

Telescope Simulator - User Manual

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Introduction

The Telescope Simulator is a comprehensive Python-based software system designed for simulating telescope operations and celestial observations. Originally developed for the Nooitgedacht farm by the North-West University (NWU), this simulator provides hands-on experience for computer science and physics students working with telescope simulation software.

Key Features

- **Real-time Telescope Control:** Move telescope to specific coordinates or track celestial objects
- **Coordinate Conversion:** Convert between Altitude/Azimuth and Right Ascension/Declination systems
- **Celestial Object Tracking:** Automatic tracking of astronomical objects using online databases
- **User Management:** Role-based access control with admin and operator privileges
- **Simulation Integration:** Works with CoppeliaSim for 3D telescope visualization
- **Comprehensive Logging:** Detailed logging of all operations and system events
- **Safety Systems:** Built-in safety checks to prevent telescope damage

System Requirements

Hardware Requirements

- **CPU:** Intel Core i5 or equivalent (minimum)
- **RAM:** 4GB minimum, 8GB recommended
- **Storage:** 2GB free disk space
- **Network:** Internet connection for celestial object data

Software Requirements

- **Operating System:** Windows 10/11, macOS 10.14+, or Ubuntu 18.04+
- **Python:** Version 3.8 or higher
- **CoppeliaSim:** Version 4.0 or higher (for simulation features)
- **MongoDB:** Version 4.0 or higher (for user management)

Python Dependencies

The following packages are automatically installed with the simulator:

- astropy - Astronomical calculations
- astroquery - Online astronomical databases
- pymongo - MongoDB database connectivity
- bcrypt - Password hashing
- Flask - Web API framework
- PyJWT - JSON Web Token authentication
- python-dotenv - Environment variable management
- requests - HTTP requests
- tabulate - Data formatting
- geocoder - Location services

Installation Guide

Step 1: Download and Setup

1. **Clone or download** the Telescope Simulator repository
2. **Navigate** to the project directory:
`cd Telescope-Simulator`

Step 2: Python Environment Setup

Step 2: Virtual Environment Setup

1. **Create a virtual environment (recommended):**
`python -m venv telescope_env`
2. **Activate the virtual environment:**
 - **Windows:**
`telescope_env\Scripts\activate`
 - **macOS/Linux:**
`source telescope_env/bin/activate`
3. **Install dependencies:**
`pip install -r requirements.txt`
4. **Create a .env file** in the project root.

```
# Database Configuration
MONGO_URI=mongodb://localhost:27017/
DB_NAME=celestiCodeServerDB

# Authentication
SECRET_KEY=your-secret-key-here
JWT_ALGORITHM=HS256
TOKEN_EXPIRY_HOURS=24

# Default Admin (only used if no admin exists)
DEFAULT_ADMIN_USERNAME=admin
DEFAULT_ADMIN_PASSWORD=admin123
```

2. Replace **your-secret-key-here** with a secure random string

Step 4: Database Setup

1. **Install MongoDB:**
 - **Windows:** Download from MongoDB website.
 - **macOS:** `brew install mongodb-community`
 - **Ubuntu:** `sudo apt-get install mongodb`
2. **Start MongoDB Service:**
 - **Windows:** Start MongoDB service from “Services”
 - **macOS/Linux:** `sudo systemctl start mongodb`

Step 5: CoppeliaSim Setup (Optional)

1. **Download CoppeliaSim Edu** from CoppeliaSim website.
2. **Extract and Install CoppeliaSim.**
3. **Copy Remote API Files:**
 - Copy `remoteApi.dll` (Windows) or `remoteApi.so` (Linux) to the `simulation/` directory.
 - These files are located in CoppeliaSim’s `programming/legacyRemoteApi/remoteApiBindings/` folder

Step 6: Verification

1. **Test the installation:**
`python test_imports.py`

Step 7: Run the simulator:

```
python main.py
```

Getting Started

First Launch

1. **Start the Simulator:**

```
python main.py
```

2. **Login with Default Credentials:**

- **Username:** admin
- **Password:** admin123

3. **Change Default Password** immediately after first login.

