SAR APPLICATION POLICY STUDY – ANALYSIS OF SAR-RELATED JOURNAL PAPERS

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ABSTRACT:

This paper presents a preliminary analysis result on SAR-related journal papers published since 1960s. Abstracts of more than 2700 peer-reviewed English journal papers were collected and classified into various categories according to their systems, techniques, and application fields. Statistics on each category were provided so that one can understand historical and on-going development in SAR systems, techniques, and a variety of application fields such as land, ocean, cryosphere and atmosphere. This statistical data would be an essential guideline to establish a future SAR system application and satellite manoeuvring policy.

KEY WORDS: SAR, system, technique, application, policy

1. INTRODUCTION

Since the development of synthetic aperture radar concept by Carl Wiley of Goodyear Aircraft Corporation in 1951, SAR systems have become a major source of remote sensing data for land, ocean, cryosphere and atmosphere, and planetary exploration. Since Seasat launched in 1978, there has been many satellite SAR systems and numerous airborne systems available for science community and for commercial use.

This paper reports a statistical analysis result of SAR-related English journal papers published up to early 2005, according to the abstract of each journal collected. The result will give statistical trend of SAR application fields, which can be served as a general guidance in establishing SAR system development, management and application policy.

2. DATA

2.1 Procedures

The journal list and abstracts were collected from the Cambridge Scientific Abstracts(www.consortia.co.kr/csa) under Kangwon National University License. The SAR-related, peer-reviewed English journal papers were searched using the keyword: synthetic aperture radar. Total 2839 journal papers were initially searched and transformed to RefWorks (www.refworks.com) also under Kangwon National University License. The data was reduced to 2733 by automatic duplicate removal function provided by RefWorks. Failure of initial attempt to automatically classify the journal papers have provoked the necessity of classification by selected experts. The data transformed into Microsoft Excel format, sorted by author, and delivered to several selected experts for analysis. Initial category for classification was also handed over.

The results of initial classification were collected from the experts and rectified by merging, splitting, adding, or deleting the category if necessary.

2.2 Statistics on Journals and Papers

Removing irrelevant papers during analysis, total 2665 papers published in 243 journals were finally chosen for classification. More than a quarter of papers were published in IEEE TGRS(26%), followed by IJRS(11%), JGR(9%), IEEE AES(6%), and RSE(5%) as shown in Fig. 1. The above five major journals takes up 57% of the whole papers.

The yearly amount of publication have increased dramatically since the launch of Seasat in 1978, followed by several shuttle flights (1981, 1984, 1994, and 2000), ERS-1(1991), JERS-1(1992), ERS-2(1995), Radarsat-1(1995), and Envisat(2002), as shown in Fig. 2. The recent decrease since 2002 might be the delay of update in CSA or might reflect recent delays of new satellites such as JERS-2, Radarsat-2.

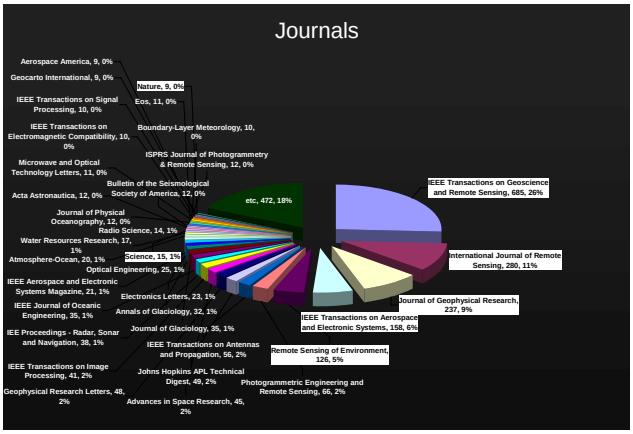

Figure 1. SAR Journals and Papers

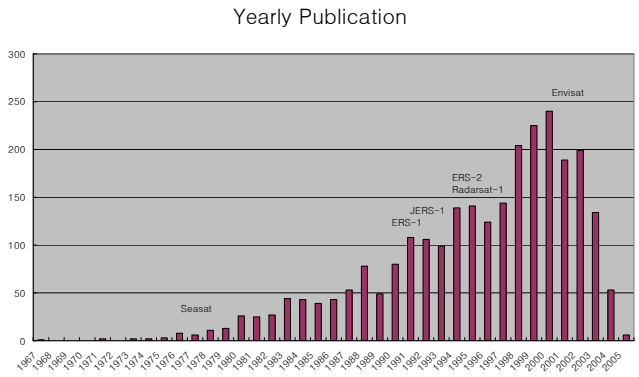

Figure 2. Yearly publication of SAR-related journal papers

3. RESULT - STAR CATEGORY

Each journal was classified into four major categories such as STAR(System, Technology, Application and Recommended) according to the system and technology the paper have used, and its application field as shown in Table 1. Review papers or the Recommended papers were selected by the experts. The STAR categories were subdivided as follows.

