Stellarium
Astronomical Simulation for Research and Outreach

Georg Zotti

Stellarium
   The perfect learning/teaching/outreach tool?
   Notes about development

Virtual Archaeoastronomy
   Landscapes
   Architecture and skyscapes
   OUTREACH: 100m² of skyscape in an archaeological exhibition

Some further highlights

Skycultures
Stellarium Desktop Planetarium

- Multiplatform
- Pretty sky simulation
- Diverse projections (spherographic, cylindrical, etc.)
- Exchangeable constellation patterns (star myths)
- Photo horizons
- Plugin-extendable
- Open-source community project

→ ADD YOUR CORRECTIONS
Stellarium Facts

- Started in Summer of 2000 by Fabien Chéreau
- First team active until ~2012: Look&Feel
- About 10 major contributors
- Currently 2-4 active developers
  - Alexander Wolf (Maintainer; Barnaul, Russia)
  - Georg Zotti (Vienna, Austria)
  - Fabien Chéreau
  - Guillaume Chéreau
- 18,500 commits by 186 contributors
- >900,000 lines of code
- >80 languages – 429 translators on transifex
- 658 financial supporters: THANK YOU!
- Quarterly releases, about 300,000 to 700,000 downloads each
Community Effort: Translation

- >36,000 strings
- 429 translators
- 80 languages
- +15 without translators

Join the team!
Landscape + Sky + Observer = Skyscape
The Night Sky is alive!
Why do we have to Simulate the Sky?

• Site accessibility
  – not required to disturb the site
• The past sky cannot be observed!
  – Earth’s precession
Why do we have to Simulate the Sky?

• Site accessibility
  – not required to disturb the site
• The past sky cannot be observed!
  – Earth’s precession
  – Stellar proper motion
  – Light pollution
• Speed-up research
  – allows observations during a full year within minutes
Requirements of Astronomical Accuracy for Historical Application

Planet positions:
- VSOP87 (recommended: -4000 ... +8000)
- JPL DE430/DE431 Accurate planet positions -13.000...+17.000

Precession/Obliquity: IAU 2006, Vondrák et al. 2011/12
Nutation: IAU 2000B

ΔT (earth rotation): over 30 models

Accurate Lunar Physical Ephemeris (Lunar Rotation) and planet axes

Coming 0.21.0

TODO Fix mismatch with Lunar occultations (aberration)
Landscapes and Horizons in Stellarium 0.20

From Polygonal line
• Measured
• Computed (GIS)
Landscapes and Horizons in Stellarium 0.20

Polygonal and/or Photographic
Andrew Smith: Horizon - http://agksmith.net/horizon/default.html

can export Stellarium Landscapes (SRTM 90m and 30m based; others: TBD).
Landscapes and Horizons in Stellarium 0.20

G. Zotti: Make Stellarium panoramas from Google Earth
Calibrated Horizon Panorama for Stellarium

- Diagram of surveyed horizon line, may be augmented with
  - azimuth/altitude
  - solar and lunar key tracks
- star tracks
- Photo series from location of total station
- Panoramisation (Hugin open-source panorama software)
- Combine pano with diagram of surveyed horizon line
- Adjustment of anchor image orientation
- Iterate into perfection
Edit Panorama in Layer-aware Image Editor

• e.g., the GIMP, Photoshop

Use Magic Wand to select Sky
Edit Panorama in Layer-aware Image Editor

- e.g., the GIMP, Photoshop

Mask out Sky
Edit Panorama in Layer-aware Image Editor

- e.g., the GIMP, Photoshop

Fill gaps, prettify panorama
Edit Panorama in Layer-aware Image Editor

- e.g., the GIMP, Photoshop
Edit Panorama in Layer-aware Image Editor

• e.g., the GIMP, Photoshop

Use black background
Edit Panorama in Layer-aware Image Editor

• e.g., the GIMP, Photoshop
Edit Panorama in Layer-aware Image Editor

- e.g., the GIMP, Photoshop

Add City sky glow (where needed)
Example: Valletta (Malta), Great Harbour
Example: Valletta (Malta), Great Harbour
Landscapes and Horizons in Stellarium 0.20

HeyWhatsThat/HoriZONE

Google Earth/Hugin + Survey Line

Andrew Smith’s Horizon + Survey Line

Photos/Hugin + Survey Line
One Horizon for Each Viewpoint
Therefore… 3D Models in Stellarium!

