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Correlation Using Pair-wise Combinations of Multiple Data Sources and Dimensions at Ultra-Large Scales

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Technical Focus

- Current analysis relies heavily on SME knowledge
- Need for automated discovery of non-biased pattern and relationship detectors
- Need for large scale data analytics
  - Traditional single machine data warehousing solutions struggle with scale
  - Data locality requirements cause parallelization challenges
  - Approach to multidimensional database (MDD) implementation in the cloud
  - Using data denormalization techniques to construct planes of enrichment in a distributed environment
- Ability to apply basic analytic techniques at massive scale
  - Supporting massive combinatorialanalysis (ranging into the trillions of comparisons)
  - Assorted distance matrix calculations of feature vectors
  - Covariance / Correlation / Adjacency matrix calculations

Hypercube Introduction

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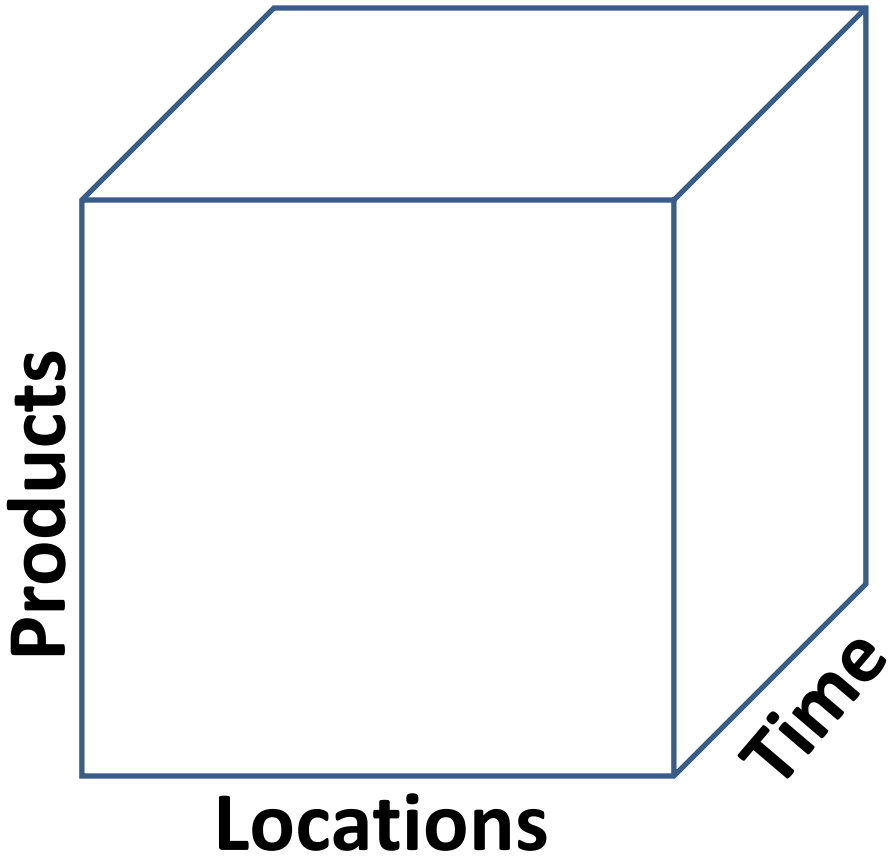
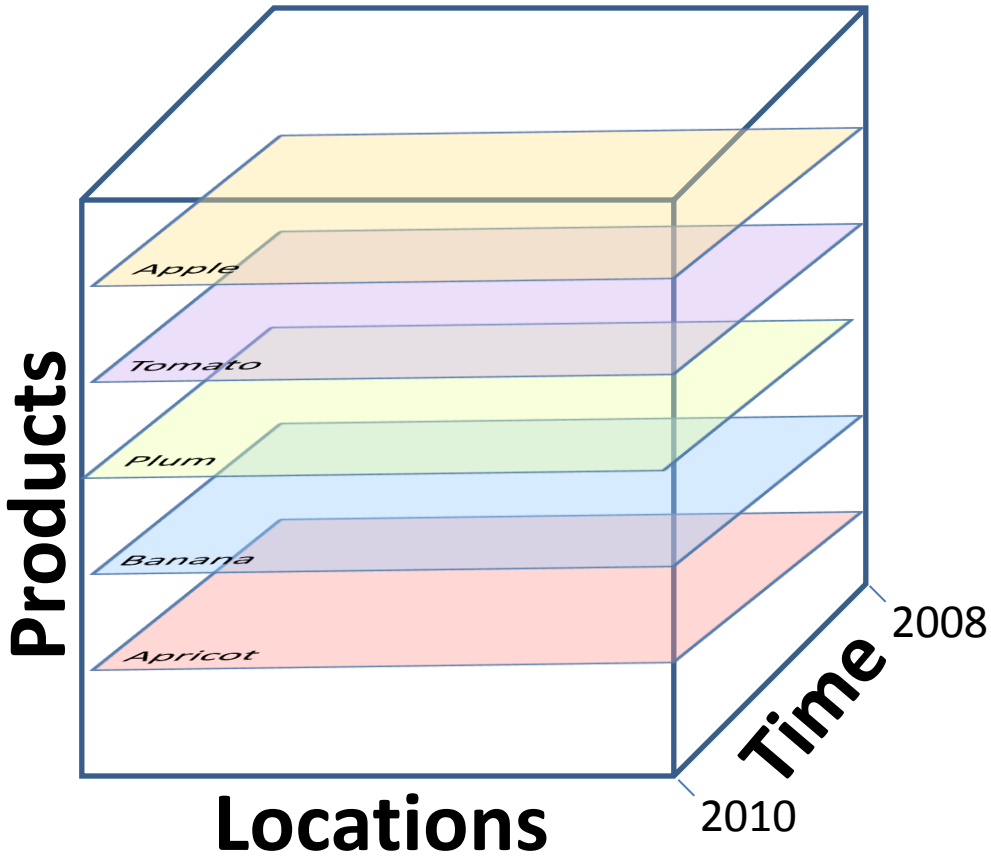
3-D Hypercube