SYSTEM:
- **SEASAT**
- **ERS1/2**
- **Radarsat-1**
- **JERS-1**
- **Envisat**
- **Shuttle**: SIR-A, SIR-B, SRTM
- **Airborne Sensors**: onboard airplane
- **Planetary Sensors**: Radio Telescope, Magellan.
- **Ground/ISAR**: Ground-based, Inverse SAR.
- **Simulated**: SAR simulation
- **ETC**: Almaz, Receiving System, etc.

The result shows that ERS-1/2(24%) and Airborne sensors(24%) have mainly contributed to SAR papers, followed by Shuttle(9%), Seasat(7%), Radarsat-1(7%) as shown in Fig. 3.

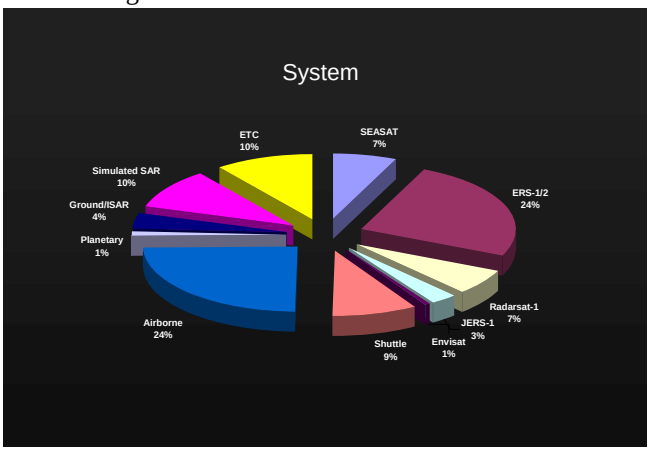

Figure 3. SAR System Category

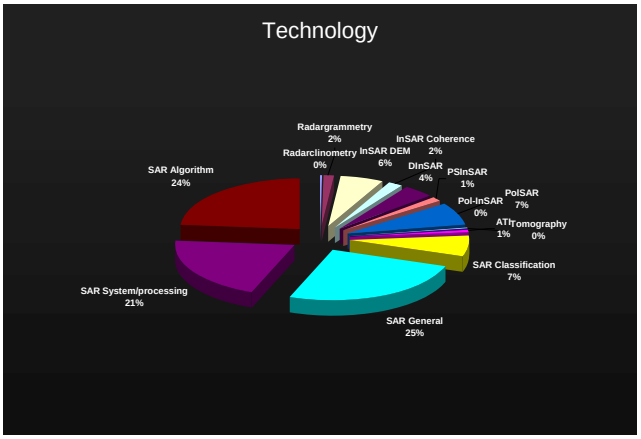

Figure 4. Technology Category

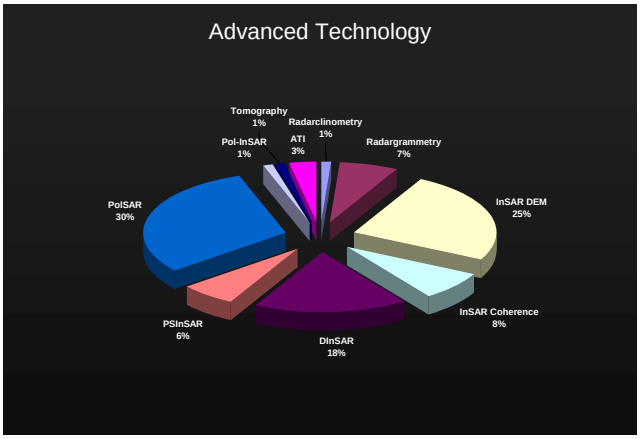

Figure 5. Advanced Technology Category

Technology was subdivided into two: Basics and Advanced. Basics were the technology based on SAR amplitude images only. Advance technology uses multiple amplitude or phase information. More detailed sub-divisions are as follows.

