Combinatorial Coverage and Distance Measurements of Test Sets

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Key Facts

Use Cases
- Measure coverage of existing test sets.
- Verify coverage of constructed Covering Arrays.
- Qualitative comparison of test sets with identical coverage with additional distribution and distance analysis.

Architecture
- Rust implementation:
  - Native Executable (Linux, Windows, macOS)
  - WebAssembly
- Modular input parsing.
- Machine- or human-readable output.

Implementation Highlights of CAmetrics
- Significantly fast based on experiments:
  - Multi-threaded
  - Multiple algorithms
- Low memory usage.
- Web UI and command line interface.
- Sophisticated constraint support.

Future improvements
- HPC and cluster implementations.
- Faster constraint processing.

Select between Two Algorithms

Input: \( N \times k \) array, alphabet size \( v \), strength \( t \)

- cametrics-fast
  - Great general-purpose performance
  - \( O(\frac{k}{t}(v^{t})^3) \) memory
  - \( O(\frac{k}{t}(v^{t})^3) \) time

- cametrics-light
  - Prevents memory explosion, great for binary/small arrays
  - \( O(\frac{k}{t}v^t) \) memory
  - \( O(\frac{k}{t}v^t) \) time

Coverage

- Simple \( t \)-way combination coverage: How many \( t \)-selections of parameters are fully covered?
- Simple \( (t+1) \)-way coverage: \( t \)-tuple

![Figure 2: Simple \( t \)-way combination and tuple coverage](image)

Distance Metrics

Inter-test distance: baseline for success
- (Generalized) Hamming Distance: How many parameter values differ between tests?
- Total Cartesian/Euclidean Distance of test \( t \) to array \( A \):
  \[
  \text{CD}(A, T) = \sum_{i=1}^{k} \sum_{j=1}^{v} (A_{ij} - T_{ij})^2
  \]

Balance is everything!
- Balanced array: Each parameter value (or \( t \)-tuple) appears roughly the same number of times.

Modified \( \chi^2 \) Distance:
- How close to ideal distribution of parameter values?
  - Ideal distribution: \( p_i = \frac{1}{v} \)
  - Actual distribution: \( p_i = \frac{1}{v} \)
  - Modified \( \chi^2 \) Distance:
    \[
    \chi^2 = \sum_{i=1}^{v} \frac{(f_i - e_i)^2}{e_i}
    \]

Expand the text with more details on the mathematical expressions and diagrams.