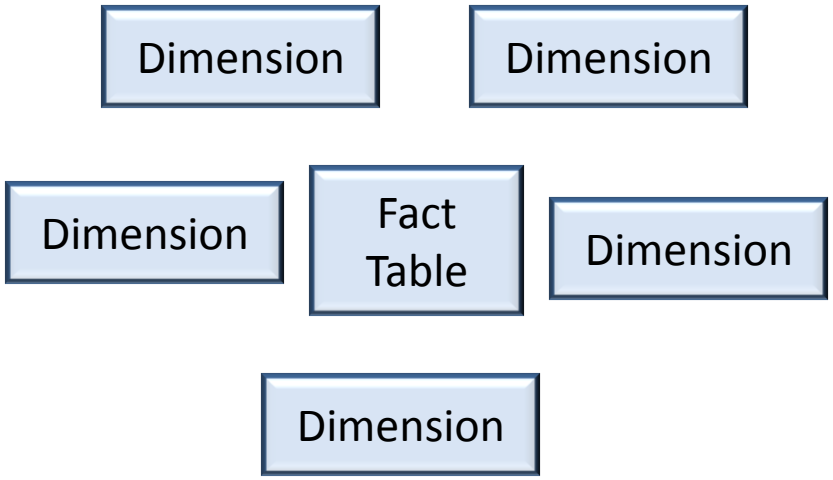


Looking at product layers



MDD Implementations

Example: Star Schema



Example: *1 row of data representing 3 Dimensions "sliced" 9 different ways*

John D	Kabul	2010
John D	2010	Kabul
Kabul	John D	2010
Kabul	2010	John D
2010	Kabul	John D
2010	John D	Kabul

ROLAP — **HOLAP** — **MOLAP**

Normalized
Dynamically Calculated (run time)
Efficient Storage

De-normalized
Extremely Performant
Enormous Storage
Specialized Indexes

Hypercube Rollups

- Examples of aggregate rollups
  - Suppose a timestamp of 12:21:06 on January 6, 2011
    - Rollup to Minute / Hour / Day / Month / Week / Day of Week
  - Suppose a latitude / longitude coordinate
    - Rollup to City / District / County / Province / Country
- Aggregation and subsequent serialization greatly expedites derivative analytics – IE: detecting patterns based on day of week on a per province basis. Reduces data footprint for subsequent analytics by orders of magnitude.