Basic Navigation

The simulator uses a menu-driven interface:

- **Main Menu:** Access to all major functions
- **Telescope Control:** Move and track telescope
- **Configuration:** System settings (admin only)
- **User Management:** Manage user accounts (admin only)
- **Display Data:** View system information and logs

User Roles

- **Admin:** Full access to all features including configuration and user management
- **Operator:** Limited access to telescope control and data viewing

User Interface Guide

Admin Menu

1. Telescope Control
2. Configure Settings
3. Coordinate System
4. User Management
5. Display Data

6. Object Management
7. Exit

```
=====
Current User: admin (admin)
Current Menu: MAIN
=====
1. Telescope Control
2. Configure Settings
3. Coordinate System
4. User Management
5. Display Data
6. Object Management
7. Exit

Enter your choice: █
```

Figure 1: Admin Menu

Operator Menu

1. Telescope Control
2. Display Data
3. Exit

```
=====
Current User: thabang (operator)
Current Menu: MAIN
=====
1. Telescope Control
2. Display Data
3. Exit

Enter your choice: █
```

Figure 2: Operator Menu

Menu Navigation

- **Enter numbers** to select menu options
- **Press Enter** to confirm selections
- **Use 'Back' options** to return to previous menus
- **Press Ctrl+C** to exit the program

Command Descriptions

All commands include built-in help descriptions accessible through the “Display All Commands & Descriptions” option in the Display Data menu.

Telescope Operations

Basic Movement

Point to Altitude/Azimuth

1. Select **Telescope Control** → **Point To AltAz**
2. Enter **Altitude** (5° to 90°)
3. Enter **Azimuth** (25° to 335°)
4. Telescope moves to specified coordinates

Point to Right Ascension/Declination

1. Select **Telescope Control** → **Point To RaDec**
2. Enter **RA** in hours or HMS format (e.g., 12.5 or 12h30m00s)
3. Enter **Dec** in degrees or DMS format (e.g., 45.5 or +45d30m00s)
4. Telescope automatically converts and moves to coordinates

Object Tracking

Track Celestial Object

1. Select **Telescope Control** → **Tracking**
2. Enter **celestial object code** (e.g., M31, NGC1234)
3. Telescope continuously tracks the object
4. Press ‘q’ to stop tracking

Select from Object List

1. Select **Telescope Control** → **Objects**
2. Choose from available celestial objects
3. Telescope moves to selected object

Rest Mode

- Select **Telescope Control** → **Rest Mode**
- Telescope moves to safe rest position (straight up)
- Used for parking telescope safely

Safety Features

- **Coordinate Validation:** All coordinates are checked against telescope limits
- **Below Horizon Protection:** Prevents telescope from pointing below horizon
- **Safety Margins:** Built-in safety margins prevent damage
- **Movement Timeout:** Automatic timeout if movement takes too long

Configuration Management

Note: Configuration options are only available to admin users

Location Settings

```
=====
Current User: admin (admin)
Current Menu: CONFIG
=====
1. Change Telescope Location
2. Change Telescope Limits
3. Change Movement Settings
4. Change Safety Settings
5. Change Simulation Settings
6. View All Settings
7. Back
```

Figure 3: Configuration Management

Change Telescope Location

1. Select **Configure Settings** → **Change Telescope Location**
2. Enter **Latitude** (-90° to 90°)
3. Enter **Longitude** (-180° to 180°)
4. Enter **Elevation** in meters
5. Confirm changes

Movement Limits Change Telescope Limits

1. Select **Configure Settings** → **Change Telescope Limits**
2. Set **Altitude limits** (minimum and maximum)
3. Set **Azimuth limits** (minimum and maximum)
4. Confirm changes

Movement Settings

Change Movement Settings

1. Select **Configure Settings** → **Change Movement Settings**
2. Configure:
 - **Movement Timeout** (1-60 seconds)
 - **Position Tolerance** (0.001-1.0 degrees)
 - **Clamp to Limits** (yes/no)
 - **Invert Elevation Axis** (yes/no)
 - **Force First Movement Clockwise** (yes/no)

