ATR for various modalities

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Summary

- Algorithm development is a complex process with several external dependencies (test protocols, test materials, test sites).
- Algorithms must have predictable performance and not be overfit.
- Algorithms are a necessary but not sufficient condition for commercial success.
- Algorithm development using simulated data or target surrogates is probably not sufficient to insure success.

Outline

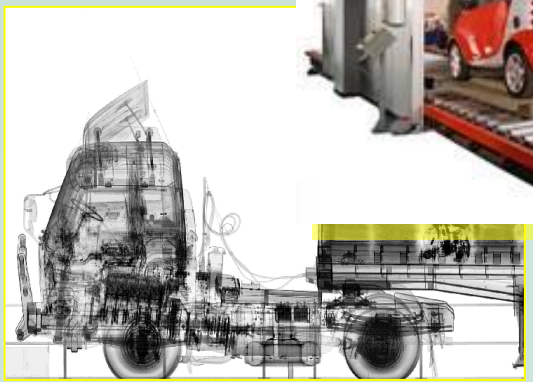
- Perspective
- Preliminaries
- Process

Perspective

L-3 develops many ATR algorithms across its product lines (luggage, hand carry, people)

TSA Certified Systems

Automated AT



Cargo Systems

Checkpoint Screening

Solution space has three axes

- Discrimination. Systems must provide excellent detection with a minimum number of false alarms. Must also provide operator threat resolution tools.
- Cost. Systems must provide reasonable price and costs of installation, operation (and operators) and maintenance.
- Operations. Systems must function in their designated environment and be safe for people and their possessions. Systems must have reasonable throughput and be reliable with minimum downtime. Must be able to be serviced on site.
  - The threat detection algorithm is a necessary but not a sufficient condition for commercial success. Not all TSA certified systems have been successful.

ATR project scale

- Most projects are in the 10's of millions of dollars and 10's of man years. The prototype is often required on very short time scales (2-3 years). Not DOD, NASA.
- There is only modest infrastructure for testing (a handful of established test centers in USA and EU).
- Time, money, and man power limit the due diligence that can be put into a design.

Goals

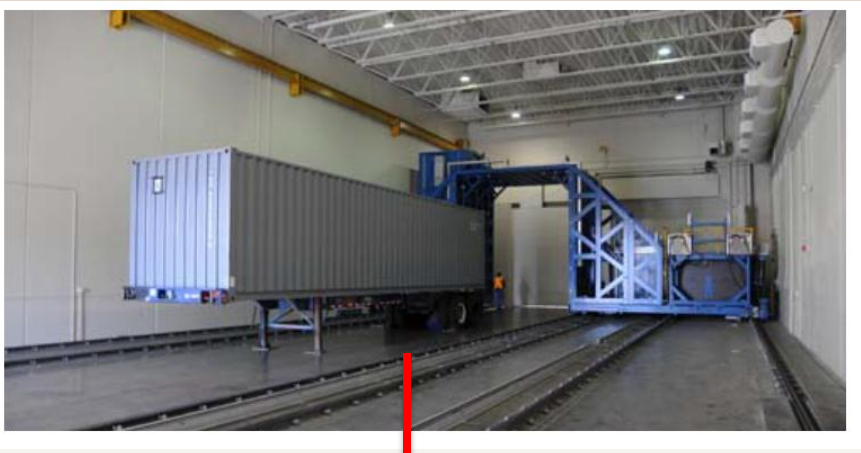
- The primary goal of industrial algorithm development is to obtain the regulatory approval necessary to sell the equipment. No letter, no product.
- All detection systems have pre-defined goals for probability of detection (PD) and probability of false alarm (PFA). How they are measured is another story.
- The PD and PFA that characterize the system are those of the regulatory test environment and not necessarily the operational environment.

