulating Instruments and Radios

- All real-life instruments have errors
  - As well as subtle failures to catch inattentive pilots
  - We calculate the physics and determine the error
  - Without this, the simulator is much too easy
- Note that the HUD is computer generated
  - The computer can do the physics modelling too
  - Real-life HUDs generally don't have these errors
- Navigation radios have been implemented this year
  - Errors are not (they make real-life use challenging)
- Communication radios are not implemented
  - Pilots cannot use their microphone inputs to interact
  - Radio usage is a large part of aviation complexity
  - Another source of challenging distractions

Simulator Structure - Properties

- Core is directly interacting objects
  - High level state is also generalized out of them
- Property database is new this year
  - Relates a hierarchical name: /position/latitude
  - To an object with getter and setter methods
  - Ideal for user interface needs and saved state
  - Used for parametric graphics elements, configuration files
- Properties are network accessible
  - runfgfs --props=socket,bi,20,,5555,tcp
  - telnet localhost 5555
  - Especially useful for Flight Instructor activities
  - Independent programs can interact with the simulation

Simulating the World - TerraGear

- Open-source tools and rendering libraries
  - Collect free data for building 3D representations
  - The whole earth usable in real time rendering
- Much freely available GIS data on the internet
  - Core data for FlightGear has to be unrestricted
  - So many sources of raw data cannot be incorporated
- Three categories of data are in use
  - Digital Elevation Model (DEM), 1 km grid worldwide
  - Polygon outlines for lakes, islands, towns
  - New this year, we also use vegetation and land usage
  - Landmarks such as lighthouses, radio and water towers
- Individual users and groups can rebuild
  - Generate larger, slower files for faster computers

TerraGear - Screen dump

TerraGear - Storage size

- Clearly a synthetic image, but sufficient
  - Navigate by pilotage - comparing view to a chart
- Compact, about one kilobyte per square kilometer
  - Necessary, since about 10000 sq km may be in view
- Stored in a 4 level hierarchy, each 10-100 smaller
  - One planet, currently only the Earth
  - 10 deg x 10 deg rectangle
  - 1 deg x 1 deg, approx 100 km x 60 km
  - A rectangular tile of 100 km^2 approximately
- Tiles are demand loaded and unloaded
  - Runs slower when the visibility is better
  - Needs more memory to store tiles too

National data limitations

- Poor worldwide data 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/transform the data
  - Creates a standardized format, for these applications
  - 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 us scenery
  - Run their data through TerraGear and burn some CDs
  - You can expect a high price tag for such reliable data

Mismatched Charts - Atlas

- Public domain data is generally of reduced quality
  - or out of date, or selective, or local coverage, etc
- The scenery generated from that data is actually wrong
  - Compared to the real world out there
- Synthetic charts - Atlas project
  - Automatic translation of TerraGear files
  - Generates usable aviation style charts
  - Inaccurate compared to the real world
  - Therefore useless for flight in an aircraft
- The Atlas application is for browsing
  - This year, it connects directly to FlightGear
  - Display aircraft current location on moving map
  - Most small aircraft do not have moving map GPS

Synthetic chart - example

Worldwide detail within airports

- This year, added support for various databases
  - These list worldwide airport details
  - And their runway positions, lengths, etc
  - With hints on surface type and markings
  - This is sufficient to generate all runways
- What about the rest of the airport
  - Taxiways and ramp areas available in CVS version
    - Courtesy of Robin Peel's taxiway database
  - Control tower, hangars, terminals and similar
    - Not available, users can add them manually using PPE
  - Surface navigation signs and markings
    - No general support available, a lot of work with PPE
- Clearly, realism is poor below stalling speed
  - No central government control of those areas
  - Thus, no convenient data archive we can use

Standard landing screenshot 2001

Example of future support for signs

Simulator Applications

- A wide range of people interested
  - Building a realistic home simulator out old airplane parts
  - Simply having a viable alternative to commercial sims
  - A platform for icing research at Smart Icing Systems Project
  - Control algorithms for an autonomous aerial vehicle
  - Retrofit some older sim hardware with FGFS based software
  - Renew an old Agwagon single seat, single engine simulator
  - Image generator for eval of ski-jump launch
    - and arrested recovery from an aircraft carrier
  - Scenery and out-the-window view for the Genesis 3000 sim
  - Airport familiarization to avoid runway incursions
- ... and many more
  - How about selling it ?

