SRC Project 879
Progress Report
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Task 879.1: Intelligent Demand Aggregation and Forecasting

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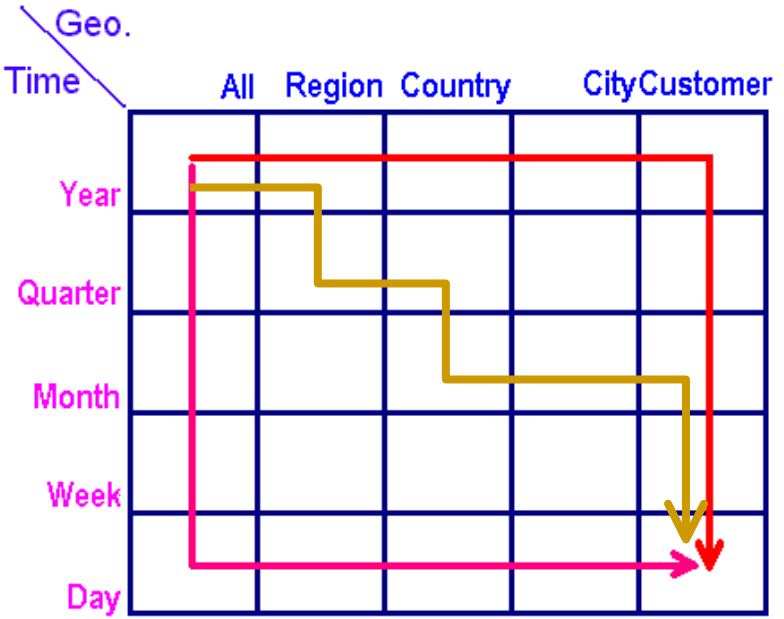
Outline

- ✓ Prior work: Demand Planning Hierarchy (DPH)
- Product Hierarchy
- DPH Extension for Product Hierarchy
- DPH Analysis System Prototype
- Feature Works

Problem Description

- Strategies for Demand Planning:
  - Top-down approach
  - Bottom-up approach
  - Middle-out approach
- Problems:
  - What dimension should be considered to aggregate/disaggregate first?
  - What's the difference?
- Objectives:
  - Define Demand Planning Views
  - Develop an optimal strategy for Demand Planning: Demand Planning Hierarchy (DPH)

Demand Planning Hierarchy (DPH)



Example:

- Two demands views: Time and Geography
- Strategy: Top-down

- Path 1: break down along Geography View first, then along Time View

- Path 2: break down along Time View first, then along Geography View

- Path 3: ……

Demand Planning Hierarchy: Sequence of Aggregation Levels

Representation of Demand Views

- **View with Hierarchical Levels: e.g. time horizon (necessary), geography view, etc..**

  Notation: $\text{VIEW}_{\text{level1} \cdot \text{level2}}$

  Example: $\text{TIME}_{\text{Year} \cdot \text{Quarter} \cdot \text{Month} \cdot \text{Week}}$

  $\text{GEOGRAPHY}_{\text{Continent} \cdot \text{Country} \cdot \text{City}}$

- **View with Attributes: e.g. product type**

  Notation: $\text{VIEW}_{\text{attribute} \times \text{attribute}}$

  Example: $\text{PRODUCT}_{\text{Generation} \times \text{Function} \times \text{Technology}}$

- **View with Mixed Attributes**

  Example: $\text{PRODUCT}_{(\text{Generation} \times \text{Function} \times \text{Technology}) \cdot \text{PartNumber}}$

DPH Evaluation Metric: Actual Demand Fluctuation

- Coefficient of Variation (CV):

$$\text{CV} = \frac{\textit{Std.Dev} \text{ of demand } (\sigma)}{\textit{Mean} \text{ of demand } (\mu)} = \text{degree of fluctuation}$$

- Weighted Average CV: by demand volume

$$\frac{\mu_1}{\sum_{i=1}^{n}\mu_i}\cdot CV_1 + \frac{\mu_2}{\sum_{i=1}^{n}\mu_i}\cdot CV_2 + \cdots + \frac{\mu_n}{\sum_{i=1}^{n}\mu_i}\cdot CV_n$$

Weighted-average CV values at all levels are averaged to represent the demand stability of a DPH

Case Study

- Demand Views
  - Product: ASIC
  - Views with Hierarchical Levels:

