Experimental Designs for Walk-Through Metal Detectors at Large Stadiums

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Introduction

- Background
- Additional literature research
- Experimental design
- Conclusion

Overview of Walkthrough Metal Detectors (WTMDs)

- It is “a free-standing screening device having an electromagnetic field within its portal structure (aperture) for detecting metallic objects, including some nuclear shielding materials, carried by persons walking through the aperture.”
- Walk-throughs also have the ability to change the amounts of metal they detect, giving an advantage in large venue situations, targeting whatever amounts of metal the venue prefers to target. It can be calibrated to different security levels, depending on the venue and situation.
- Common usage – primarily indoors
  - Airports, corrections, schools, etc.

NIJ (1999)

Experimental Designs for Testing Metal Detectors at a Large Sports Stadium, Nelson, Kantor, et al. (2014)

Stadium Metal Detectors

- Outdoor environment
  - Impact of weather
- Many people arrive in short period of time
  - High throughput, high accuracy important

The Ballpark Guide

Literature Review

- Many recent press releases on increased usage of WTMDs in stadium settings
- However, there are not many publically available documents with information on how WTMDs work and best practices
  - Much of this is sensitive information
  - We were able to find some older documents

Literature Review: Corrections

- Common Problems with WTMD
  - Most frequent causes of false alarms – 56 surveys of correctional security and administrator personnel (1993)
    - A metal object too close to the detector
    - Atmospheric conditions such as wind, humidity, rain, cold, heat, snow and sun
    - Other sources, such as clothing, power surges, touching or bumping the unit, radio waves and static electricity
  - Metal Problem
    - Detection of non-metallic contraband

Correctional Technology: A User's Guide,
U.S. Department of Justice (1993)

Literature Review: Schools

- Walk-through metal detectors
  - Overview of principles of operation
    - Electromagnetic pulses → small currents in conductive materials → generate magnetic fields → detected by the receiver between pulses
  - Detection factors of objects
    - Size, shape, electrical conductivity, magnetic properties
    - Speed of entry
    - Surroundings
      - 2-4 foot detection range
      - Nearby objects

The Appropriate and Effective Use of Security Technologies in U.S. Schools, National Institute of Justice (1999)

Literature Review: Schools

- Detection of objects

Item	Source of an alarm?
Most boots with steel shanks	Yes
Orthodontic braces	No
Orthodontic braces with head gear	Borderline
Zippers in clothing	No
Underwires in brassieres	No
Large closed-loop earrings	Yes
Small closed-loop earrings	No
Large loop earrings that are not a complete circle	Borderline
Glasses (for vision) with metal rims	Borderline
Soda can	Yes
Keys	No
Key rings	Borderline
Three-ring metal binder	Yes
Musical instruments and cases	Yes
Foil gum wrappers and cigarette packages	Borderline

The Appropriate and Effective Use of Security Technologies in U.S. Schools, National Institute of Justice (1999)

Literature Review: Schools

- Acceptance Testing
  - Determine test objects based on likely threats
    - A test object is intended to replicate prohibited item
  - Baseline set – clean subject walks through metal detector
  - Enter with test object – varying factors
    - Run 20 tests or until 2 "failures"
      - Must trigger alarm at least 19 out of 20 times for each set of factors to be deemed acceptable

The Appropriate and Effective Use of Security Technologies in U.S. Schools, National Institute of Justice (1999)

Literature Review: Experimental Design

- Design of experiments with variation/treatment typically controlled by the experimenter
- Experimenter interested in impact of a treatment on the outcome
- We will be using the ACTS combinatorial experimental design software from NIST
  - ACTS can create pairwise (or higher) combinations of factors

Design of Experiments, Wikipedia (2015)

Experimental Design
Parameter Values (toy example)

- Feature1: A, B, E
- Feature2: 1–10
- Feature3: 5, 50, 165
- Feature4: True/False
- Feature5: 1–3
- Feature6: True/False
- Feature7: True/False
- Feature8: 1–3
- Feature9: 1–3
- Feature10: 1–3

Highly Efficient Experimental Design: ISERC Presentation, Kantor, Nelson, Roberts, Pottenger (2015)

Experimental Design

Efficiency of the Combinatorial Experimental Design:

- For conventional experimental design able to resolve main and pairwise effects, there have to be:

$$N_2(L_1, \cdots, L_k) = \sum_{i<j} L_i L_j$$

- =1/2 sq(sum)−Sum(squares)

  1156
  − 166
  990 divided by 2
  = 495

- For Combinatorial Experimental Design we need only 32 to check all values of all pairs.

