Improvement of crop classification accuracy using multi-frequency synthetic aperture radar data

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Outline

1. Introduction
2. Study area
3. Crop classification using multi-frequency SAR data
4. Crop classification combine SAR and optical data
Introduction

- LAN0563-- Crop identification using multi-frequency SAR data
  - Objects: Developing crop identification method based on multi-frequency SAR data
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    - Assoc. Prof. Li Qiangzi
    - Ph. D. Candidate: Jia Kun and Du Xin
  - Funding sources: Knowledge Innovation Project of the Chinese Academy of Sciences (No. KSCX1-YW-09) and National High Technology Research and Development Program of China (863 Program) (No. 2009AA12Z1462)
  - Joint project
    - ESA-NRSCC Dragon 2 Programme (ID: 5279)
Introduction

• LAN0563-- Crop identification using multi-frequency SAR data
  • Data acquisition: 15 TerraSAR-X data in total
    – 8 for Yuchen (2009)
    – 3 for Jinchang (2009)
    – 1 for Neimenggu (2009)
    – 3 for Heilongjiang (2010)
  • Ground observation
    • Synchronous field survey with data acquisition
    • Crop type distribution survey
    • Crop canopy structure parameter measurements
    • Soil condition observation
  • Publications
Introduction

- Agriculture is an essential component of societal economy, accurate crop production information is needed
  - Management of agriculture policy
  - Food Security for increasing populations
  - Agriculture losing area due to industry and urban expansion...
  - Climate change and increased extreme weather events
CropWatch

- Routine monitoring
  - China and 26 other countries
  - Yield, acreage and production
  - Crop planting structure
  - Multiple cropping index
  - Agro-meteorological situation
  - Drought
- Emergency monitoring
  - Snow disaster in south Chain (2008)
  - Wenchun earthquake (2008)
  - Drought in Xiangjiang (2008)
  - Drought in North China (2008-2009)
  - ...

Grain Supply-Demand Balance and early-warning

Crop condition monitoring
Agr: drought monitoring
Production Estimation
Crop Acreage
Crop planting structure monitoring
Crop planting structure
Cropping index

Multi-remote sensing data
Social and economical data
Field data

Validation & Accuracy assessment

Legend
Non-monitoring Area
Monitoring Area
Introduction

• Crop type mapping is the key issue
  – Traditional methods are census with ground surveying
  – Current RS method hard to meet requirement if no ground survey support
  – Identifying the crop types and delineating their extent
    • Forecasting food supplies
    • Facilitating crop rotation records
    • Mapping crop productivity
    • Identification of factors influencing crop stress
Introduction

- Why SAR data?
  - Intention: Crop Identification without ground survey
  - SAR data is sensitive to crop canopy structure parameters, like LAI, plant height etc. Different crop type has different canopy structure characters.
  - All-weather data acquisition. It is easy to get time series data and multi-source data
  - A complementary data source for optical data in crop acreage estimation
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Study area

- Yucheng is a typical agriculture region of the North China Plain
- Winter wheat and corn are widely planted, some cotton and vegetable
Field measurement and crop mapping
Crop mapping at field with UAV
### Field Measurement