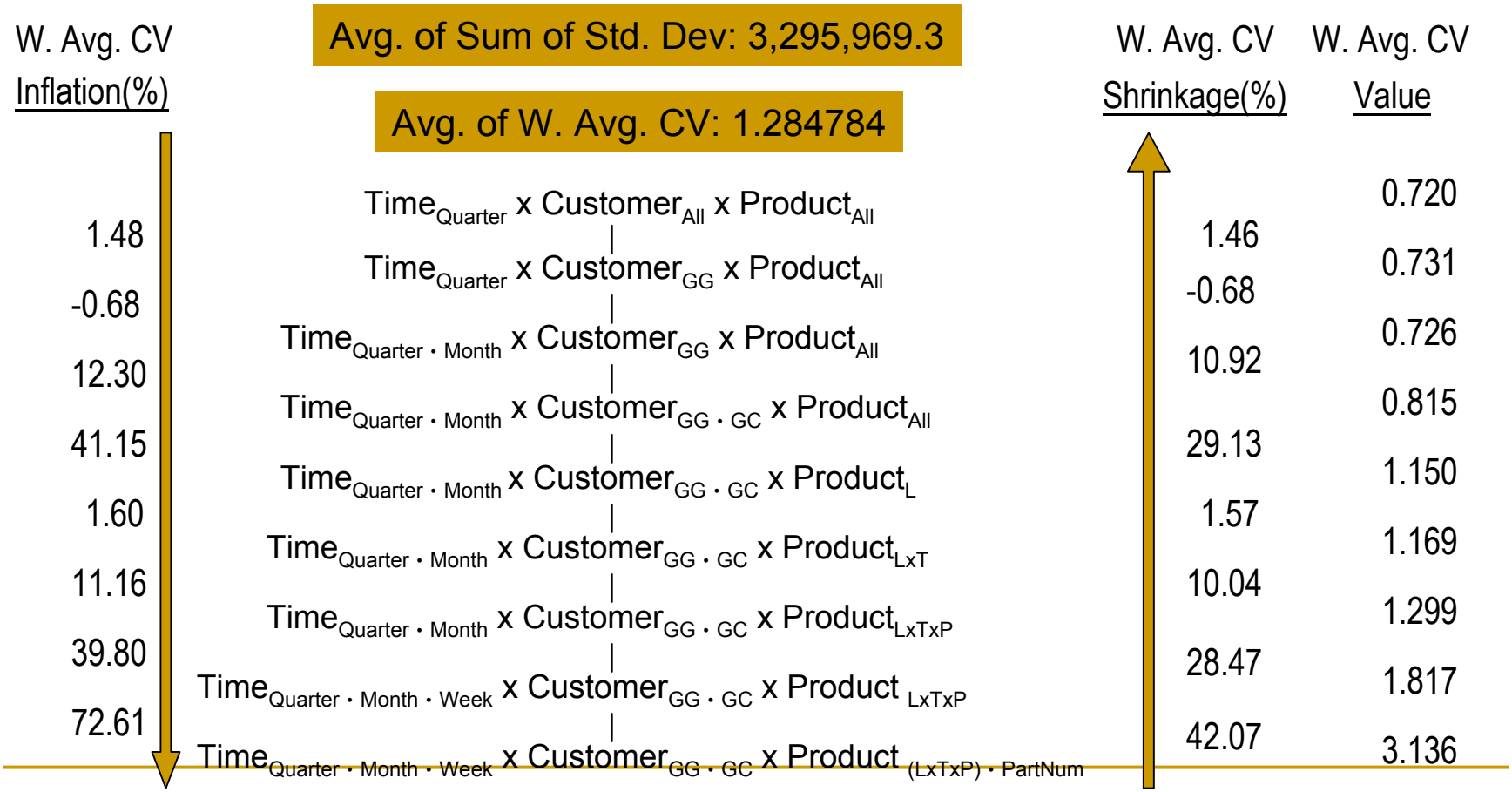
    Time: Quarter, Month, Week

    Customer: Geocorp Geography (GG), Geocorp Code (GC)
  - View with Mixed Attributes:

    Product: Technology (T), Number of Metal Layers(L), Package (P); PartNum is hierarchical to the combination of T, L, P

