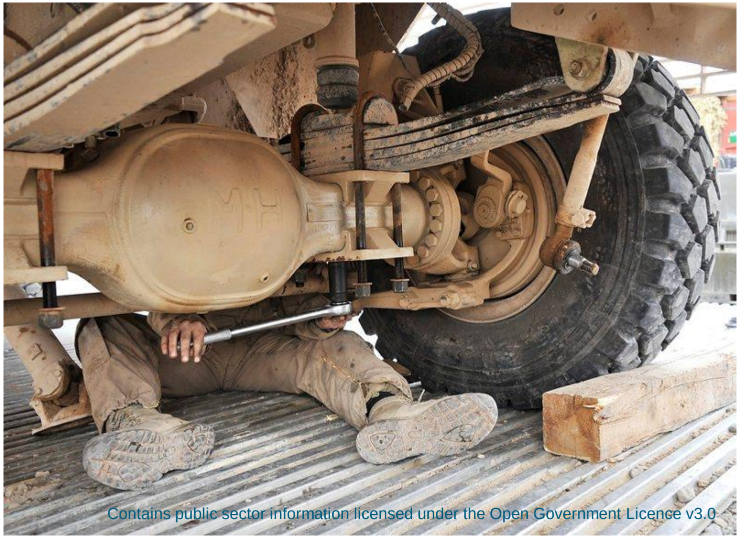
UDRC Phase 2 Challenge Workshops

A retrospective



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DSTL/PUB105892

Purpose

- No challenge workshop today
- An opportunity to look back at the challenges of the past 5 years
  - What worked
  - What didn't
- Pats on the back
- And one prize winner to be announced…

Challenge Workshop

- Run during themed meetings
- 1-2 per meeting
- Addresses current signal processing challenge
- Well-constrained
- Comes with data
- Short horizon
- Prize
- ‘Spare time’ activity

Challenge workshops

Challenge	Meeting	Start	End	Data	Source
Spectral Deconvolution	Source separation	October 2013	May 2014	Mixtures of chemicals	Explosive Substances Detection and Identification
Cyber Situational Awareness		October 2013	May 2014	Cyber time series	Cyber Situation Awareness
WAMI anomaly detection	Anomaly detection	May 2014	April 2015	Wide-area motion imagery	Applied Imagery Processing
GPR anomaly detection		May 2014	October 2014	Ground-penetrating radar	Countering Terrorist Weapons
Underwater Automatic Target Recognition	Autonomous systems	November 2014	January 2015	Underwater mine classification	Maritime Freedom of Manoeuvre
Temporal Anomaly Detection		November 2014	March 2015	Time series of unidentified provenance	Identify project
SAR Processing	MIMO and SAR	May 2015	October 2015	Synthetic aperture radar	Selex ES (now Leonardo)
Golden Dongle		May 2015	September 2015	Multi-source Wifi	Electronic surveillance
Raspberry Pi Challenge	Implementation	November 2015	April 2017	Electronic surveillance from space platforms	Satellite
Occlusion detection	Image and video processing	May 2016	November 2016	Wide-area motion imagery	Roke
Orbital object tracking	Space	November 2016	August 2017	Night-time electro-optic imagery	Space Situation Awareness

Gross statistics

- 11 challenges
- ~100 data sets distributed
- ~20 entries
- 7 winners
- 3 entries attracted further funding from MOD
- 1 ended up in a commercial product
- at least 6 entries have ended up making their way into Dstl research projects

Winners

Spectral Deconvolution

Underwater ATR

GPR Anomaly Detection

Raspberry Pi

WAMI Anomaly Detection

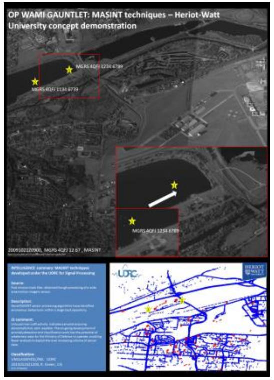
Temporal Anomaly Detection

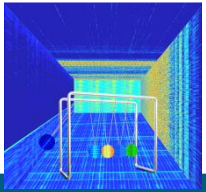
Golden Dongle

All images from mod-udrc.org

Prizes

- Raman spectrometer/1950’s ray gun
- Land mine (most likely inert)
- Personalised imagery intelligence report
- Autonomous underwater vehicle (not water resistant)
- A framed time series
- An actual golden dongle
- And one yet to be awarded…





Highlight: fast Raman spectral deconvolution

- Challenge
  - Enabling agreement
    - baseline correction
    - complexity reduction
  - Enabling agreement 2
    - prototyping
    - Industry involvement
  - Enabling agreement 3
    - technical refinement
  - Contract with industrial supplier
  - Licensing agreement

< 3yrs

Fast Sparse Raman Spectral Unmixing for Chemical Fingerprinting and Quantification

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ABSTRACT

Raman spectroscopy is a well-established spectroscopic method for the detection of condensed phase chemicals. It is based on scattered light from exposure of a target material to a narrowband laser beam. The information generated enables presumptive identification from measuring correlation with library spectra. Whilst this approach is successful in identification of chemical information of samples with one component, it is more difficult to apply to spectral mixtures. The capability of handling spectral mixtures is crucial for defence and security applications as hazardous materials may be present as mixtures due to the presence of degradation, interferents or precursors. A novel method for spectral unmixing is proposed here. Most modern decomposition techniques are based on the sparse decomposition of mixture and the application of extra constraints to preserve the sum of concentrations. These methods have often been proposed for passive spectroscopy, where spectral baseline correction is not required. Most successful methods are computationally expensive, *e.g.* convex optimisation and Bayesian approaches.