<table>
<thead>
<tr>
<th>观测内容</th>
<th>指标</th>
<th>测量方法</th>
<th>观测频率</th>
</tr>
</thead>
<tbody>
<tr>
<td>基本要素</td>
<td>密度</td>
<td>株数/单位面积</td>
<td>基本要素的观测以月为频率进行，观测时间为4、5、6、7、8、9月，观测时间为月底-月初</td>
</tr>
<tr>
<td>生产要素</td>
<td>高度</td>
<td>皮尺</td>
<td></td>
</tr>
<tr>
<td>生化参数</td>
<td>叶面积指数</td>
<td>LAI2000</td>
<td></td>
</tr>
<tr>
<td>品质指标</td>
<td>生物量</td>
<td>烘干法</td>
<td></td>
</tr>
<tr>
<td>地面光谱</td>
<td>覆盖度</td>
<td>数码摄影利用法</td>
<td></td>
</tr>
<tr>
<td>温度</td>
<td>点温计测量</td>
<td></td>
<td></td>
</tr>
<tr>
<td>土壤含水量测量</td>
<td>土壤测被仪</td>
<td></td>
<td></td>
</tr>
<tr>
<td>产量要素</td>
<td>作物产量</td>
<td>收割法</td>
<td>在作物收获期观测一次，观测时间随物候有变化</td>
</tr>
<tr>
<td></td>
<td>千粒重</td>
<td>电子称</td>
<td></td>
</tr>
<tr>
<td></td>
<td>每穗平均粒数</td>
<td>计数法</td>
<td></td>
</tr>
<tr>
<td>作物生长参数</td>
<td>水分</td>
<td>烘干恒重法</td>
<td>在作物开花期进行采样，采样后的样品分析委托河北农业大学新科学院来完成</td>
</tr>
<tr>
<td></td>
<td>全糖</td>
<td>感温比色法</td>
<td></td>
</tr>
<tr>
<td></td>
<td>全氮</td>
<td>半微量凯氏法</td>
<td></td>
</tr>
<tr>
<td></td>
<td>粗蛋白</td>
<td>全氮*6.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>粗纤维</td>
<td>酸碱洗涤法</td>
<td></td>
</tr>
<tr>
<td></td>
<td>膳胡罗卜素</td>
<td>比色法</td>
<td></td>
</tr>
<tr>
<td></td>
<td>木质素</td>
<td>酸性洗涤法</td>
<td></td>
</tr>
<tr>
<td></td>
<td>淀粉</td>
<td>酸水解法</td>
<td></td>
</tr>
<tr>
<td></td>
<td>叶绿素</td>
<td>比色法</td>
<td></td>
</tr>
<tr>
<td></td>
<td>磷</td>
<td>酸溶-钒钼黄比色</td>
<td></td>
</tr>
<tr>
<td></td>
<td>钾</td>
<td>酸溶-火焰光度法</td>
<td></td>
</tr>
</tbody>
</table>

### 小麦

- 粒蛋白质含量
- 湿面筋含量
- 淀粉
- 出粉率
- 纤维素
- 纤维素

### 玉米

- 粒蛋白质含量
- 酿粒氨基酸含量

### 地面光谱

- 光谱反射率
- ASD光谱仪

在作物开花期观测，每月一次
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4. Crop classification combine SAR and optical data
Crop classification using multi-frequency SAR data

Main characteristics of the data sets used for the autumn and summer harvested crop

<table>
<thead>
<tr>
<th>SAR data</th>
<th>Date (dd/mm/yy)</th>
<th>Incidence angle</th>
<th>Polarization</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radarsat-2</td>
<td>28/08/2008</td>
<td>30.3° - 32.0°</td>
<td>Quad Polarization</td>
<td>Fine</td>
</tr>
<tr>
<td>TerraSAR-X</td>
<td>30/08/2008</td>
<td>40.0° - 41.2°</td>
<td>HH+HV</td>
<td>Stripmode</td>
</tr>
<tr>
<td>ASAR</td>
<td>27/02/2009</td>
<td>19.2° - 26.2°</td>
<td>VV</td>
<td>IMP</td>
</tr>
<tr>
<td>ASAR</td>
<td>03/04/2009</td>
<td>19.2° - 26.2°</td>
<td>VV</td>
<td>IMP</td>
</tr>
<tr>
<td>ASAR</td>
<td>08/05/2009</td>
<td>19.2° - 26.2°</td>
<td>VV</td>
<td>IMP</td>
</tr>
<tr>
<td>TerraSAR-X</td>
<td>10/05/2009</td>
<td>40.0° - 41.2°</td>
<td>HH</td>
<td>Stripmode</td>
</tr>
</tbody>
</table>
Crop classification using multi-frequency SAR data

1. Classes
   - 3 class for summer harvest crops: Wheat, cotton and non-crop
   - 6 class for autumn harvest crops: Corn, cotton, vegetables, house, tree and water.