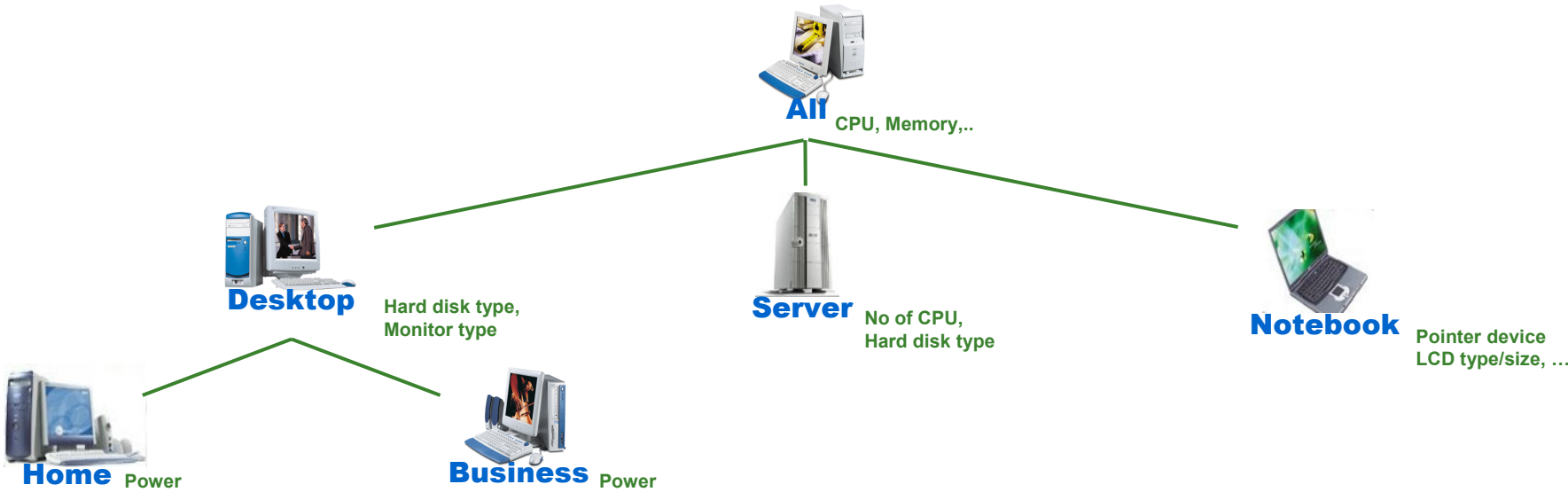
Least-Fluctuation DPH

- Dynamic programming search:



DPH Extension - Motivation

- Prior work: DPH for only one product type
- DPH for an entire product hierarchy?
  - A product hierarchy example



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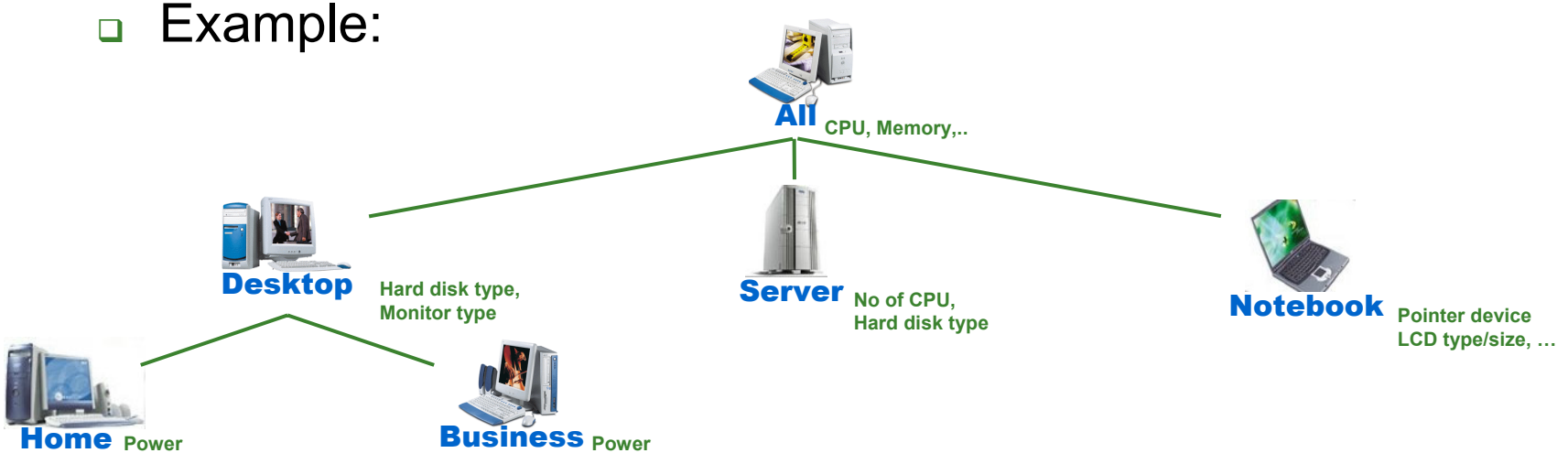
Product Hierarchy

