

Lunar Cargo Base Smart Management System Using Digital Twin

FORUM8 14th CPWC Team Blue

Background

With the development of lunar exploration missions, future lunar bases require efficient cargo storage, transportation and autonomous management systems.
Traditional manual operation methods cannot meet the requirements of:
· Large-scale cargo management
. Autonomous transportation
. Complex lunar environments

Significance

◯ Autonomous Operation Enhancement
Enables autonomous cargo handling and robot coordination, improving efficiency and reducing manual operations in lunar environments.

◯ Digital Twin Management
Builds a real-time virtual replica of the lunar base for monitoring, simulation, and intelligent decision support.

◯ AI-driven Intelligent Integration
Integrates AI perception and decision algorithms to achieve cargo recognition, task planning, and intelligent management.

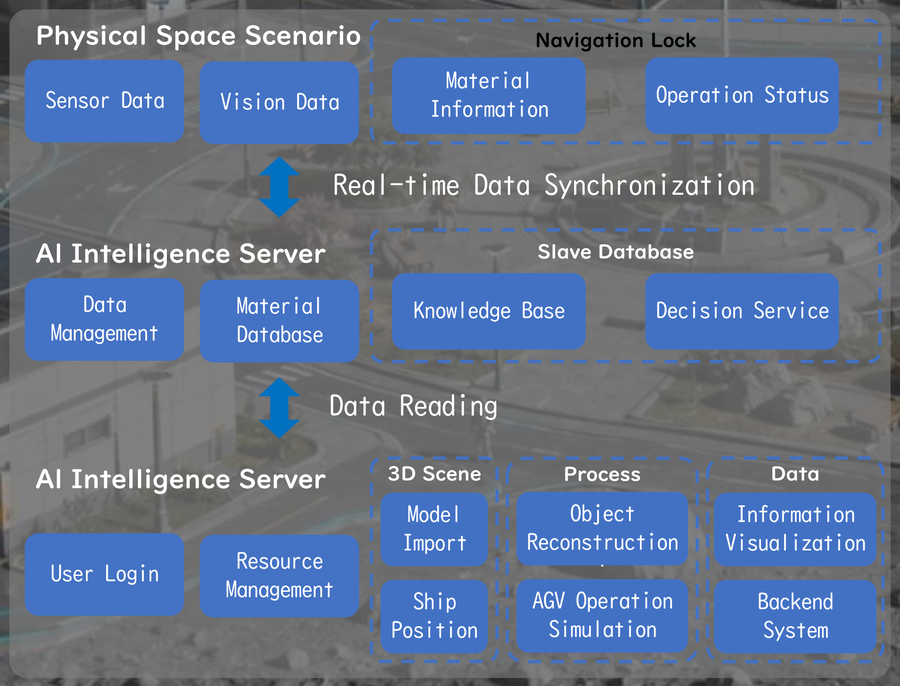
Digital Twin System - Lunar Cargo Twin



Real Scene



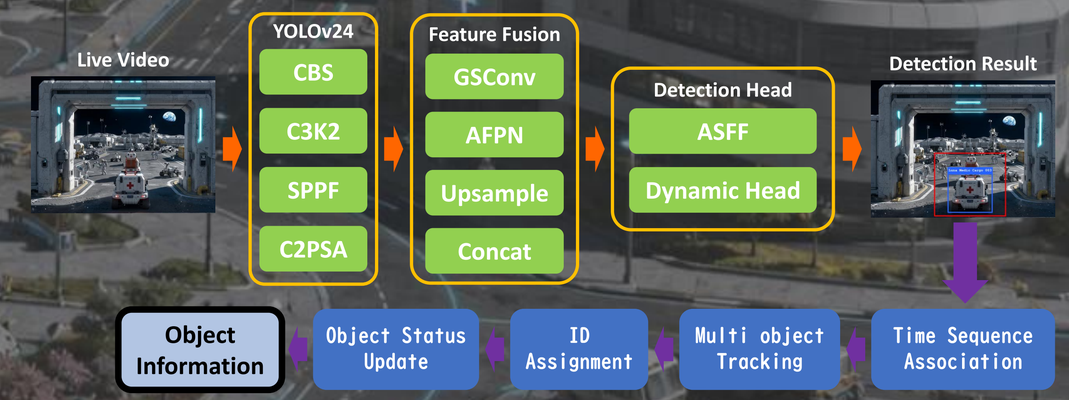
Digital Twin System



Lunar Cargo Detection & Tracking Algorithm

◯ Advanced Perception Layer:
This module provides the foundational awareness of the physical environment:
1. Object Detection & Tracking: Utilizes deep learning models (e.g., YOLOv2, Byte Track) to detect every cargo unit and vehicle in real-time. It assigns persistent IDs, tracks movement paths, and reports detailed status information (Material ID, location, state).
2. Semantic Segmentation: Employs specialized models (e.g., SAM3) to perform pixel-level segmentation. This allows the system to precisely delineate object boundaries—crucial for accurate 3D modeling.
3. 3D Reconstruction: Uses generative foundational models (e.g., TRELLIS) to transform simple 2D images of cargo into high-fidelity, structured 3D digital models, enabling comprehensive virtual viewing and measurement.

◯ Operational Simulation & Visualization:
The system validates its capabilities through realistic scenario simulations:
1. Scenario Modeling: Allows operators to simulate complex operations across various physical perspectives (overhead views, street level) and different environmental conditions (Daytime vs. Nighttime), ensuring robustness regardless of lighting or angle.
2. Real-Time Tracking & Visualization: Provides an immediate overview (dashboard) showing the location and status of every piece of equipment and container within a massive yard map.



Future

Integrate multi-source perception data, including vision, sensors and environmental information, to improve object recognition accuracy and robustness in complex space environments.
Develop intelligent scheduling algorithms based on large language models to achieve autonomous task planning, multi-robot coordination, and efficient material transportation.
Enhance digital twin capabilities by integrating real-time data synchronization, 3D modeling and intelligent interaction for comprehensive space material management.