TECHNOLOGY:

Basic Technology: amplitude only.
- **SAR General**: visual interpretation.
- **SAR Algorithm**: modelling, parameter extraction
- **SAR System/Processor**: focusing, filter, new system
- **SAR Classification:** Thematic Mapping

Advanced Technology: use multiple amplitude/phase
- **Radarclinometry**: Shape-from-shading
- **Radargrammetry**: Stereo SAR
- **InSAR DEM**: Interferometry, Phase unwrapping
- **InSAR Coherence**: change detection, decorrelation
- **DInSAR**: Differential InSAR, surface deformation
- **PSInSAR**: Permanent Scatterer InSAR
- **PolSAR**: Polarimetry
- **Pol-InSAR**: Polarimetric and Interferometric SAR
- **Tomography**: 3D modelling
- **ATI**: Along Track Interferometry

77% of papers used basic technologies and 33% used Advanced technology as shown in Fig. 4. Fig. 5 shows more details about the advanced technology only. Almost all advanced SAR technology include multi-temporal phase information. 30% of Advanced Technolgy are for PolSAR, 25% for InSAR DEM, 18% for DInSAR, 8% for InSAR Coherence.

Application is largely divided into Land(45%), Ocean(32%), Cryosphere(19%), and Atmosphere(4%) as shown in Fig. 6. Each application fields were subdivided as follows (Fig. 7-10):

APPLICATION – LAND:

Agriculture: Agricultural crop, vegetation, trees, but agricultural soil goes to Soil.
Archeology/Subsurface: Subsurface penetration, paleo-channel, landmine detection.
Topography: DEM from InSAR, radargrammetry, and radarclinometry. Slope angle from PolSAR.
Forestry: Forest, biomass, vegetation. forest fire, deforestation, but crop goes to agriculture.
Geology: Lithology, structural mapping, geomorphology, mineral exploration, lineament.
Geotectonics: Tectonic motion, subsidence, land slide, tectonic strain.
Hydrology: Rivers. lakes, limnology, flood, snow, ice.
Seismology: Earthquake displacement.
Soil: Soil moisture, soil type (natural or agricultural)
Volcanology: Volcanic morphology, swell, subsidence, lava flow, eruption.
Urban/Manmade: Urban area mapping. Target, building, power line, foliage/snow penetrating target detection.
Thematic Mapping: Land cover of composite surface. Classification of various surface type.

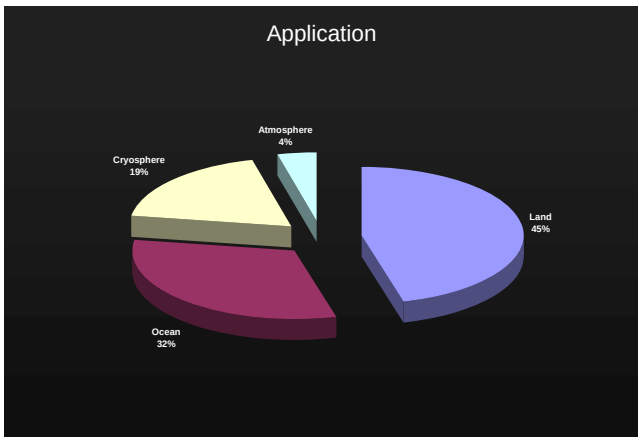

Figure 6. Application Category

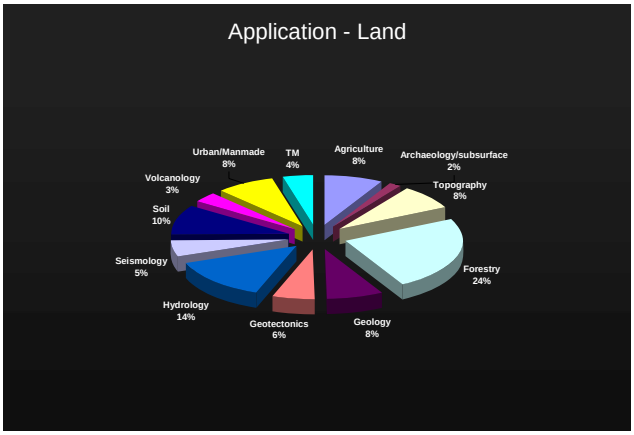

Figure 7. Application – Land Category

APPLICATION - OCEAN:

Wind: Wind speed and direction measurement from capillary or gravity wave by backscattering coefficient. Comparison study with scatterometer.
Surface Wave: Wave caused by wind, bathymetry, etc. wave spectra. The waves visible in SAR resolution.
Internal Wave: surface imprint of internal wave.
Current: Eddies, upwelling, current, frontal system
Bathymetry: subwater topography from wind/wave/tide pattern.
Slick: Oil slick, biological film
Ship: Ship detection, ship wake
Intertidal/Coastal: Intertidal zone, coastal zone. but tidal wave -> surface wave