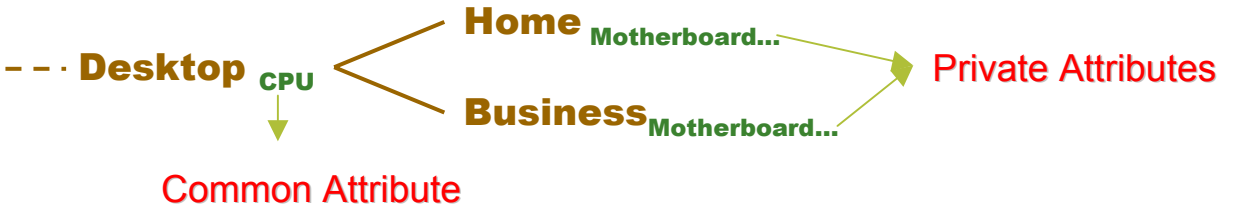
- Product Differentiation
  - Base on the substitutive and/or heterogeneous properties of different products, we can classify and arrange all products into a product hierarchy
- Product Hierarchy
  - Hierarchical product differentiation
  - Example:



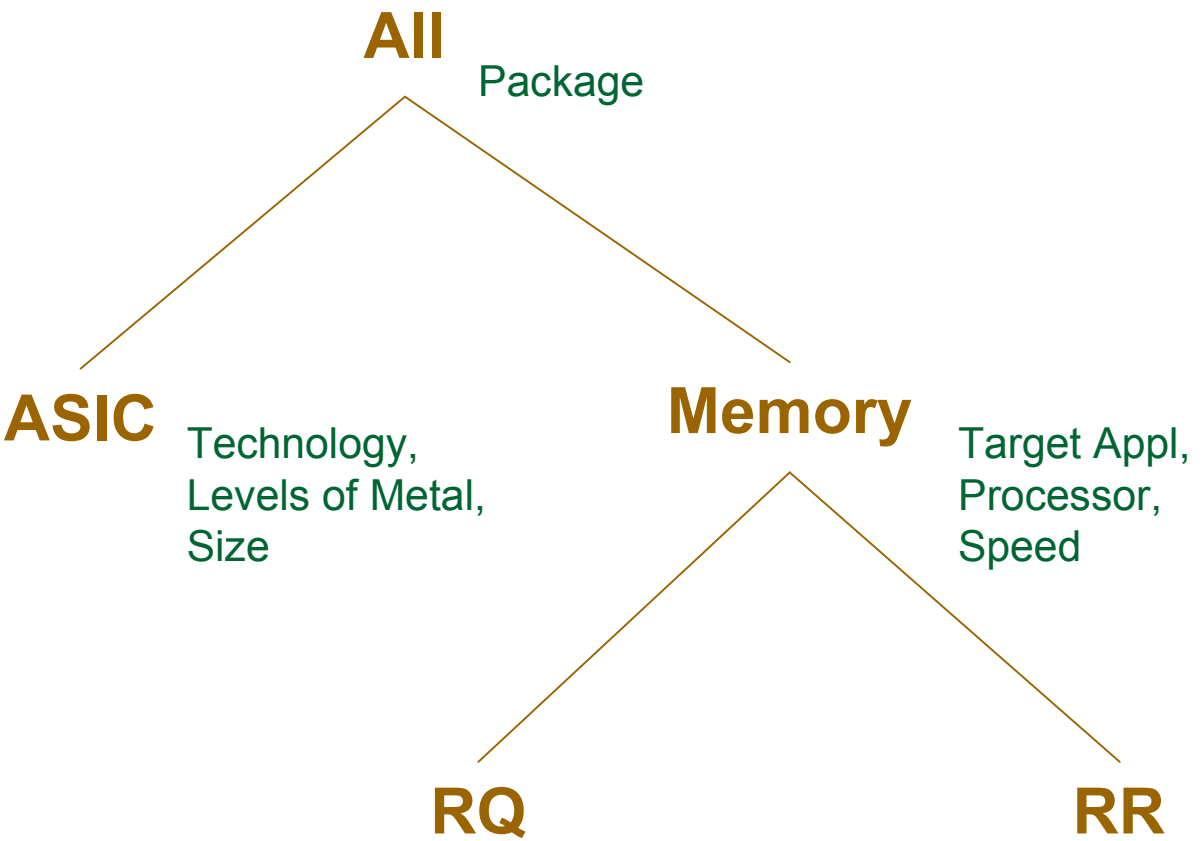
Common Attributes in Product Hierarchy

- Common Attributes
  - It is possible for different nodes have the same product attributes