Safety Settings

Change Safety Settings

1. Select **Configure Settings** → **Change Safety Settings**
2. Configure:
 - **Prevent Below Horizon** (yes/no)
 - **Safety Altitude Margin** (0.1-5.0 degrees)
 - **Safety Azimuth Margin** (0.1-10.0 degrees)

Simulation Settings

Change Simulation Settings

1. Select **Configure Settings** → **Change Simulation Settings**
2. Configure:
 - **Base Joint Name** (CoppeliaSim joint name)
 - **Mount Joint Name** (CoppeliaSim joint name)
 - **Base Max Force** (100-5000 N)
 - **Elevation Max Force** (100-5000 N)
 - **Celestial Ping Time** (1-30 seconds)

- **Tracking in Background** (yes/no)
- **Headless Tracking** (yes/no)

View All Settings

- Select **Configure Settings** → **View All Settings**
- Displays all current configuration values

User Management

Note: User management is only available to admin users

```
=====
Current User: admin (admin)
Current Menu: USER_MANAGEMENT
=====
1. Create User
2. List Users
3. Update User
4. Delete User
5. Back
```

Figure 4: User Management

Create User

1. Select **User Management** → **Create User**
2. Enter user details:
 - **Name**
 - **Surname**
 - **Username**
 - **Password**
 - **Role** (admin/operator)
3. User is created and can login immediately

List Users

1. Select **User Management** → **List Users**
2. View all users with their roles and names

Update User

1. Select **User Management** → **Update User**
2. Enter **username** to update
3. Modify desired fields (leave blank to keep current values)
4. Changes are saved immediately

Delete User

1. Select **User Management** → **Delete User**
2. Enter **username** to delete
3. Confirm deletion
4. User account is permanently removed

Object Management

```
=====
Current User: admin (admin)
Current Menu: OBJECT_MANAGEMENT
=====
1. Create Object
2. List Objects
3. Update Object
4. Delete Object
5. Back
```

Figure 5: Object Management

Note: Object management is only available to admin users

Create Object

1. Select **Object Management** → **Create Object**.
2. Enter object details:
 - **Name:** e.g., “Orion Nebula”
 - **Description:** Detailed description of the object.
 - **RA/Dec Coordinates:** Format RA,Dec
 - **NED Code:** Astronomical catalog code
3. Object is added to the database.

List Objects

1. Select **Object Management** → **List Objects**
2. View all available celestial objects

Update Object

1. Select **Object Management** → **Update Object**
2. Enter **object name** to update
3. Modify desired fields (leave blank to keep current values)
4. Changes are saved immediately

Delete Object

1. Select **Object Management** → **Delete Object**
2. Enter **object name** to delete
3. Confirm deletion
4. Object is permanently removed from database

Coordinate Systems

Altitude/Azimuth (Alt/Az)

```
=====
Current User: admin (admin)
Current Menu: COORDS
=====
1. Convert Alt & Az to Ra & Dec
2. Convert Ra & Dec to Alt & Az
3. Back
```

Figure 6: Coordinate Systems

- **Altitude:** Angle above horizon (0° = horizon, 90° = zenith)
- **Azimuth:** Compass direction (0° = North, 90° = East, 180° = South, 270° = West)
- **Range:** Altitude 0° - 90° , Azimuth 0° - 360°

Right Ascension/Declination (RA/Dec)

- **Right Ascension:** Celestial longitude (0h-24h)

- **Declination:** Celestial latitude (-90° to $+90^\circ$)
- **Format:** Can be entered as decimal or HMS/DMS format

Coordinate Conversion Convert Alt/Az to RA/Dec

1. Select **Coordinate System** → **Convert Alt & Az to Ra & Dec**
2. Enter **Altitude** and **Azimuth**
3. System converts using current location and time

Convert RA/Dec to Alt/Az

1. Select **Coordinate System** → **Convert Ra & Dec to Alt & Az**
2. Enter **RA** and **Dec**
3. System converts using current location and time

Location-Based Calculations

- All coordinate conversions use the telescope's configured location
- Time-based calculations use current system time
- Elevation is considered for atmospheric refraction corrections

Simulation Setup

CoppeliaSim Integration Scene Setup

Simulation Setup

CoppeliaSim Integration Scene Setup

1. **Open CoppeliaSim**
Launch the CoppeliaSim application.
2. **Load Scene**
Navigate to **File** → **Open Scene** and select **Radio Telescope Scene.ttt**.