Planes of Enrichment

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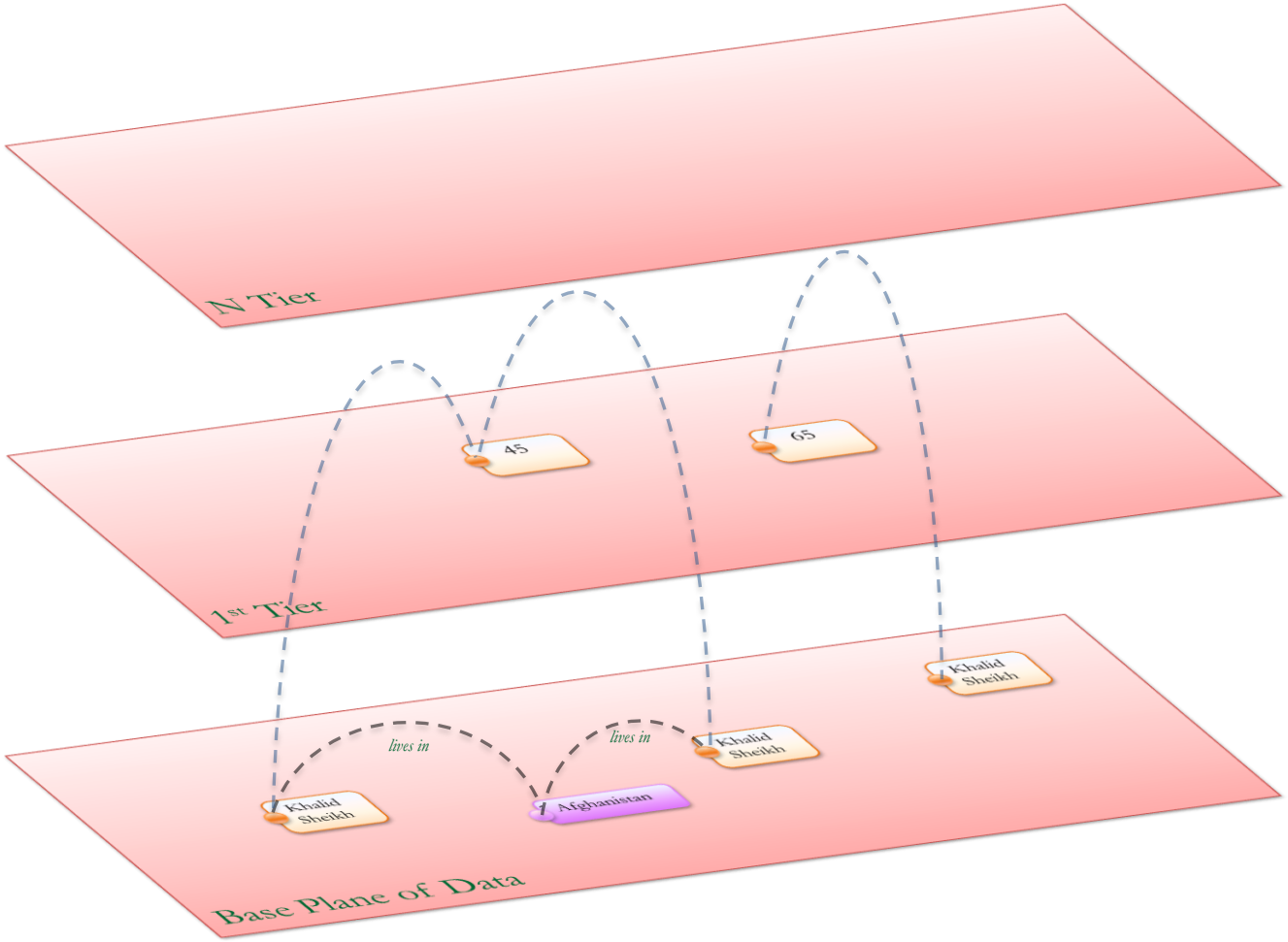
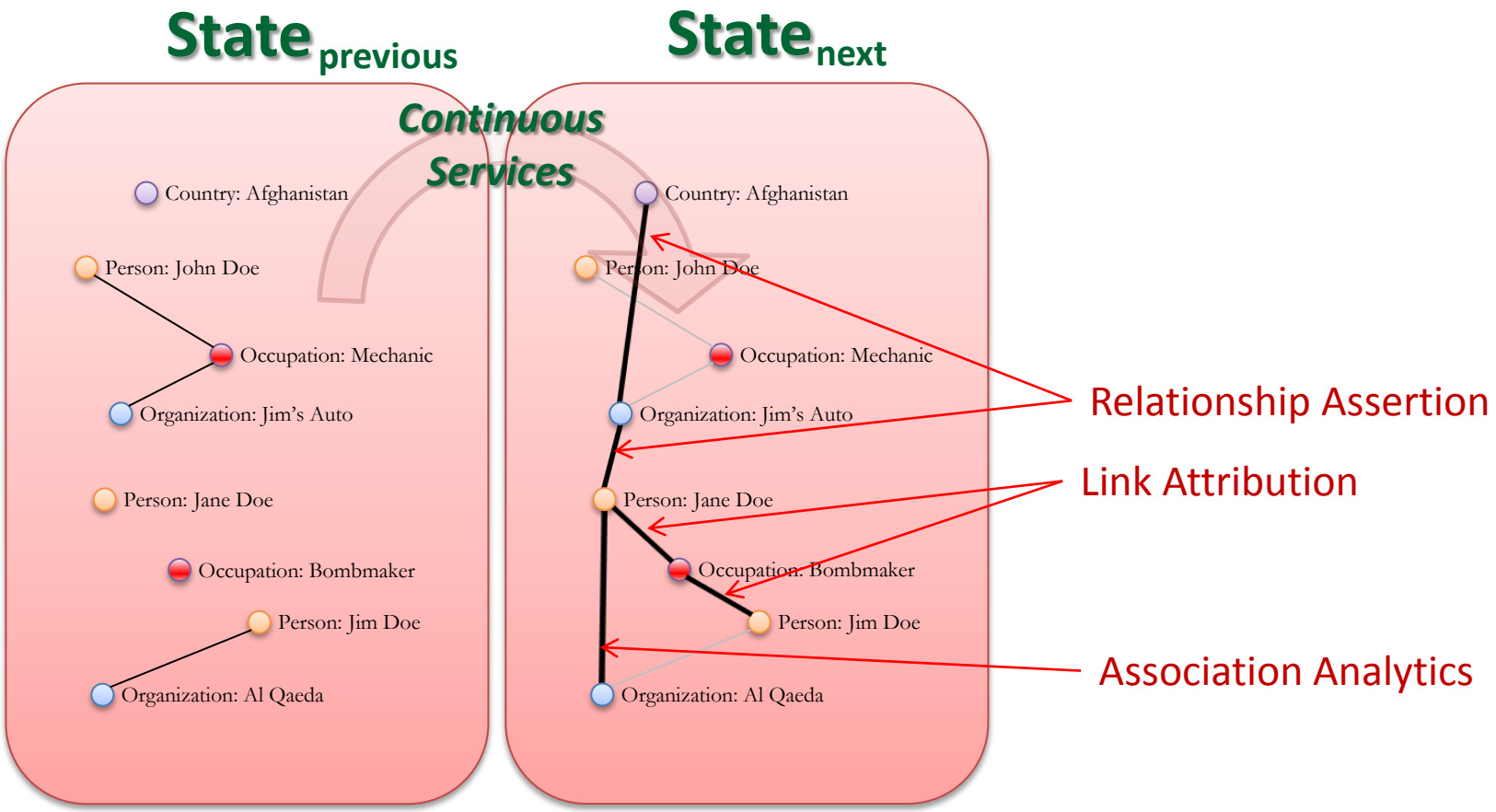