Using Virtual Reconstructions in Stellarium’s Scenery3D Plugin:

– Landscape model from
  • GIS (ArcGIS, QGIS, …)
  • Sketchup Pro (Trimble) → TIN export/convert

– Building/feature model from
  • Modellers (CAD, 3D Studio, Maya, Blender, …)
  • Laserscan models
  • Image-Based Models (Photoscan, SfM-MVS, …)
  • etc.

→ georeferenced .OBJ
A Test Model: Vienna Sterngarten

Modelled 2011/12 in Google SketchUp 8
A place to demonstrate basic astronomical concepts to the public.
Sterngarten Model: Testing Geometry

Altitude marks coincide with altitudes in the sky, Pole disk indicates celestial pole.
Sterngarten Model: Testing Refraction
Sterngarten Model: Testing Refraction

No refraction

Sunrise behind pillar

Refraction

Sunrise behind notch
Sun squashed
Sterngarten Model: Testing Shadows

- Winter
- Polar Disk
- Sundial
- Equinox
- Summer
Sterngarten Model: Testing Shadows
Dengfeng observatory (Gaocheng; AD1276)
Sterngarten Model: Testing Shadows

Noon Shadow Transit on 2010-03-20

Image sequence 2010-03-20 (~Spring equinox)
Disk shadow must touch pillar foot

Simulation in Stellarium/Scenery3d
+ Same behaviour
- optional soft shadows only blurred (fake)
Chichen Itza: El Castillo equinox “snake” phenomenon

“Snake Shadow” (Wikimedia)

Model from Google 3D Gallery

Stellarium simulation for same day, 2009-03-21
3D Models in Stellarium

- Immediate experience
3D Models in Stellarium

• Immediate experience
• Interactive exploration
Astronomical Cultural Heritage: Chankillo, Peru

One of the oldest monuments in the Americas (3rd century BC) devoted to Solar observation.

Made from LiDAR data courtesy Clive Ruggles & Ivan Ghezzi
Astronomical Cultural Heritage: Chankillo, Peru

Made from LiDAR data courtesy Clive Ruggles & Ivan Ghezzi
Combine with Unity Game Engine
Combine with Unity Game Engine

G. Zotti et al.
Serious Gaming for Virtual Archaeoastronomy
DOI:10.14434/sdh.v4i1.31041
OUTREACH: The Skyscape Planetarium

- Exhibition in the MAMUZ Museum for Prehistory, Mistelbach (Austria) 2016-17.
- Stonehenge Horseshoe in 1:1 replica stones
- 25x4m curved screen, 5 projectors
- Scripted show (~20 minutes)
- Archaeoastronomical details explained with simulated sky

The Skyscape Planetarium

https://www.cultureandcosmos.org/pdfs/21/CCv21_17Zotti.pdf
Only 2D Panoramas, but varying illumination
Remote Control Web Interface

- Stellarium as web server
- Replicates most GUI settings
- Avoids user interface on big screen
- Allows
  - external communication
  - starting shows at preprogrammed times
- Optional
  Operator uses web browser
  - on PC
  - simple 7” Tablet
Here comes the Sun…
MAMUZ: Nightly Tours
MAMUZ: Nightly Tours
Remote Sync Plugin

- Synchronize time and settings on several screens
  - Useful when projection not possible
- Exclude particular settings from synchronisation

→ highlight different settings per screen
- skyculture
- unaided vs. telescope view
- ...