2. Classification method
   - Using different combination of image
   - Samples being selected based on ground survey, half for training and others for validation
   - Classifier: Support Vector Machine (SVM)

3. Validation
   - Classification accuracy
   - Kappa statistics
Crop classification using multi-frequency SAR data

Classification results of autumn harvested crops

- using TerraSAR;
- using Radarsat-2;
- using both
Crop classification using multi-frequency SAR data

Classification accuracy of autumn harvested crops

<table>
<thead>
<tr>
<th>Image used</th>
<th>Accuracy</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>TerraSAR</td>
<td>70.83%</td>
<td>0.6438</td>
</tr>
<tr>
<td>Radarsat-2</td>
<td>74.35%</td>
<td>0.6878</td>
</tr>
<tr>
<td>Both</td>
<td>87.46%</td>
<td>0.8476</td>
</tr>
</tbody>
</table>

The Both Radarsat and TerraSAR data could improve for distinguishing corn, cotton, tree and vegetable. The overall accuracy of classification using both has a about 13% improvement.
Crop classification using multi-frequency SAR data

Classification results of summer harvested crops

- Wheat
- Cotton
- Non-crop
## Crop classification using multi-frequency SAR data

### Accuracy of summer harvested crops

<table>
<thead>
<tr>
<th>SAR Data</th>
<th>Accuracy</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1+A2 a</td>
<td>59.31%</td>
<td>0.25</td>
</tr>
<tr>
<td>A1+A3</td>
<td>82.19%</td>
<td>0.67</td>
</tr>
<tr>
<td>A2+A3</td>
<td>82.39%</td>
<td>0.68</td>
</tr>
<tr>
<td>A1+A2+A3</td>
<td>84.12%</td>
<td>0.71</td>
</tr>
<tr>
<td>T+A1</td>
<td>71.74%</td>
<td>0.48</td>
</tr>
<tr>
<td>T+A2</td>
<td>71.63%</td>
<td>0.48</td>
</tr>
<tr>
<td>T+A3</td>
<td>86.55%</td>
<td>0.76</td>
</tr>
<tr>
<td>T+A1+A2</td>
<td>71.23%</td>
<td>0.47</td>
</tr>
<tr>
<td>T+A1+A3</td>
<td>86.91%</td>
<td>0.76</td>
</tr>
<tr>
<td>T+A2+A3</td>
<td>87.72%</td>
<td>0.78</td>
</tr>
<tr>
<td>T+A1+A2+A3</td>
<td>88.48%</td>
<td>0.79</td>
</tr>
</tbody>
</table>

*The sample code explanations are given in Table 1. (e.g.: A means ASAR data. A1+A2 means the classification was done using A1 and A2 data.*
Crop classification using multi-frequency SAR data

Discussion

• Classification accuracy improved as more data involved
  – Multi-frequency is better than one
  – 87.46% (R2+TerraSAR)
  – 88.48% (TerraSAR+ASAR1+ASAR+ASAR3)
Discussion

• Multi-temporal ASAR data
  – Accuracy increased with more ASAR data
    • Overall classification accuracy 84.12% (A1+A2+A3)
  – Importance of ASAR acquired in different time
    • A3 (anthesis stage) > A2 (jointing stage) > A1 (regreen stage)
  – A2+A3 performed nearly as well as A1+A2+A3
Crop classification using multi-frequency SAR data

Discussion

• Multi-frequency SAR data (Radarsat-2+TerraSAR, ASAR + TerraSAR)
  – Multi-frequency is better than multi-temporal
    • 86.55% (TerraSAR+ASAR3)
    • 84.12% (A1+A2+A3)
  – Importance of different frequency SAR data
    • A3 > T (overall accuracy: A2+A3 > T + A2) ???
      – Maybe C band is better
      – Different polarization
      – Different spatial resolution
      – Investigation in future work
Conclusion

