REPRODUCIBILITY IN COMPUTER VISION: TOWARDS OPEN PUBLICATION OF IMAGE ANALYSIS EXPERIMENTS AS SEMANTIC WORKFLOWS

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Reproducibility in Computer Vision

- The importance of reproducible computational research has come to the forefront in computer vision.
- Premier conferences like Computer Vision and Pattern Recognition (CVPR) requiring reviewers to comment on the reproducibility of papers.
  - The International Conference on Image Processing (ICIP) has round tables on reproducibility.

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Repeatability Criteria: The CVPR 2010 reviewer form will include the following additional criteria, with rating and associated comment field: "Are there sufficient algorithmic and experimental details and available datasets that a graduate student could replicate the experiments in the paper? Alternatively, will a reference implementation be provided?". During paper registration, authors will be asked to answer the following two checkbox questions: "1. Are the datasets used in this paper already publicly available, or will they be made available for research use at the time of submission of the final camera-ready version of the paper (if accepted)? 2. Will a reference implementation adequate to replicate results in the paper be made publicly available (if accepted)?" If either these boxes are checked, the authors should specify in the submitted paper the scope of such datasets and/or implementations so that the reviewers can judge the merit of that aspect of the submission's contribution. The Program Chairs realize that for certain CVPR subfields providing such datasets, implementations, or detailed specification is impractical, but in other areas it is reasonable and sometimes even standard, so on balance repeatability is a relevant criteria for reviewer consideration. "N.A." will be an available reviewer score for this field, as it is for other fields.
Overview

- Reproducibility Crisis
- Addressing reproducibility with scientific workflows
- Case Study: Video Activity Recognition
- Case Study: Multimedia Analysis
- Case Study: Neural Algorithm of Artistic Style
- Benefits of scientific workflows for computer vision analysis
- Conclusions
Addressing reproducibility with scientific workflows...

- General technique for describing and enacting a process
- Capture complex analytical processes at various levels of abstraction
  - Visually describes what you want to do
- Tracks metadata, parameters, and intermediate results
  - Debugging, inspectability
- Accommodate large amounts of data and large number of computations
- Semantic Workflows incorporate semantic constraints about datasets and workflow components
  - Used to create and validate workflows and to generate metadata for new data products
Examples of Scientific Workflows

Workflows from [Hauder, et al., SC WORKS 2011]
Creating workflows: WINGS

- WINGS is a semantic workflow system that assists scientists with the design of computational experiments.
- Workflow representations incorporate semantic constraints about datasets and workflow components, and are used to create and validate workflows and to generate metadata for new data products.
- WINGS submits workflows to execution frameworks such as Pegasus and OODT to run workflows at large scale in distributed resources.

http://wings-workflows.org/
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Case Study: Detecting Groups in Videos

- How can we figure out when we go from a collection of individuals to formation of a crowd in video?
- Reminiscent of the $n$-body problem in fluid dynamics: the transition from a collection of individual particles to a fluid
Workflows for Group Analysis

(a) *Group Formation:* $G_{tr}$ decreases from about 2 to about 0.5. Sample image shows individuals converging and forming a group.

(b) *Group Movement:* $G_{tr}$ stays steady at about 0.2. Sample image shows group moving together.
## Computer Vision Workflows

- **Workflow Fragments created for Computer Vision**

<table>
<thead>
<tr>
<th>Category</th>
<th>Workflow Fragments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Computer Vision</strong></td>
<td>OpenCV components (Optical Flow, Kalman tracker, Mixture of Gaussians, Particle filter, etc.), N-Cuts, PhaseSpace, $G_{tr}$, $Relative_Velocity$, $Relative_Distance$, Image Extractor, Background/Foreground Extraction, Neural Algorithm for Artistic Style (Lua/Torch), Neural Algorithm for Artistic Style (TensorFlow)</td>
</tr>
<tr>
<td><strong>General Machine Learning</strong></td>
<td>K-Means, Latent Dirichlet Allocation, Mallet, libSVM, Caffe, Convolutional Neural Networks (Lua/Torch), TensorFlow, Adam Optimizer, Recurrent Neural Networks</td>
</tr>
<tr>
<td><strong>Statistical Evaluation</strong></td>
<td>Confusion Matrices, Heatmaps, Precision-Recall Curves, ROC Curves, AUC Curves, Equal Error Rate, F-Measure</td>
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**Motivation: Human Trafficking Detection**