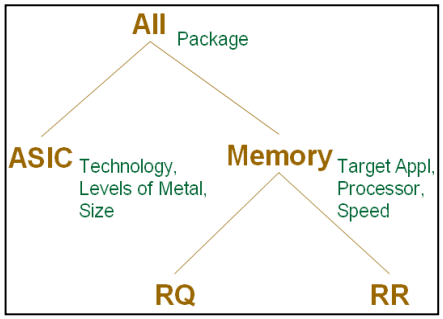
  - We may like to raise some of the attribute to a higher planning level that called common attribute



A Semiconductor Example



A DPH Solution



$Product_{All} \times Time_{Year} \times Customer_{All}$

$Product_{All} \times Time_{Year} \times Customer_{GG}$

$Product_{ASIC} \times Time_{Year} \times Customer_{GG}$

$Product_{Memory} \times Time_{Year} \times Customer_{GG}$

$Product_{ASIC} \times Time_{Year} \times Customer_{GG \cdot GC}$

$Product_{Memory} \times Time_{Year} \times Customer_{GG \cdot GC}$

$Product_{ASIC(Package)} \times Time_{Year} \times Customer_{GG \cdot GC}$

$Product_{Memory(Package)} \times Time_{Year} \times Customer_{GG \cdot GC}$

$roduct_{ASIC(Package,\ Levls\ of\ Metal)} \times Time_{Year} \times Customer_{GG \cdot GC}$

$Product_{Memory(Package,\ Target\ Appl)} \times Time_{Year} \times Customer_{GG \cdot GC}$

$oduct_{ASIC(Package,\ Levls\ of\ Metal,\ Technology)} \times Time_{Year} \times Customer_{GG \cdot GC}$

$Product_{RR(Package,\ Target\ Appl)} \times Time_{Year} \times Customer_{GG \cdot GC}$

$Product_{RQ(Package,\ Target\ Appl)} \times Time_{Year} \times Customer_{GG \cdot G}$

$duct_{ASIC(Package,\ Levls\ of\ Metal,\ Technology,\ Size)} \times Time_{Year} \times Customer_{GG \cdot GC}$

$Product_{RR(Package,\ Target\ Appl,\ Processor)} \times Time_{Year} \times Customer_{GG \cdot GC}$

$Product_{RQ(Package,\ Target\ Appl,\ Processor)} \times Time_{Year} \times Customer_{G}$

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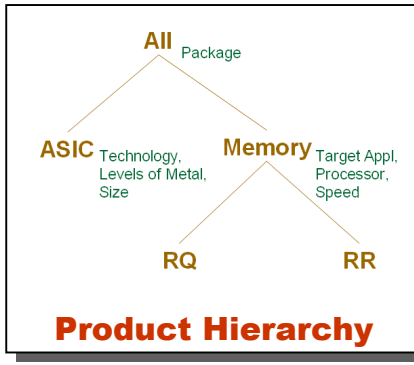
Balanced DPH – Example



$Product_{All}$

$Product_{All(Package)}$

$Product_{ASIC(Package)}$ $Product_{Memory(Package)}$

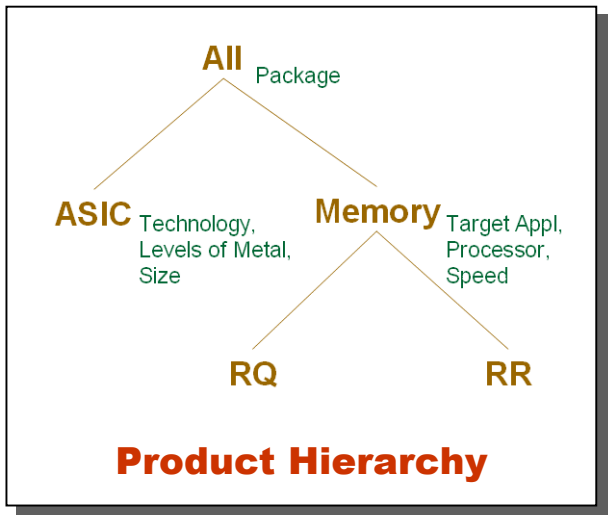
$Product_{ASIC(Package, Size)}$ $Product_{Memory(Package, Speed)}$