...
A Few More Highlights
Admittedly, Nature Wins!
Solar Eclipses
Solar Corona from 2008, Mongolia

- Type: solar
- Event Date: 2008
- Location: Mongolia
- Observation Date: 2008-08-21
- Eclipse Type: annular
- Eclipse Duration: 10 minutes
- Maximum Eclipse: 99.2% coverage
- Eclipse Magnitude: 1.00

Additional Details:
- Sun's Distance: 1.14 AU
- Apparent Diameter: 1.00
- Eclipse Magnitude: 1.00
(Eclipse Day, July 22\textsuperscript{nd}, 2009, near Shanghai...)
Comet Tails in Stellarium (since 2014)

• Coma diameter and tail length formulae
  – taken from Project Pluto (Guide)
  – https://www.projectpluto.com/update7b.htm#comet_tail_formula
  – Original formulae by Andreas Kammerer
• Parabola-shaped tail shells
• Dust tail curvature from R and v
• Details visually tweaked mostly from
  – C/1996 B1 Hyakutake and
  – C/1995 O1 Hale-Bopp
• Individual parameterisation possible
C/1996 B2 (Hyakutake)

Type: comet (periodic)
Magnitude: 6.29 (projected to 0.80)
Absolute Magnitude: 5.00

Right Ascension: 20:02:30.00
Declination: 80°11'51.6"

At/Az: +34°53’00.0” / +39°15’23.6” (approx.

Gal. Long./Lat.: 113°14’49.3” / 27°22’22.2”

Ecl. Long./Lat.: 289°10’17.9” / 156°19’17.3”

Ecl. Long./Lat.: 170°13’15.9” / 105°13’45.9”

Apparent Sidereal Time: 11:04:28.31

Transit: 19:34 h.

Closer to: Gamma 2000.0

Distance from Sun: 0.95 AU (1.41 cm)
Distance from Earth: 0.81 AU (120 km)
Orbital Velocity: 42 km/s

Orbital Period: 3.1 years

Phase angle: 51.3°

Evaporation: 8.0 km³

Circumference: 5.6 km

C/1996 B2 (Hyakutake)
Comet Tails in Stellarium

C/1858 L1 (1858 IV) Donati
C/2006 P McNaught?
Comet Debris: Meteors!

• Sporadic meteors (eye candy)
• Meteor Showers plugin (by Marcos Cardinot)
  – Auto-update with IMO data

• WANTED
  – Fireball/meteorite fall plugin with particular events
    • Chelyabinsk
    • Europ. Fireball Network data
    • ...

The 1833 Leonid Storm over N. America
Novae

• Plugin
• Automatic update feature
• Data from:
  Catalog of 93 Nova Light Curves: Classification and Properties
  Richard J. Strope, Bradley E. Schaefer, Arne A. Henden
Currently only simple models for Type Ia or Type II


Better modelling desirable (SUGGESTIONS?)
Note the Chinese constellations and star names!
STELLARIUM SKY CULTURES
How Various Cultures See and Use the Sky
Current Status (1)
Current Status (1)

- Constellations
  - „official“ constellations
Current Status (1)

• Constellations
  – „official“ constellations
  – line art („stick figures“)
Current Status (1)

- Constellations
  - „official“ constellations
  - line art („stick figures“)
  - figure artwork (optional)
Current Status (1)

- **Constellations**
  - „official“ constellations
  - line art („stick figures“)
  - figure artwork (optional)

- **Asterisms**
  - inofficial figures
  - only line art
Current Status (1)

- Constellations
  - "official" constellations
  - line art ("stick figures")
  - figure artwork (optional)

- Asterisms
  - unofficial figures
  - only line art

- Ray Helpers
  - Long distance "pointers" (alignments)
Current Status (2)

Other Cultures,
Other Figures!

Ojibwe

Chinese-Medieval

Belarus
Observed by many Asian cultures

Current workarounds by coding as asterisms

But several schemes seem to exist:

- Asterism
- Abstract region in ecliptical coordinates
- Abstract region in equatorial coordinates
- Others?
**Missing/TBD: Dark Constellations**

- Dark clouds in the Milky Way
  - Australian Aboriginals: „Emu in the Sky“
  - Inca „Yacana“ (Llama)
  - A few more
    - (see Gullberg et al., 2020)
  - others?