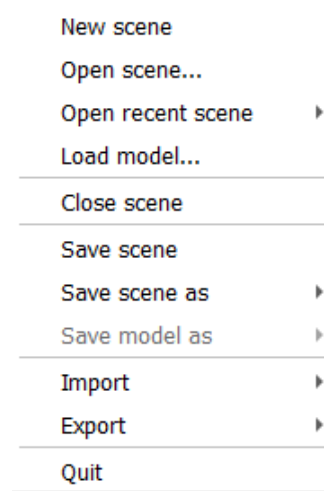


Figure 7: File Menu

3. Start Simulation

Press the *Play* button to start the simulation.

4. Run Telescope Software

The telescope control software will automatically connect to the simulator.

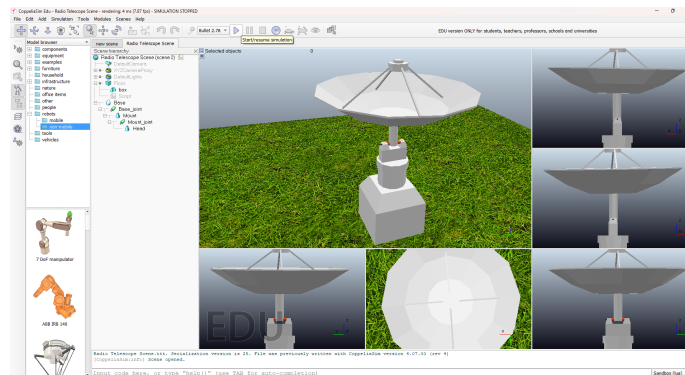


Figure 8: Radio Telescope Scene

Connection Settings

- **Default port:** 19999
- **Connection timeout:** 5 seconds
- **Automatic reconnection:** Enabled

Joint Configuration

- **Base Joint:** Controls azimuth rotation
- **Mount Joint:** Controls elevation movement
- **Force settings:** Configurable maximum forces

Simulation Features

- **Real-time visualization:** Watch telescope move in 3D
- **Physics simulation:** Realistic movement with forces and constraints
- **Collision detection:** Prevents telescope from hitting obstacles
- **Joint limits:** Enforces mechanical limits

Troubleshooting

Common Issues and Solutions

- **Connection Problem:** “Failed to connect to telescope”
 - **Solution:** Ensure CoppeliaSim is running and the scene is loaded.
 - **Check:** Port 19999 is not blocked by the firewall.
 - **Verify:** Remote API files are in the correct location.
- **Database Connection Failed:**
 - **Solution:** Start the MongoDB service.
 - **Check:** MongoDB is running on the default port 27017.
 - **Verify:** The connection string in the `.env` file is correct.
- **Authentication Issues:** “User not found” or “Invalid password”
 - **Solution:** Check username and password spelling.
 - **Reset:** Use default admin credentials if available.
 - **Create:** Create a new user account if needed.
- **Movement Problem:** “Coordinates are outside telescope limits”
 - **Solution:** Check coordinate values against configured limits.

- **Adjust:** Use coordinate conversion to find valid coordinates.
- **Configure:** Modify limits if needed (admin only).
- **Movement Timeout:** “Telescope movement timed out”
 - **Solution:** Check if telescope is physically blocked.
 - **Increase:** Increase movement timeout in settings.
 - **Restart:** Restart simulation if needed.
- **Import Errors:** “Import error” when starting the application
 - **Solution:** Run `python test_imports.py` to identify specific problems.
 - **Install:** Install missing dependencies with `pip install -r requirements.txt`.
 - **Check:** Verify Python version is 3.8 or higher.