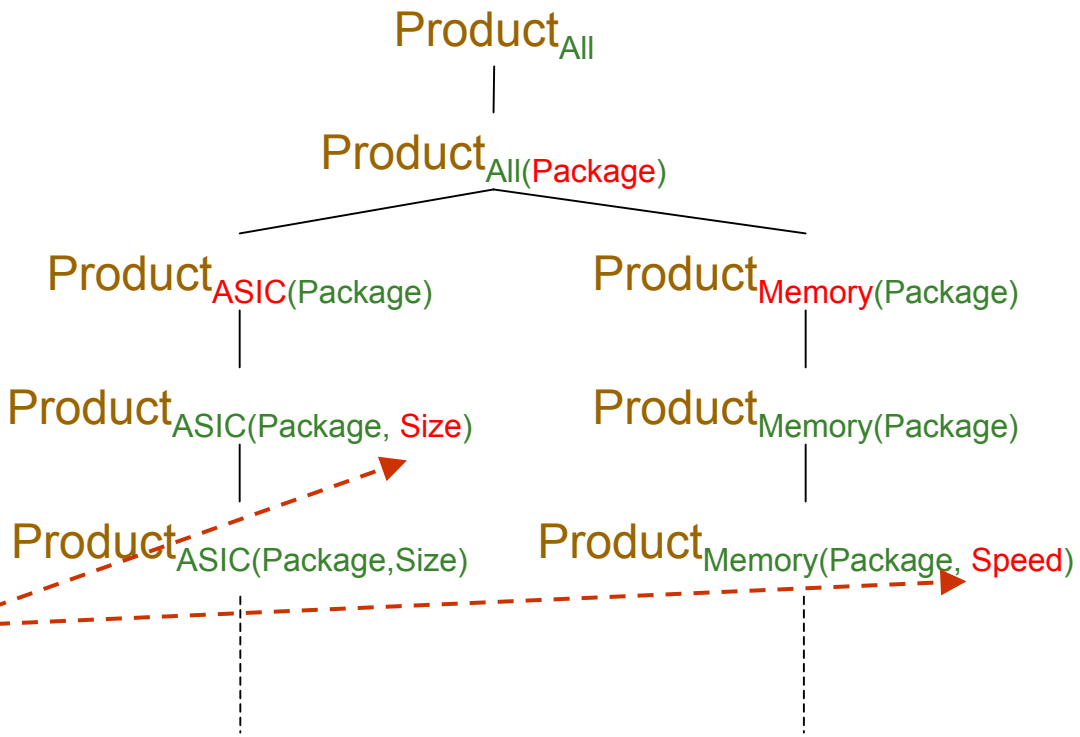
$Product_{ASIC(Package, Size, Technology)}$ $Product_{RR(Package, Speed)}$ $Product_{RQ(Package, Speed)}$

For every branches, disaggregate by one of the attributes or one of the middle nodes