- **2M children** estimated to be exploited by the global trafficking trade

- **12.3M individuals** worldwide as forced laborers, bonded laborers or trafficking victims. **1.39M of them worked as trafficked slaves, 98% are women and girls**

- Global profits estimated to be **US$ 31.6B from trafficked victims**, from forced laborers **US$ 44.3B per year**. The largest profits - more than **US$ 15B** - are in industrialized countries.
The Need for Automation of Human Trafficking Detection

Law enforcement activities such as tracking and capture (sting) operations are more effective through monitoring on-line ads across sites.

**AD CHARACTERISTICS**
- Falsifying information
  - E.g. age
- Obscuring information
- Use of aliases
- Across locations

**TASKS**
- Extract service modality, detect illicit services
- Estimate true age
- Link ads of same provider
- Link ads across sites/locations
- Cross-reference with DBs (e.g., missing children)

Currently done by hand!
Multimedia Analysis for Human Trafficking Detection

**IMAGE ANALYSIS**

- Image age estimation/age projection
- Match face with likely victims (e.g., runaways/abductees)
- Detect multiple faces; co-trafficking highly correlated with underage participation
- Use of stock/photoshopped images inversely correlated with underage participation
- Reuse of banner images may indicate association/sharing
- ID/matching of locations (hotel decor), personal effects, tattoos even if face has been obscured
- Race/ethnicity/body characteristics estimation

**TEXT ANALYSIS**

- Text indications of underage participation ("young") weaker than other methods; very often deceptive/false
- Text indication of race/ethnicity/body also have high degree of deception
- Text descriptions of co-trafficking (multiple victims) have been found to be more reliable

Combining text and image cues narrows search more effectively

TrafficBot project: 6 sites, each 400 locations, 20,000-40,000 posts/day
High-Level Workflow for Multimedia Analysis

- Workflow shows the following modules:
  - Componentized Workflow Fragment
  - N-Cut segmentation on the image
  - Workflow Fragment for Feature Generation, as well as doing feature selection
  - Workflow Fragment for Fusion: combines the results from the Image Analysis (LDA and SVM) as well as the results from the Text Analysis (Topic Models and SVM).
Workflow for Multimedia Analysis

High-Level Workflow

Detailed Workflow

[Sethi, et al., ACM MM 2013]
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The Neural Algorithm of Artistic Style by Gatys, et al., uses deep neural networks to separate the style and content of an image.

- Specifically, a Convolutional Neural Network, CNN

Uses 2 images:
- one image is a style image
- and one is a target image

It then extracts the style from the style image and applies it to the content of the target image to create a new image in the style of the style image.
Reproducing their results

- We implemented two workflow versions: one using lua/torch and one using TensorFlow
- We reproduced the results from the paper
- We used the target image of a scene from Tubingen as presented in the original paper and reproduced their results as shown.
Workflows

- Workflow using an implementation of CNNs that use the Lua/Torch languages
- Workflow using an implementation of CNNs that uses Google’s TensorFlow library
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Benefits of Workflows for computer vision analysis

- **Accessibility**
- **Time savings**
  - Site crawlers had been previously written, turned into workflow components in 2 days
  - Pre-existing workflows for text and video analytics: 1 day of work
  - Time/effort savings estimated at 300 hours of work
- **Facilitate exploration and reuse**
  - Explore different parameter values
  - Easy to add new components
  - Can use off-the-shelf components or roll your own
Conclusions

- Reproducibility in computer vision is challenging
- Collection of workflows and workflow fragments for computer vision
  - Quick deployment of state of the art techniques for image analysis
  - Integration of heterogeneous codebases and standard implementations
  - Easy to extend
- Future work: let non-experts to use image analysis workflows
  - Geoscience analysis of samples
  - Art students to analyze pieces of art