Error Messages System Errors

- **“Configuration file not found”:** Check `Resources/config.json` exists
- **“Environment variable not set”:** Verify `.env` file configuration
- **“Permission denied”:** Run with appropriate user permissions

Telescope Errors

- **“Movement blocked”:** Coordinates outside safe limits
- **“Connection lost”:** CoppeliaSim connection interrupted
- **“Joint not found”:** Incorrect joint names in simulation

Log Files

Log Locations

- **Main log:** `logs/telescope.log`
- **Error log:** `Resources/Errors.txt`
- **System log:** `Resources/Logs.txt`

Log Analysis

- Use **Display Data** → **Display Telescope Logs** to view recent entries
- Check timestamps for correlation with issues
- Look for ERROR or WARNING level messages

Performance Issues Slow Response

- **Check:** System resources (CPU, RAM usage)
- **Close:** Unnecessary applications
- **Restart:** Telescope simulator and CoppeliaSim

Memory Issues

- **Monitor:** Python process memory usage
- **Restart:** Application periodically for long sessions
- **Check:** Log file sizes (rotate if too large)

Advanced Features

Enhanced Data Viewer

- Access through **Display Data** → **Enhanced Data Viewer**.
- Configurable display options
- Data filtering capabilities
- Export functionality
- Real-time data monitoring

Background Tracking: Enable in **Configure Settings** → **Change Simulation Settings**.

- **Tracking in Background:** Allows other operations during tracking.
- **Headless Tracking:** Tracking without user interaction.
- **Automatic Object Updates:** Continuous coordinate updates.

API Integration

The simulator includes REST API endpoints for:

- **User management**

- **Telescope control**
- **Object management**
- **System monitoring**
- **Custom Object Catalogs**
- **Add custom objects** through Object Management
- **Import from CSV files** (future feature)
- **Export object lists** for backup

Logging and Monitoring Enhanced Logging

- **Structured logging** with categories
- **Performance metrics** tracking
- **Security event logging**
- **Audit trail** for all operations

System Monitoring

- **Connection status** monitoring
- **Performance metrics** collection
- **Error rate** tracking
- **Usage statistics**

Safety Guidelines

General Safety

1. **Always use rest mode** when not actively observing
2. **Check coordinates** before moving telescope
3. **Respect movement limits** to prevent damage
4. **Monitor telescope** during movement operations
5. **Stop operations** if unusual behavior is observed

Emergency Procedures Emergency Stop

- **Press ‘q’** during tracking operations
- **Use Ctrl+C** to exit program immediately

- **Manually stop** CoppeliaSim simulation if needed

Recovery Procedures

1. **Check telescope position** in simulation
2. **Use rest mode** to return to safe position
3. **Restart simulation** if necessary
4. **Check logs** for error information

Maintenance Regular Checks

- **Verify configuration** settings
- **Check log files** for errors
- **Test connections** to CoppeliaSim
- **Update dependencies** regularly

Backup Procedures

- **Backup configuration files**
- **Export user data** regularly
- **Save object catalogs** before major changes
- **Document custom settings**

Training Requirements

- **Basic astronomy knowledge** recommended
- **Understanding of coordinate systems** essential
- **Familiarity with telescope operations** helpful
- **System administration skills** for advanced features

Support and Resources

Documentation

- **README.md**: Basic project information
- **SETUP.md**: Installation and setup guide
- **API Documentation**: Available in docs/api/ directory
- **Simulation Documentation**: Located in Virtual-Prototype-Scene-and-Documents/

Online Resources

- **CoppeliaSim Documentation:** CoppeliaSim User Manual
- **Astropy Documentation:** Astropy User Guide
- **MongoDB Documentation:** MongoDB Manual

Community Support

- **GitHub Issues:** Report bugs and request features
- **Discussion Forums:** Community support and questions
- **Email Support:** Contact project maintainers

Training Materials

- **Video Tutorials:** Available on project website
- **Example Scripts:** Located in examples/ directory
- **Test Files:** Use test_imports.py for troubleshooting

Version Information

- **Current Version:** 2.0
- **Python Compatibility:** 3.8+
- **Last Updated:** 2024
- **License:** MIT License

Conclusion

The Telescope Simulator provides a comprehensive platform for learning and practising telescope operations in a safe, simulated environment. With its user-friendly interface, robust safety features, and extensive configuration options, it serves as an excellent tool for educational and for research purposes.

For additional support or questions, please refer to the troubleshooting section or contact the development team through the provided channels.

This manual covers the Telescope Simulator version 2.0. For updates and additional information, please visit the project repository.