Unbalanced DPH – Example

- We focus on product dimension only

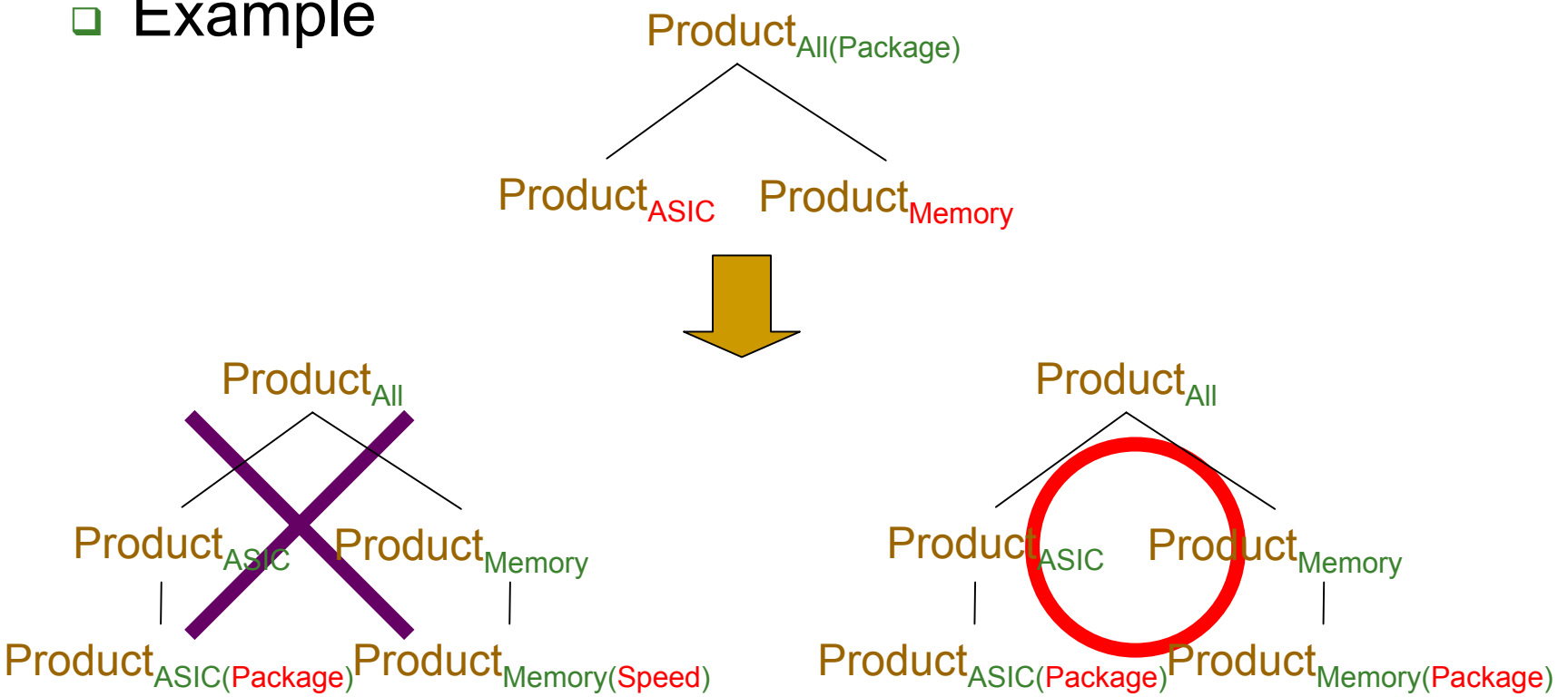




Disaggregate by one of the middle nodes or one of the attributes at one step

Optional Planning Constrains

- There are optional constrains that can be set to prevent irrational hierarchical relations
  - Example



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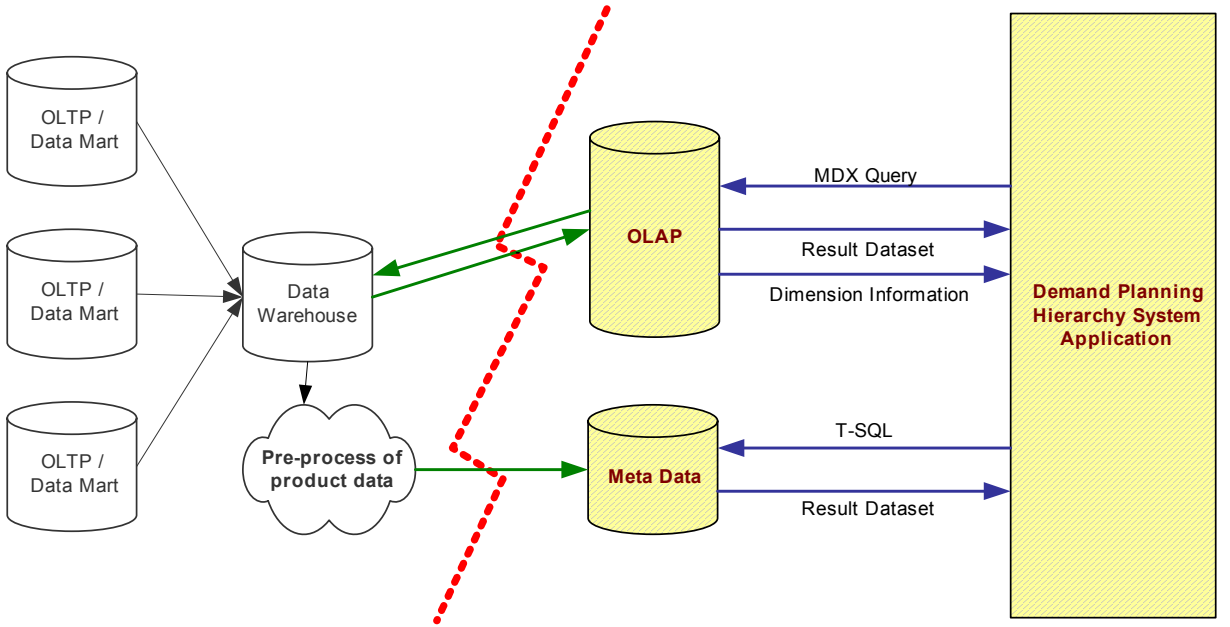
System Architecture