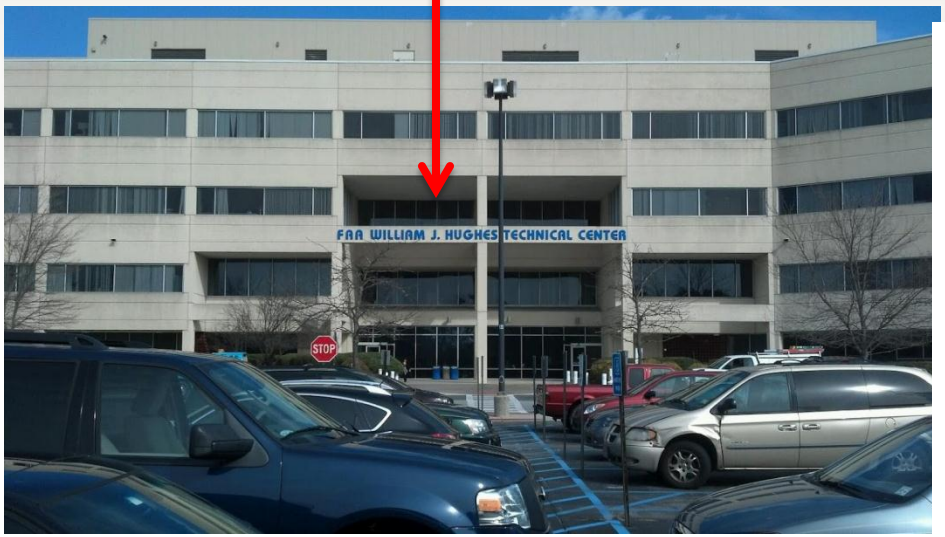
Preliminaries

Questions before setting out

- Is there an established test protocol?
- Is there an established scoring protocol (when is a alarm counted as a detection)?
- Are there test materials or vetted simulants available for target data collection and performance testing? What about “clean” data for false alarms?
- Is there a test site or will the testers come to you?

Established regulatory vs. pilot testing





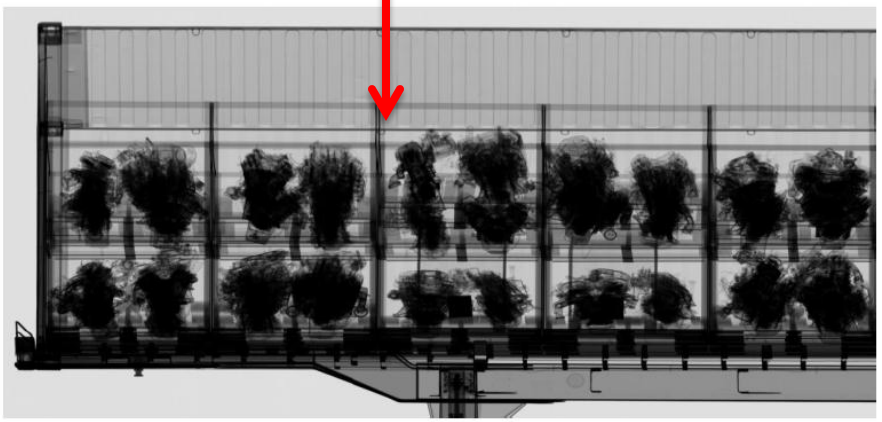


Figure 1. Test object is hidden in cargo container filled with automobile engines.

Testing experiences

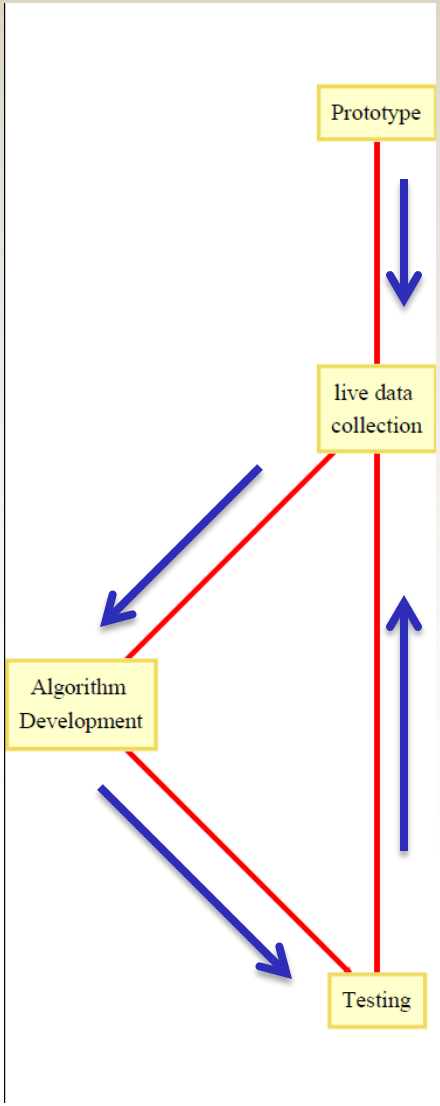
- Invited to a test for a type of contraband held at a national lab. Government regulations prohibit that contraband at the lab.
- While executing government contracts to develop new detection modalities, difficulty obtaining detection targets and/or securing a test facility may occur.