Highly Efficient Experimental Design: ISERC Presentation, Kantor, Nelson, Roberts, Pottenger (2015)

Experimental Design

Toy Example – Shown in ACTS Software

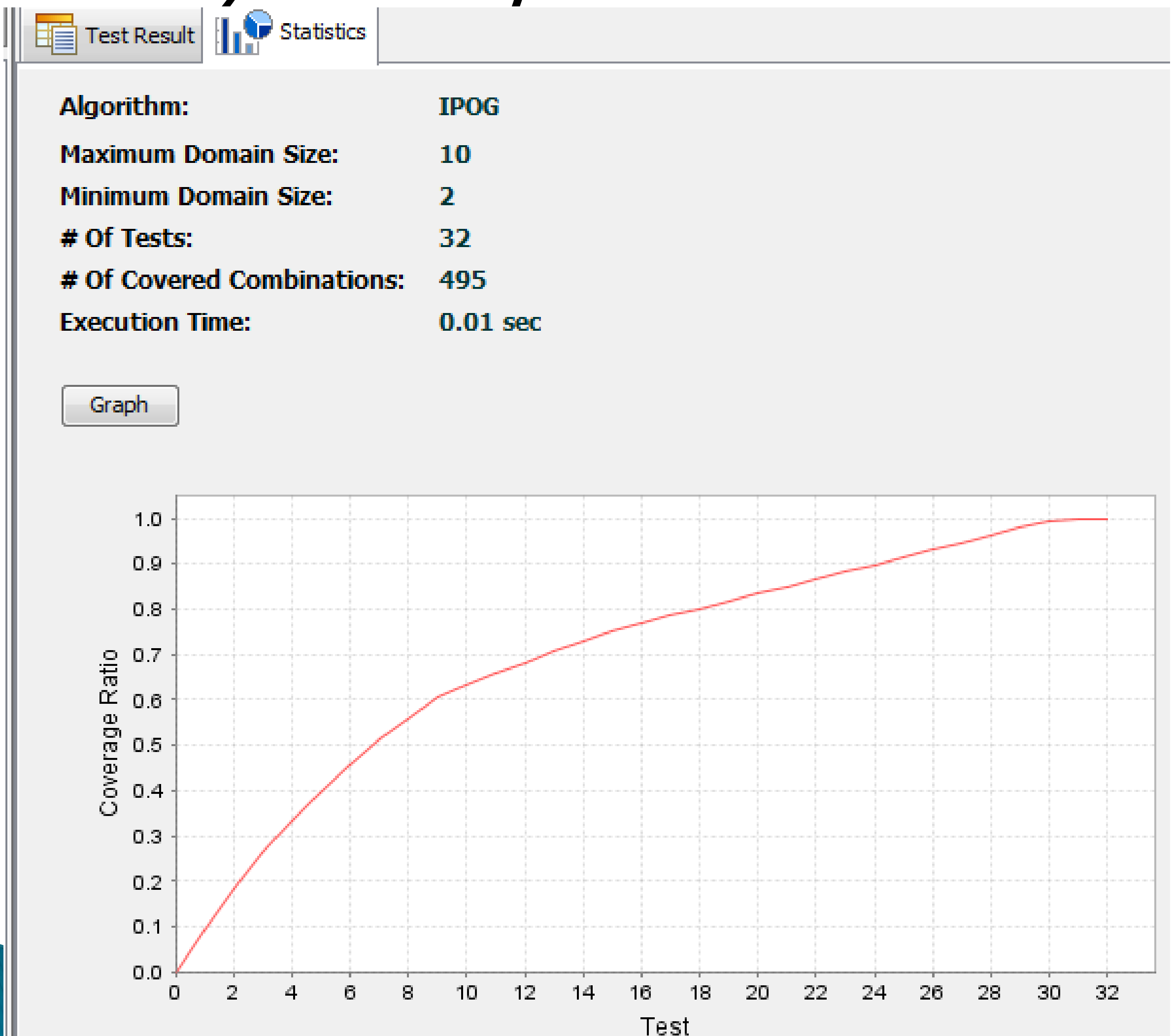
Test Result | Statistics

	FEATURE1	FEATURE2	FEATURE3	FEATURE4	FEATURE5	FEATURE6	FEATURE7	FEATURE8	FEATURE9	FEATURE10
1	A	1	50	false	2	false	false	2	2	2
2	B	1	165	true	3	true	true	3	3	3
3	E	1	5	false	1	true	false	1	1	1
4	A	2	165	true	1	false	true	2	3	1
5	B	2	5	true	2	false	false	3	1	2
6	E	2	50	true	3	false	true	1	2	3
7	A	3	5	false	3	true	true	2	1	3
8	B	3	50	false	1	true	false	3	2	1
9	E	3	165	false	2	true	true	1	3	2
10	A	4	5	true	3	false	false	3	2	1
11	B	4	50	false	1	true	true	1	3	2
12	E	4	165	false	2	false	false	2	1	3
13	A	5	5	true	3	false	false	1	3	2
14	B	5	50	false	1	true	true	2	1	3
15	E	5	165	true	2	false	false	3	2	1
16	A	6	5	true	3	false	false	1	3	2
17	B	6	50	false	1	true	true	2	1	3
18	E	6	165	true	2	false	true	3	2	1
19	A	7	5	true	3	false	false	1	3	2
20	B	7	50	false	1	true	true	2	1	3
21	E	7	165	false	2	false	true	3	2	1
22	A	8	5	true	3	false	false	1	3	2
23	B	8	50	false	1	true	true	2	1	3
24	E	8	165	true	2	true	false	3	2	1
25	A	9	5	true	3	false	false	1	3	2
26	B	9	50	false	1	true	true	2	1	3