- **How to show these properly?**

Gullberg et al., 2020
We don’t know everything!

• Seasonal Constellations
  – depending on Solar longitude
  – other schemes?
• Different aspect of planets
  – e.g. Mercury, Venus as Morning/Evening Stars
  – others?
• Seasonally differing star names?
• Temporally evolving Sky Cultures?
  – MUL.APIN → Greek → Ptolemy → “European/Western” → IAU
  – Old Chinese → ... → Modern Chinese?
  – ...
• Any other needs?
Translation Issues (1)

• Proper name or just a term in original language?
• Shall we totally switch off „Western“ names?
  – Will the „foreign“ user still know the stars & planets?
• Translation
  – Not every translatable name has been translated to English
  – Serious problem for our „Community Translators“
• Meaning
  – Missing context prevents translation
    • E.g. What is the „Blue Birth Woman“ in (D/L/N)akota Skyculture?
    • „Snake Large Anus“ → ???
Translation Issues (2)

TODO: Show any useful combination of

• Original spelling
  – All characters from Unicode (Cuneiform, Hieroglyphs, Maya, ...)
• Transliteration
  – May depend on user language
  – Need experts for transliteration
• Translation to user language
  – Meaning may get lost!
  – Needs experts in the respective culture
  – How to preserve meaning and myths?
    • Add meta information for translators?

• → Need better description.
Review and Quality Assurance?

New in version 0.19: Tentative *Classification scheme*

- **Traditional**
  - „Living“ sky culture
  - Created by members of respective culture/community
- **Ethnographic**
  - „Living“ sky culture
  - From fieldwork by foreign researchers
- **Historical**
  - Past sky culture
  - Textual transmission by historians
- **Single**
  - Discrete, mostly historical work (Bayer, Schiller, Hevelius, Bode, ...)
- **Personal**
  - Not based on (peer-reviewed) culture astronomy research
  - Not supported by noteworthy community
- **Incomplete**
  - No references/further reading
  - Obviously lacking information
Calendar Questions

• Several times in Stellarium’s forum:
  – Q: “Why is the sun not at the equator at spring equinox in -8750?”
  – Reply: What date did you set for spring equinox?
  – Q: March 21
  – Reply: WRONG.

• Equinox is defined by sun crossing equator
• The name of the day is irrelevant
### Calendar Questions

- **Stellarium has astronomical date counting**

<table>
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<th>...</th>
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<th>2 B.C.</th>
<th>1 B.C.</th>
<th>1 A.D.</th>
<th>2 A.D.</th>
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<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>...</td>
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</table>

- **Gregorian Calendar reform, October 1582**

<table>
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<tr>
<th>Julian (&quot;old style&quot;)</th>
<th>...</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gregorian (&quot;new style&quot;)</td>
<td>...</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>...</td>
</tr>
</tbody>
</table>

Protestant countries ignored the new style

→ Take care when reading ~17th century observation reports!
NEW PLUGIN: Calendars (since V0.20.4)

• Started with 17 calendars:
  – Julian (B.C./A.D.), Gregorian, ISO Week
  – Roman, Olympiad
  – Icelandic
  – Egyptian, Armenian, Zoroastrian
  – Coptic, Ethiopic
  – Maya Long Count, Tzolkin, Haab
  – Aztec Tonalpohualli, Xihuitl
  – Balinese Pawukon

• Next version:
  – Islamic (algorithmic), Hebrew
  – Old Hindu Solar and Lunar
  – …

• Further:
  – Chinese
  – Tibetan
  – …
If **YOU** can and want to participate

please contact us

https://github.com/Stellarium/stellarium

Funded collaboration preferred!
Thank You for Your Attention!

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Download Stellarium only from https://stellarium.org
Current release V0.20.4 (2020-12-27)
Extensive PDF Manual