Planes of Enrichment - Continuous Enrichment

There is no steady state to the system. Each enrichment triggers additional enrichment.



Large Data Analytic Framework

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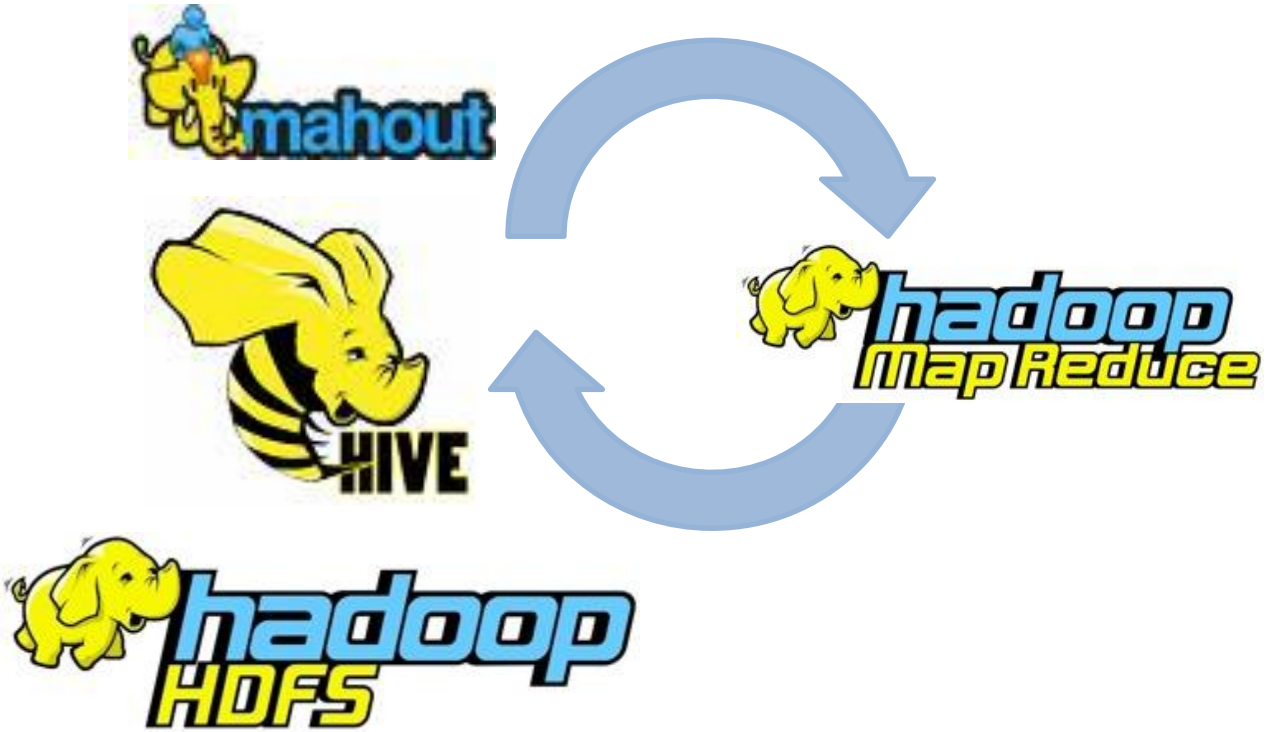
Distributing analytic processing across a cloud of machines using open source technologies

Complex parallelized AI capabilities

Schema information and parallelization of transformations

Raw data and MDD planes of enrichment



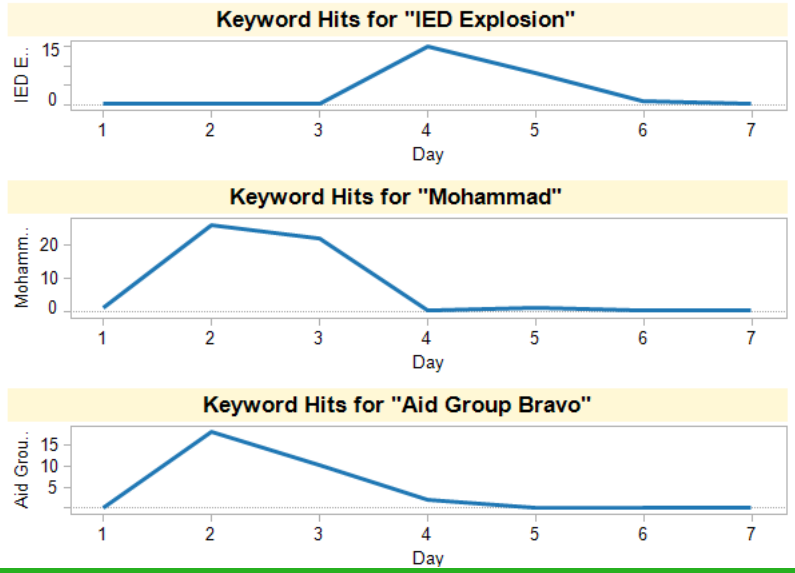
Correlation Analytics

Example correlation scenario:

Alert keyword hit frequency

	Aid Group Bravo	IED Explosion	Mohammad
1	0	0	1
2	18	0	26
3	10	0	22
4	2	15	0
5	0	8	1
6	0	1	0
7	0	0	0

Trend Lines for keyword hits



Pairwise correlation matrix for keyword hit trends

-Correlations > .9 in **bold**

	Aid Group	IED Explosion	Mohammad
Aid Group	**1**	-0.29214	**0.964963**
IED Explosion	-0.29214	**1**	-0.3997
Mohammad	**0.964963**	-0.3997	**1**

Pairwise correlation matrix for keyword hit trends with 2 day lag on y-axis

-Correlations > .9 in **bold**

	Aid Group	IED Explosion	Mohammad
Aid Group	-0.09762	-0.31254	-0.09152
IED Explosion	**0.999007**	-0.32393	**0.965013**
Mohammad	-0.25296	-0.27041	-0.20954

Pairwise Combinatorial Analysis

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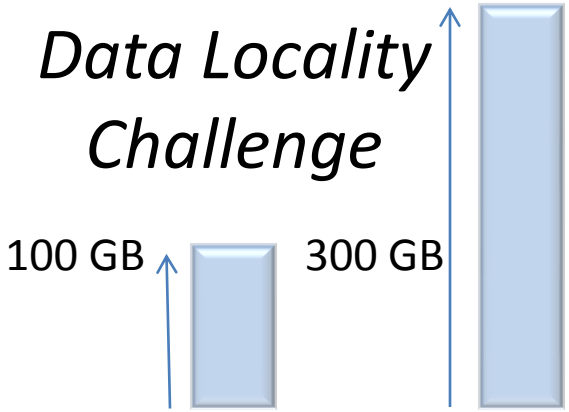
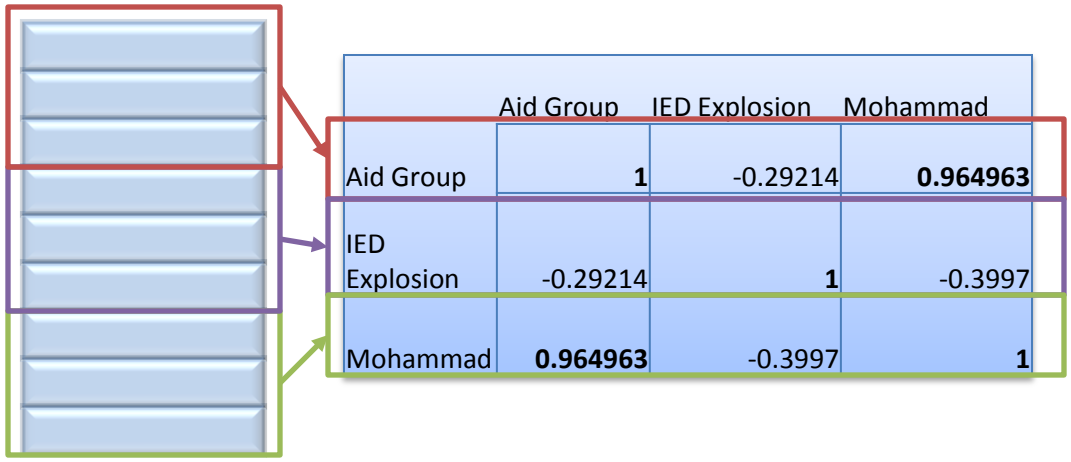
- Combinations build out at ((N^2) – N)/2 pairwise comparisons where N is the number of feature vectors being analyzed.
- For lag window calculations, L*(N^2) pairwise comparisons are needed where N is the number of feature vectors being analyzed and L is the number of lag windows being tested.
- Comparisons ideally require data locality of all data in the same location. Thus, if this exceeds a single machine's RAM specifications, efficient calculation becomes very difficult.
- We have successfully test this technique in a distributed system into the order of trillions of vector value comparisons.

Data Locality Challenge



Memory capacity of single machine

Memory required to calculate correlation matrix



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Sharding off calculations of correlation matrix

Next Steps

- Investigation into real time processing - Brisk (Cassandra based HDFS)
- Better use of estimation / approximation algorithms (IE: covariance metric estimation)
- Further leveraging cloud based AI packages (IE: Mahout)

Questions?