27	E	9	165	false	2	false	false	3	2	1
28	A	10	5	true	3	false	false	1	3	2
29	B	10	50	false	1	true	true	2	1	3
30	E	10	165	true	2	false	true	3	2	1
31	B	3	5	true	3	false	true	3	3	2
32	B	2	5	false	3	true	true	3	3	3

Highly Efficient Experimental Design: ISERC Presentation, Kantor, Nelson, Roberts, Pottenger (2015)

Experimental Design

Toy Example – Shown in ACTS Software



This plot shows how the number of combinations covered increases with the addition of tests. With 32 we cover all 495 combinations as required

Highly Efficient Experimental Design: ISERC Presentation, Kantor, Nelson, Roberts, Pottenger (2015)

CCICADA Prior Work

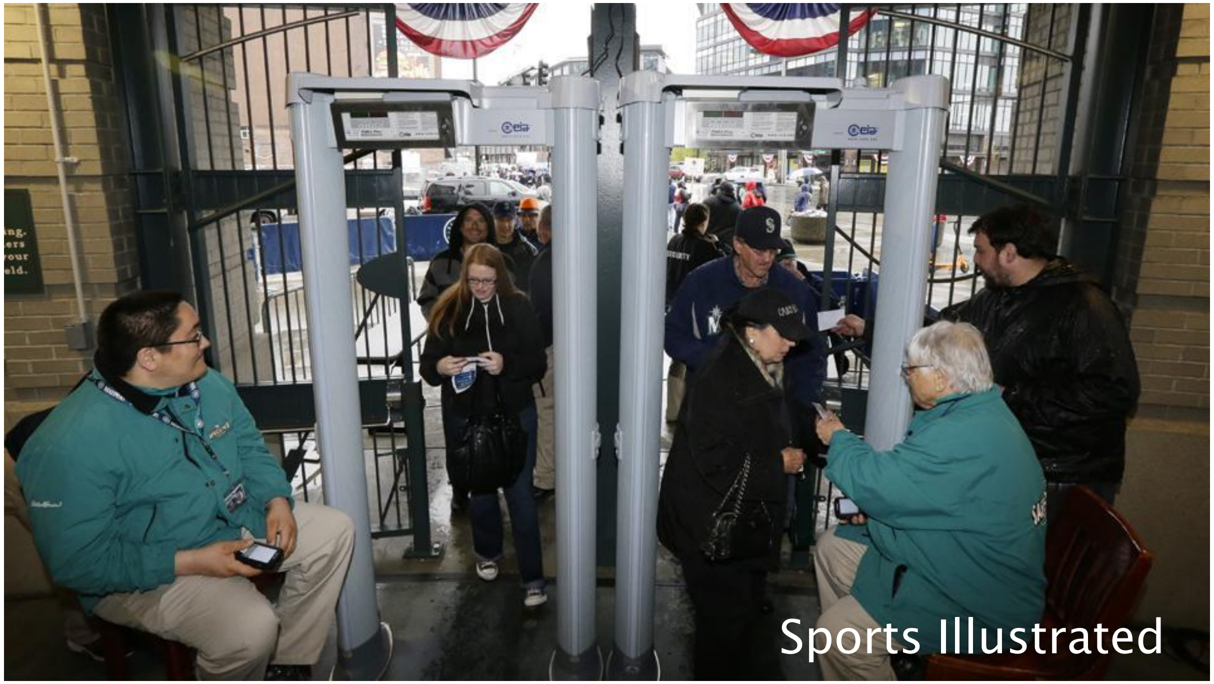
- Walk-Through Metal Detectors
  - Several factors, such as type of item, location, orientation of test object, walkthrough setting, were to be considered for the experiment. Hence, Combinatorial Experimental Design was used to reduce the number of necessary test cases.
  - It focused on the understanding the performance of walk-throughs in real situations (as opposed to lab situation).
  - It examined how consistent the walkthroughs were at detecting the pre-specified items in the same setting in different height/orientation locations.