Ocean surface imprint of atmospheric wave or front -> atmosphere

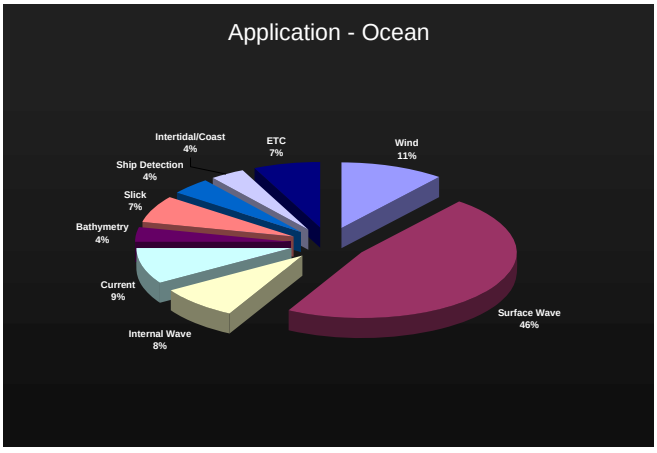

Figure 8. Application – Ocean Category

APPLICATION - CRYOSPHERE:

Glaciers: Glacier motion, Glacier snow cover, Glacier retreat/expansion.

Sea Ice: Sea ice type, first year ice, multi-year ice, pressure ridge, lead, polynya, floe, Iceberg, sea ice snow cover.

Ice Sheet/Ice Shelf: Continental ice cap, ice stream, ice sheet motion, topography, hinge-line of ice shelf, snow on ice sheet/ice shelf.

Snow over sea ice, glaciers, ice sheet/Ice shelf goes to Cryosphere. Snow and ice on non-polar region goes to Land-Hydrology.

APPLICATION - ATMOSPHERE:

amplitude: Weather systems imprinted on ocean surface. Storm, rain, wind, weather front, atmospheric lee wave, marine atmospheric boundary layer, vortex, solitons, atmospheric gravity wave.

phase: atmospheric delay or refraction of radar signal by water vapor, ionosphere, etc.

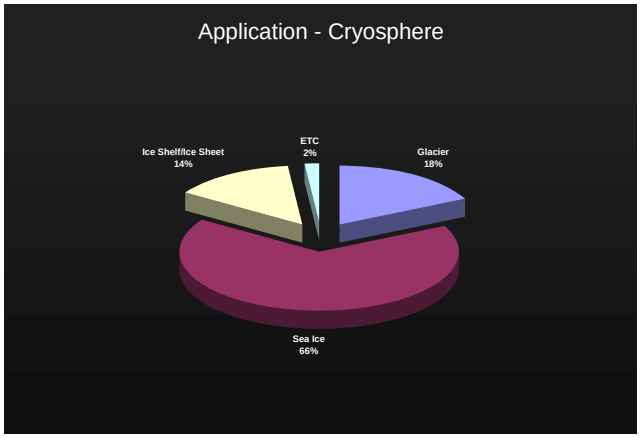

Figure 9. Application – Cryosphere Category

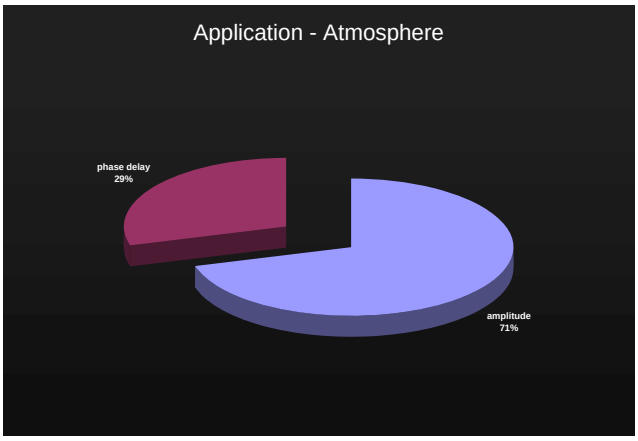

Figure 10. Application – Atmosphere Category

4. CONCLUSION

The analysis of SAR-related journal papers has shown numerous systems, technologies, and wide variety of application fields for synthetic aperture radar. Also it might imply the way SAR system, technology, and application field goes in the future. Based on this statistical analysis, more valuable interpretation can be derived further in the scientific SAR community.

5. ACKNOWLEDGEMENT

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