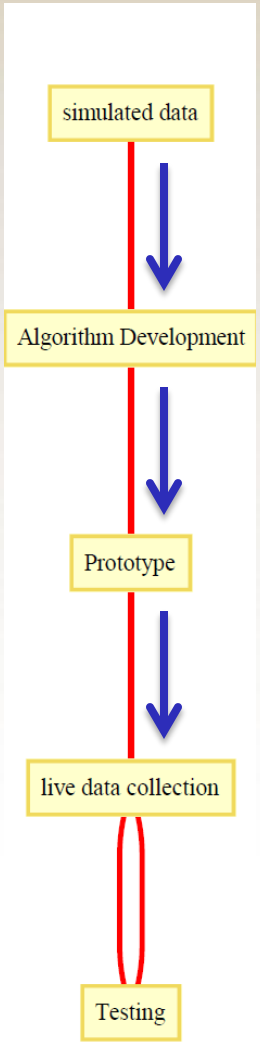
Process

Major steps for regulatory approval

- System design
- Prototype fabrication
- Data Collection
- Algorithm Development
- Testing

Algorithm development sequences

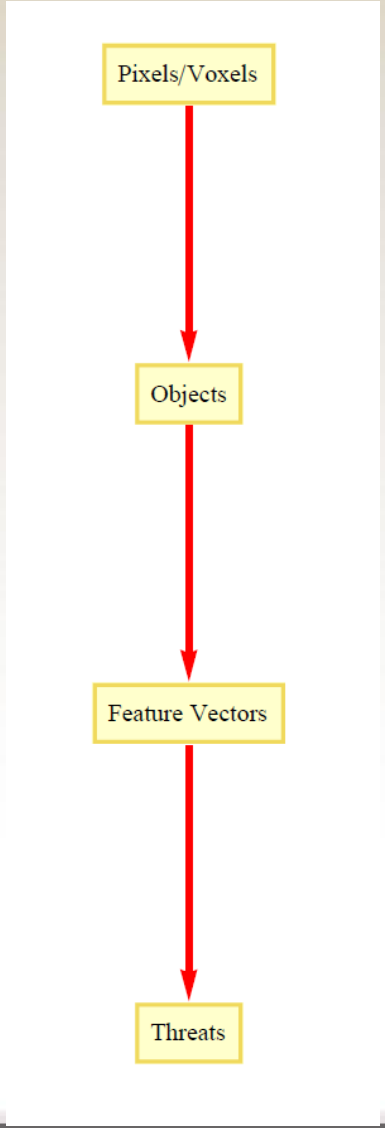




Data collection options

- Simulation of targets and calibration data
- Live system collection of targets
- Live system collection of target simulants
- Live system collection of clean data
- Notes:
  - ~ 10^3 images
  - Vetted target simulants useful to start and benchmark
  - Simulated data useful for physics but will not illuminate the idiosyncrasies of the system (better for design than algorithm).
  - Cannot succeed on simulated data /simulants alone (will work vs. can work).

Major steps for algorithm development



Segmentation

(a) Original images.

(b) Segmentation results with distortion ($\varepsilon = 25$)

(c) Segmentation results with distortion ($\varepsilon = 400$)