Experimental Designs for Testing Metal Detectors at a Large Sports Stadium, Nelson, Kantor, et al. (2014)

Research: Principles of Operation of Walk-Through Metal Detectors

- Interaction of an Object with the Magnetic Field
  - Object Material
    - Electrical Conductivity
      - Induced Eddy current
    - Magnetic Permeability
  - Detection
    - Sources
    - Sensors
      - Detecting the Primary Magnetic Field
      - Detecting the Secondary Magnetic Field
      - Both of them
      - Detecting any change in the performance of the source electronics
    - Noise and Electromagnetic Interference (EMI)

Users' Guide for Hand-Held and Walk-Through Metal Detectors, NIJ (2001)


Sports Illustrated

The Ballpark Guide

Research: Standards for Walk-Through Metal Detectors

- Commonly used NILECJ 0601.00 (1974)
- Series of tests to ensure WTMD works properly
- Security Levels (focus on 1-3)
  - Level 1: Low-Threat Level
  - Level 2: Medium-Threat Level
  - Level 3: High-Threat Level
  - Level 4: High-Threat Level
  - Level 5: Very High Threat Level
- Requirements
  - Ambient temperature – 18-38ºC (~64-100ºF)
  - Alarm indicator – one inaudible indication for operator
  - Controls – hidden, resettable
  - Stability – must work after warmup period and after 24 hours
  - 105-129 volts, 58-62 Hz

Research: Standards for Walk-Through Metal Detectors

- NILECJ 0601.00

Research: Standards for Walk-Through Metal Detectors

- Updates: NIJ 0601.01-03
- Additions or modifications for outdoor use
  - Temp. range increased: -37-65ºC (~-35-149ºF)
  - Additional testing to account for new external conditions

Experimental Design

- Purpose
  - To gain understanding about performance of WTMDs in an outdoor situation (as compared to lab situation) outside of the typically tested matched test objects and WTMD security setting.
- Hypothesis
  - Experiment 1: Detection will change based on height of test object moving through walk-through metal detector.
  - Experiment 2: Human gait will impact detection
- Data
  - We will be collecting our own data using standard test objects and multiple WTMDs
  - Possible locations
    - MetLife Stadium
    - Rutgers Stadium
    - Others(?)

Experiments

- Exp. 1
  - Hypothesis: Detection will change based on height of test object moving through walk-through metal detector
  - Factors with varying levels
    - Test object
    - Orientation
    - Height
    - Security setting (1-3)

Experiments

- Exp. 2
  - Hypothesis: Human gait will impact detection.
  - Focus on below knee height

NIJ (1999)

Analysis of Results

- Identifying trends
- Rule out statistically significant differences between WTMDs (do not want to focus on individual machines)
- Look for statistically significant results for orientation and height
- Examine detection accuracy by height using a linear fit
- Do similar analysis examining human gait

Conclusion

- Research topics
  - Principles of operation of WTMDs
  - WTMD standards
  - Others
- Starting with 2 sets of experiments
  - Height and orientation
  - Human gait impact
  - Others may arise

Conclusion

- Other experiments that may be performed
  - Multiple test objects in a single experimental trial
  - Range of field of detection and the impact of adjacent WTMDs
  - Impact of speed passing through WTMD
  - Stationary vs. moving (below knee focus)
  - Others?

Thank You