Constellation Simulation System

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Outline

- Introduction
- Major Work
- Conclusion
- System Demo
Satellite communication is the best way to implement such kind of personal communication.
**Proposed Work**

- Develop a mathematical constellation model
- Implement a visual and developable constellation simulation system
- Load a simple routing algorithm
Major Work

- Introduction
- Mathematical Modeling
  - Constellation 3D Model
  - Orbit 3D Equation
  - Satellite Moving 3D Equation
  - Hiding Equation
- Implementation
  - Programming
  - Load Shortest Routing Algorithm
  - Programming Language: Delphi
- Conclusion
- System Demo
**Constellation Model**

- **Incline angle of Satellite orbit**
- **XOZ is equator plane**
- **The deflection angle from the ascending points. (0° - 360°)**
- **Satellite orbit plane**
- **The intersection point of orbit plane and equator plane named ascending point**

The angle between ascending plane and axis z.

\[
\alpha = \theta + H
\]

The intersection point of orbit plane named ascending point.
Orbit 3D Equation

\[ \vec{n}_1 = \{ \cos i \cos \theta, \sin i, -\cos i \sin \theta \} \]

\[ \vec{n}_2 = \{ \sin \theta, 0, \cos \theta \} \]

\[ \vec{n} = \vec{n}_1 \times \vec{n}_2 = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \cos i & \cos \theta & -\cos i \sin \theta \\ \sin \theta & 0 & \cos \theta \end{vmatrix} = \{ \cos \theta, -ctgi, -\sin \theta \} \]

\[ \begin{cases} x \cos - yctgi - z \sin \theta = 0 \\ x^2 + y^2 + z^2 = R^2 \end{cases} \]
Satellite Moving Equation

\[ \cos \psi = \frac{xx_0 + zz_0}{\sqrt{(x_0^2 + z_0^2)(x^2 + y^2 + z^2)}} = \frac{xx_0 + zz_0}{R^2} \]

\[ \begin{cases} x \cos \theta - y \cot \theta - z \sin \theta = 0 \\ x^2 + y^2 + z^2 = R^2 \end{cases} \]

\[ \begin{cases} x_0 \cos \theta - z_0 \sin \theta = 0 \\ x_0^2 + y_0^2 = R^2 \end{cases} \]

\[ \begin{cases} x_0 = R \sin \theta_0 \\ z_0 = R \cos \theta_0 \]
Satellite Moving Equation

\[
\begin{align*}
  x_0 &= R \sin \theta_0 \\
  z_0 &= R \cos \theta_0 \\
  x \cos \gamma - y \cot \gamma - z \sin \theta &= 0 \\
  x^2 + y^2 + z^2 &= R^2
\end{align*}
\]

\[
\cos \psi = \frac{x x_0 + z z_0}{\sqrt{(x_0^2 + z_0^2)(x^2 + y^2 + z^2)}} = \frac{x x_0 + z z_0}{R^2}
\]

\[
\begin{align*}
  y &= R \sin \psi \sin i \\
  x &= y \cos \theta \cot \gamma + R \sin \theta \cos \psi \\
  z &= -y \sin \theta \cot \gamma + R \cos \theta \cos \psi
\end{align*}
\]
Hiding Equation

\[ x^2 + y^2 = R_e^2 \]
\[ x^2 + y^2 + Z^2 = R^2 \]

\[ Z^* = -\sqrt{R^2 - R_e^2} = -\sqrt{H(R + H)} \]

\[ Z < Z^* = -\sqrt{H(R + H)} \]
Mathematical Modeling

Orbit 3D Equation

\[
\begin{aligned}
  x \cos \gamma - y \cot \gamma - z \sin \theta &= 0 \\
  x^2 + y^2 + z^2 &= R^2
\end{aligned}
\]

Satellite Moving Equation

\[
\begin{aligned}
  y &= R \sin \psi \sin i \\
  x &= y \cos \theta \cot \gamma + R \sin \theta \cos \psi \\
  z &= -y \sin \theta \cot \gamma + R \cos \theta \cos \psi
\end{aligned}
\]

Hiding Equation

\[Z < Z^* = -\sqrt{H(R + H)}\]
Basic Idea

1. Based on the equations of orbit and satellite, with time going on, calculate the coordinates of each satellite.

2. Call TConstellation.Refresh function at a certain time interval to simulate constellation.

3. Using the coordinate information provided by the simulation to constellation to load routing algorithm
Basic Objects

1. TSatellite Object

2. TTrack Object

3. TConstellation Object
Basic Objects

1. TSatellite Object
   - Function Visible: Boolean; Hiding or not;
   - Procedure Create; Create satellite model;
   - Procedure Show; Draw the satellites
   - Procedure Refresh; Draw the satellites at the position next time;

2. TTrack Object

3. TConstellation Object
Basic Objects

1. TSatellite Object

2. TTrack Object

3. TConstellation Object

procedure Create; Create Track model;
procedure DrawTrack; Draw the tracks
procedure Refresh; Draw the tracks at the position next time;
Basic Objects

1. TSatellite Object

2. TTrack Object

3. TConstellation Object

- procedure Create;
- procedure Refresh;
- Create Constellation model;
- Draw the Constellation at the position next time;
Implementation

Relationship Between Functions

Introduction

Major Work

Conclusion

System Demo

- TMainForm. FormCreate
- TConstellation. Create
- TTracks. Create
- TSatellites. Create
- TTracks. DrawTrack
- TTracks. Refresh
- TSatellites. Refresh
- TSatellites. Show
Conclusion

Major Accomplishment

- Develop a mathematical constellation model
- Implement a visual and developable constellation simulation system
- Provide user a tool to design constellations
- Load and simulate a simple routing algorithm
Conclusion

To be done …

- Load more routing algorithm
- Improve the performance of the system
- Research a way to cooperate with the existing software
- Introduction
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Constellation Simulation System

- Introduction
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Questions ?