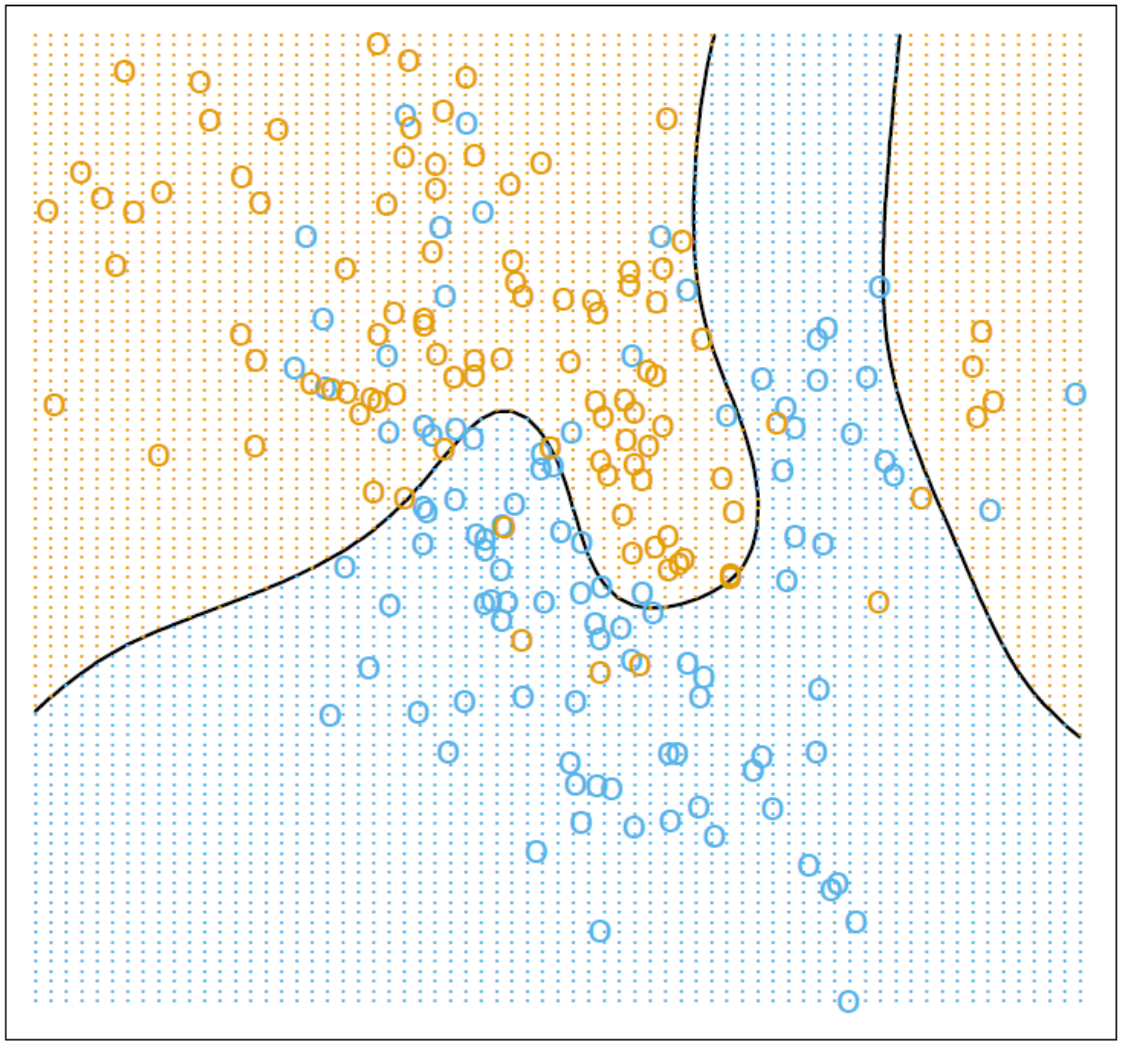
Segmentation

- Developed working with images.
- Typically use scratch pad or fast prototyping.
- Need to be sure that your targets are creating objects, if not there is no hope of detection.
- How will your algorithms execute on the live system (MATLAB dilemma)?

Feature vectors

- Once you have an object, you want to perform measurements on it. Hardware dependent.
- Art form.
- Need flexibility to quickly test features and add new ones (performance measurements).