We present a novel low complexity sparsity based method to decompose the spectra using a reference library of spectra. It can be implemented on a hand-held spectrometer in near to real-time. The algorithm is based on iteratively subtracting the contribution of selected spectra and updating the contribution of each spectrum. The core algorithm is called fast non-negative orthogonal matching pursuit, which has been proposed by the authors in the context of nonnegative sparse representations. The iteration terminates when the maximum number of expected chemicals has been found or the residual spectrum has a negligible energy, i.e. in the order of the noise level. A backtracking step removes the least contributing spectrum from the list of detected chemicals and reports it as an alternative component. This feature is particularly useful in detection of chemicals with small contributions, which are normally not detected. The proposed algorithm is easily reconfigurable to include new library entries and optional preferential threat searches in the presence of predetermined threat indicators.

Under Ministry of Defence funding, we have demonstrated the algorithm for fingerprinting and rough quantification of the concentration of chemical mixtures using a set of reference spectral mixtures. In our experiments, the algorithm successfully managed to detect the chemicals with concentrations below 10 percent. The running time of the algorithm is in the order of one second, using a single core of a desktop computer.

Keywords: Raman Spectroscopy, Spectral Decomposition, Spectral Quantification and Fingerprinting

1. INTRODUCTION

Optical spectroscopy methods are based on recording the interaction of light with the materials. These interactions through absorption, transmission, reflection or scattering can provide fundamental, and in some instances characteristic, information from the material under study. Raman spectroscopy, in contrast to other spectroscopic techniques, is based on measuring the scattered light from a very narrow band illuminated light, *i.e.* a

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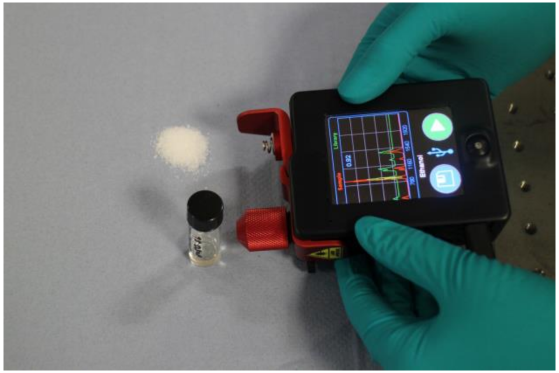
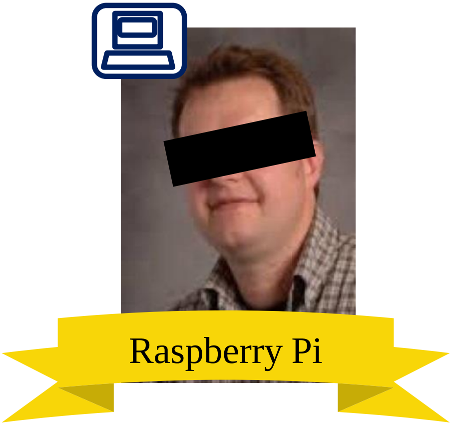


What we learned

- Collaborative workshop session
- No open-ended questions
- A clear marking scheme
- A held-in data set
- Small data
  - which requires minimal wrangling
- Relevant
- Pass mark/minimum bar to entry

Implementation challenge

- The ‘Raspberry Pi’ challenge from the Implementation Theme Meeting
- Commendation from David Nethercott, chairman of the judging panel
- And the winner is…



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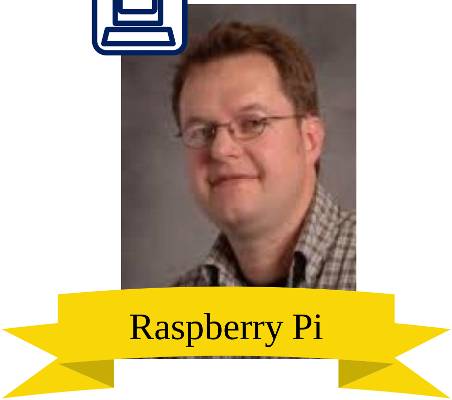

Ministry of Defence

Summary

- Competitions centred on small, self-contained data sets and an relevant problem has led to exploitation success
  - make the challenge relevant
  - make the data manageable
  - engage after the event
- Pyramid effect
  - Some just take the data
  - N_data >> N_entries > N_winners ~= N_exploited