• Satisfactory accuracy would be got for upland crop classification if multi-configuration SAR data being available

• Classification accuracy could be improved when integrating of two frequency SAR data

• A combination of two frequencies SAR data (X- and C-band) is better than multi-temporal C-band SAR data for crop classification

• Two appropriate temporal SAR data sets are sufficient for crop classification in this study, and adding more temporal data has little effect on improving classification accuracy
Outline

1. Introduction
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4. Crop classification combine SAR and optical data
Crop classification combine SAR and optical data

- **ASAR data process**
  - Tools: NEXT 3A
  - The main process step
    - Import
    - Calibration
    - Filter
    - Projection

- **HJ data process**
  - The main process step
    - Calibration
    - Geo code

ASAR IMP Data
Polarization: VV
Resolution: 30m
Date: 20090508
Acquired from ESA

HJ CCD Data
Resolution: 30m
Date: 20090512
Acquired from China
Crop classification combine SAR and optical data

Main Concept

- ASAR data
  - Process
  - Fusion
  - Classification
  - Comparison

- HJ data
  - Process
  - Classification

- Classification methods used in this study
  - Maximum Likelihood Classification
  - Support Vector Machine
  - Neural network
Data fusion

ASAR and HJ data have the same spatial resolution, but the ASAR VV data is more sensitive to border of farm field, in order to get better classification result, we fused the ASAR and HJ data using PCA method.
Crop classification combine SAR and optical data

Classification of HJ data and fusion data, using MLC, SVM and NET classify method.

- HJ data, SVM
- Merged data, MLC
- Merged data, SVM
- Merged data, NET

Legend:
- Green: wheat
- Yellow: cotton
- Light gray: House & road
- Dark green: tree
Crop classification combine SAR and optical data

The ground truth of part of the study area

- Wheat: Green
- Cotton: Yellow
- House & road: Light gray
- Tree: Dark green

Trees along all the roads

Some winter wheat is planted under the tree
Crop classification combine SAR and optical data

Validation and accuracy assessment

<table>
<thead>
<tr>
<th>Data used</th>
<th>Classification method</th>
<th>wheat</th>
<th>cotton</th>
<th>tree</th>
<th>House &amp; road</th>
<th>Classification accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground truth</td>
<td>--</td>
<td>88.38%</td>
<td>0.64%</td>
<td>1.94%</td>
<td>9.04%</td>
<td>--</td>
</tr>
<tr>
<td>HJ</td>
<td>SVM</td>
<td>84.75%</td>
<td>0.04%</td>
<td>3.57%</td>
<td>11.63%</td>
<td>89.2%</td>
</tr>
<tr>
<td>Merged</td>
<td>MLC</td>
<td>75.05%</td>
<td>3.01%</td>
<td>8.68%</td>
<td>13.26%</td>
<td>90.5%</td>
</tr>
<tr>
<td>Merged</td>
<td>SVM</td>
<td>85.12%</td>
<td>0.58%</td>
<td>2.82%</td>
<td>11.48%</td>
<td>94.3%</td>
</tr>
<tr>
<td>Merged</td>
<td>NET</td>
<td>90.85%</td>
<td>0.00%</td>
<td>0.07%</td>
<td>9.08%</td>
<td>92.4%</td>
</tr>
</tbody>
</table>

The classification accuracy in this study is calculated based on randomly selected ground truth regions.
Discussion and Conclusion

• HJ multi-spectral data can effectively classify crop in the study area, but the field border can not be effectively recognized and exist misclassification.

• ASAR VV polarization data can improve the spectral information of optical data, which leading to the enlarging of the spectral difference between different classes and improving the classification accuracy.

• The overall classification performance of the fusion data are better than only using HJ CCD data.

• Envisat ASAR VV polarization data is sensitive to the non-agrarian information of planted field, and VV polarization data joined classification can effectively distinguish the field border.

• VV polarization data is sensitive to structure information and leads to the enlarging of field borders, and then the crop acreage will be shrinking in the classification result.
谢谢