Shrinkwrap sale

- Reselling open source software ?
  - It has not been a good revenue source for other companies
  - Partly because of the rapid version changes
  - And because of the low cost of bandwidth for the consumer
- Yet, several organizations are considering it
  - Can FlightGear be a viable profit center?
- It is being repackaged by many distributions
  - To ensure a painless installation for the community
  - There appears to be little benefit in making a product here
  - Closed source flight sim games are available at under $20
- Separate the database of visual scenery
  - Everything else user needs is only few megabytes
  - Which easily fits into a corner of a scenery CD
  - Will readily be downloaded when new versions available

Shrinkwrap sale - Scenery

- The scenery needs lots of space
  - About a gigabyte for each continent currently
  - Is unlikely to get any smaller in future
  - This still represents a significant download
- The scenery is relatively stable over time
  - Old versions are usually useful with newer binary software
  - Upgrades only add detail to an existing and viable database
- There is clearly a retail opportunity
  - Probably a DVD or a dozen CDs of the world
  - Trivial marginal cost of adding a few dozen binaries
    - for popular distros and driver combinations
  - Thus, this retail package is likely to be fully functional

Streaming scenery - concept

- Consider general aviation aircraft
  - Cruise usually below 200 knots, often only 120 knots
  - Flight visibility is (in real life) usually below 20 miles
  - For lower altitudes used by non-turbocharged piston engines
- Maximum of 8000 square miles per hour
  - Even when flying in a straight line (worst case)
  - This is new terrain that will come into view
  - Currently, database uses 1 MB/ 600 sq miles
- Streaming rate 12 megabytes/hour will be sufficient
  - That will fit through a normal 56K modem link
  - An airliner at cruising altitude needs all your DSL
- Bandwidth is often much lower
  - Because some scenery may already be downloaded
  - Will be zero in your favorite flight areas
  - Then there is no need to be on-line while flying

Streaming scenery - implementation

- No change to FlightGear source is needed
  - The latitude and longitude of the aircraft are exported
  - Scenery is stored in convenient 100 sqkm pieces
  - An independent program can make directed requests
  - For example, by spawning "wget" calls
- Still any need for retail scenery packages ?
- Multiply this bandwidth by worldwide community
  - That is a sizeable traffic impact on the servers
  - Latency is critical; we must keep ahead of the pilot
  - Is the total still low enough to be supported for goodwill ?
  - Will free servers transition to monthly access fees ?
  - Would they then start delivering proprietary content ?
- Who knows ... until we try it

Flight Training

- Could also be helpful when learning to fly
- Flight training is carefully regulated by government
  - To ensure that aircraft generally stay in the sky
  - Until their pilot intends for them to come down safely
  - There are real concerns, before authorities can approve a system
- What does the U.S. government want ?
  - Any pilot can sit down and immediately use it
  - It isn't dangerously different or deceptively easy
  - The instructor can specify the flight environment
- Flight Gear Avation Training Device
  - http://fgatd.sourceforge.net
  - Goal is to implement requirements to achieve approval
  - Most of the work is documentation and testing

Flight training - OverRegulated ?

- The FAA is responding to human nature
  - That doesn't go away just because it's inconvenient
- The things learnt first
  - Leave an almost unshakeable impression
  - At times of severe stress, will over-rule later training
  - Any false impressions are learned by a beginning student
  - Tend to remain hidden until a potentially lethal situation
  - At that time the pilot may react wrongly
- An excessively optimistic opinion
  - Of piloting skills will result if simulator is easy
  - Or if it does not exhibit common instrument flaws
  - A pilot will willingly fly into dangerous situations
  - that are beyond their skill proficiency and be at risk
- Only a trained instructor can judge
  - Whether the learning experience is beneficial
  - The documentation materials are essential to that

What's in the future?

- FDMs are not (yet) accurate enough
  - Only suitable for conservative flights
  - Don't reflect the challenges of acrobatic maneuvering
- Higher performance human input devices
  - Beyond the 8-bit joystick resolution limit
  - Rugged and rigid, like real aircraft controls
- 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

Conclusions

- FlightGear is a simple Open Source project
  - Builds on many existing projects
  - In the community tradition
- Due to the subject it addresses
  - It has many issues and concerns
  - Are raised that 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.
  - Questions ?

www.flightgear.org