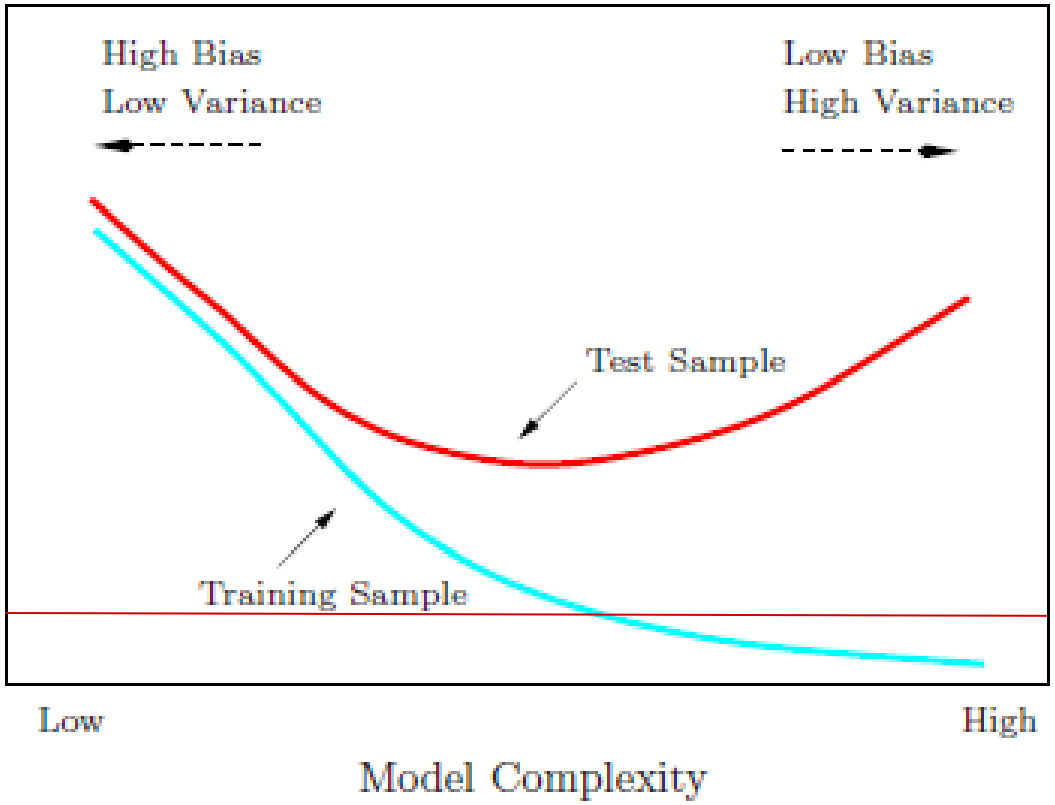
Classification/regression model development



Classification/regression model development

- Model selection (which one).
- Model tuning (selecting the simplest one).
- Feature selection (finding best set of variables to make decision).
- May need to satisfy multiple constraints (sub categorization goals)
- Performance prediction (deciding that you have met your goal and it will be achieved on the test set).

Algorithms must avoid overfitting



•Better

•Goal

FIGURE 2.11. *Test and training error as a function of model complexity.*

StatLog: large scale EU academic/industrial Algorithm “bake-off.” http://www1.maths.leeds.ac.uk/~charles/statlog/

- 23 Algorithms from three different categories
  - Statistical Learning (discriminants, K-nn)
  - Machine Learning (trees & rules)
  - Neural Nets
- 22 data sets from a diverse range of problems
  - Credit
  - Object Recognition (letters, digits, vehicle silhouettes)
  - Image Segmentation (land use, finding letters in words)
  - Medical
  - Cost penalized (medical, credit)
  - Industrial (Space Shuttle design, proprietary).

Performance by Algorithm Class

Table 10.7: Top five algorithms for all datasets, by type: Machine Learning (ML); Statistics (Stat); and Neural Net (NN).

Dataset	First	Second	Third	Fourth	Fifth
KL	Stat	Stat	Stat	NN	NN
Dig44	Stat	Stat	NN	NN	Stat
Satim	Stat	NN	NN	NN	Stat
Vehic	Stat	NN	Stat	Stat	NN
Head	Stat	NN	Stat	Stat	ML
Heart	Stat	Stat	Stat	Stat	Stat
Belg	Stat	Stat	NN	NN	Stat
Segm	Stat	ML	ML	ML	NN
Diab	Stat	NN	Stat	Stat	NN
Cr.Ger	Stat	Stat	Stat	Stat	NN
Chrom	Stat	NN	Stat	NN	Stat
Cr.Aus	ML	ML	Stat	Stat	NN
Shutt	ML	ML	ML	ML	ML
DNA	NN	NN	Stat	Stat	Stat
Tech	ML	ML	ML	ML	ML
NewBel	Stat	ML	ML	ML	ML
ISoft	ML	NN	Stat	Stat	NN
Tset	ML	ML	ML	ML	ML
cut20	ML	Stat	ML	Stat	ML
cut50	Stat	ML	Stat	ML	ML
Cr.Man	Stat	NN	ML	ML	NN
letter	Stat	Stat	NN	Stat	ML

- 13 Algorithms had a first place result.
- 5 Algs had a least a second place
- 3 Algs had at least a third place
- Only 1 Alg did not manage a top 5 finish
- "There is no silver bullet"

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Threats

- Need a well developed system to evaluate the algorithm performance.
- Need to decide when is an alarm counted as a detection (varies by regulator).
- Start to implement version control for algorithm and system software.
- Schedule test. Process can be months to years.

Questions?