Artificial Intelligence for Earth Observation Data Processing: ISRO Use cases

Ashutosh Gupta, ISRO
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Outline

❖ AI/ML at ISRO

❖ Different use cases of AI/ML
  ❖ Data acquisition related
  ❖ Data processing/augmentation related
  ❖ Information extraction related

❖ Conclusions and Outlook
Indian Space Research Organisation (ISRO)

ISRO Centres

- Jodhpur, Rajasthan
- Odisha, Odisha
- Salem, Tamil Nadu
- Hyderabad, Telangana
- Thiruvananthapuram, Kerala
- Bangalore, Karnataka
- Ahmedabad, Gujarat
- Delhi, New Delhi
- Kolkata, West Bengal
- Sikkim

Centres with projects on AI-EO.

Evolutions of Indian Satellites

- Communication Satellites
- Lunar Missions
- Interplanetary Mission
- Space Science Mission

Earth Observation Satellites

- INSAT-1A & 1B
- GSAT-1
- GSAT-4
- GSAT-6
- GSAT-7
- GSAT-10
- GSAT-11
- GSAT-12
- GSAT-13
- GSAT-15
- GSAT-17
- GSAT-18
- GSAT-19
- GSAT-20
- GSAT-21
- GSAT-22
- GSAT-23
- GSAT-24

NavIC

- INSAT-3A
- INSAT-3B
- INSAT-3C
- INSAT-3D
- INSAT-3E
- INSAT-4C & 4D
- INSAT-4A & 4B

- Chandraayan-1
- Chandraayan-2
- Chandraayan-3
- Chandrayaan-4
- Aditya 1
- Aditya 2
- Aditya 3

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ISRO – AI/ML Technology

Process definitions
- Adhoc/team level defined Matured

Delivery
- Background Models Open Models / Portals and platforms AI aaS Edge

Data and Development platforms
- Silos Individual Platforms and Systems Data lakes, Repositories Notebooks, distributed dev. On Cloud AI/ML Ready data, MLOps CI/CD

Technology
- ML/NN Models New app. domains New models, Theory for geospatial AI New applications Explainable AI Generalized models Onboard models
ISRO - Areas of AI use

**Thrust areas of AI for EO data processing at ISRO**

**Data acquisition related**
- Intelligent image acquisition (onboard AI)
- Data loss handling
- Image Restoration
- Thermal resolution improvement
- AI enabled compression

**Data processing and augmentation**
- Super-resolution
- Multi-modal Fusion
- Image-to-Map translation
- Analysis Ready Datasets
- AI-Ready datasets

**Information extraction**
- Object detection and classification pipelines
- Semantic segmentation models
- Time-series and higher level products
- Onboard intelligence (Information to user)
- Information portals

**Areas of AI use**

- AI-Research
- Foundation Models
- AI Platforms and Infrastructure
- AI-Applications
- Explainable-AI
Use cases for AI/ML at ISRO
Missing data reconstruction

Loss in band data due to detector failure/Read-out error or transmission

Cartosat device data loss reconstruction

INS-2B Nano MX – Frame data loss reconstruction (B2)

Multi-band reconstruction

Typical model architecture
Conditional GANs, Spatial attention with Cyclic loss

Criterion: MSE-Loss with regularization on network weights

"Reconstruction of Missing Multiband Images for high resolution multispectral sensors using Wassersteing GAN", In proceedings of InGARSS, 2023, M. A. Hossain, A. Gupta, S. Paul, S. K. Singh, S. D. Naidu, D. Dhar,
Improved thermal band

Sensed from Space

LiSS-4 FCC (at 5.0 m)

LiSS-3 SWIR (at 24.0 m resampled at 5.0 m)

DL Model Design for high resolution SWIR

Training and Inference using 4.7 Million parameters

Deep SWIR (at 5.0 m)
Spatial information from high resolution L4 bands: NIR, R, G at 5m and Spectral information from low resolution L3 band: SWIR at 24m

Potential Applications

Wetland Inventory and Mapping
Lake Segmentation Studies
Forest Fire

Image Restoration

- **Use of some new models** such as Generative Adversarial Networks (GANs), diffusion models, and vision transformers for recovering image information.

**Challenges:**

- **Training dataset generation** for supervised deep learning.

- **Design of network which specifically handle non-standard assumptions**
  
  - Non-uniform blurs
  - non-AWGN noise
  - Correlated noise
Image Compression

Neural net fused with traditional image compression pipeline outperforms the state-of-the-art lossless compressors on optical remote sensing data.


Image guided super-resolution for DEM

Cartosat-PAN super-resolution (Self super resolution)

- Useful in improved surface visualisation in absence of high resolution images/DEM

Map generation is a key objective of Cartographic satellites.

- **Image to Map translation** using Generative deep learning models.
- Trained with Openstreetmap, but **dataset generation is a challenge!**
Segmentation/Classification

- Cloud segmentation in Cartosat images
- Forest fire segmentation (L8 dataset)
- Building footprints extraction from Cartosat dataset


Segmentation/Classification

Snow segmentation in AWiFS images

Solar power plants (R2A-LISS IV images)

Some of these models are being devised for onboard implementation.
Object detection and CBIR

- **Object detection pipelines** for different objects in Satellite imagery.
- **Content Based Image Retrieval (CBIR)** with natural language query and object indexing.

Prompt:

“High resolution images with airplanes, taken last week”

- **More intuitive** than traditional “form based” image retrieval mechanisms.
Combination of parameters sensitive to crop water relations (SWIR-LSWI, VH) and greenness (EVI) showed better prediction accuracy

Das et al., 2023 (Remote Sensing Applications: Societies and Environment)
ISRO Portals

- **Bhuvan**: Indian Geo-Platform of ISRO
  - [https://bhuvan.nrsc.gov.in](https://bhuvan.nrsc.gov.in)

- **Mosdac**: Meteorological & Oceanographic Satellite Data Archival Centre
  - [https://mosdac.gov.in](https://mosdac.gov.in)

- **Bhoonidhi**: ISRO's EO data hub
  - [https://bhoonidhi.nrsc.gov.in](https://bhoonidhi.nrsc.gov.in)

- **Vedas**: Visualisation of Earth Observation Data and Archival System
  - [https://vedas.sac.gov.in](https://vedas.sac.gov.in)
Conclusions and Future outlook

- Large number of AI models for different applications and domains
- Standardized AI/ML data and development is a work in progress
- Future:
  - ISRO AI/ML ready datasets for community
  - Deployment
  - EO-Workbench
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References

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