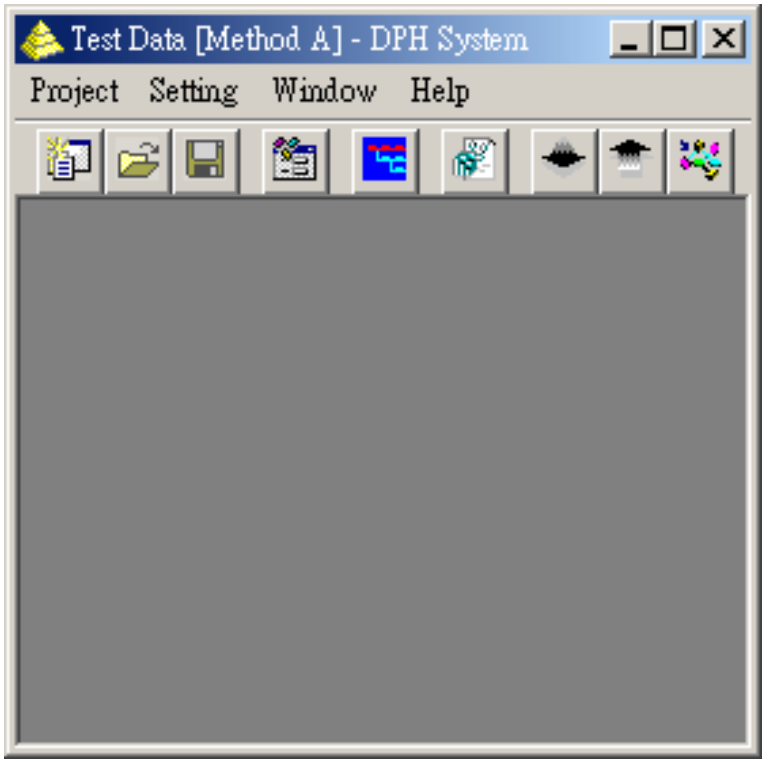


DPH System – System Architecture

- DPH system, OLAP database, metadata database can be located in one system or separated systems
- Platform: .NET; Language: C#

DPH System Preview

- Planning Flow
  - Create a New Project
    - New Project Wizard
  - Allocate Dimensions
  - Solve DPH Network
    - Top-down Greedy Search
    - Button-up Greedy Search
    - Dynamic Programming Search



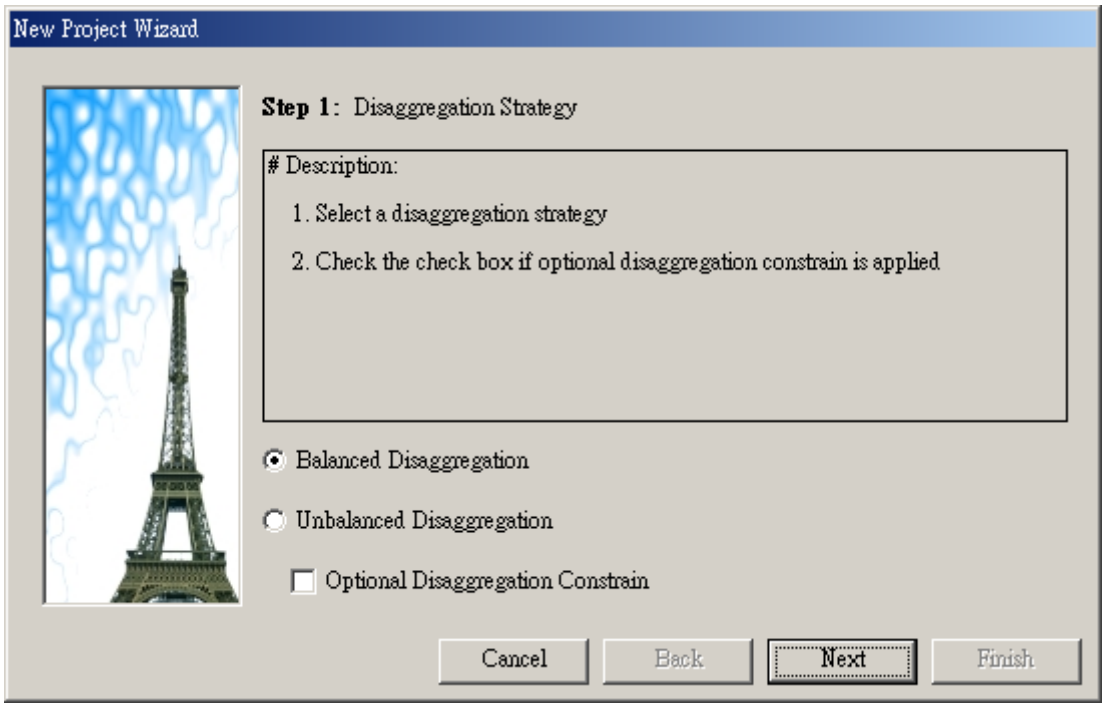
DPH System – User Interface

DPH System Demo

- New Project Wizard
- Dimension Allocation
- Solve DPH Network

New Project Wizard

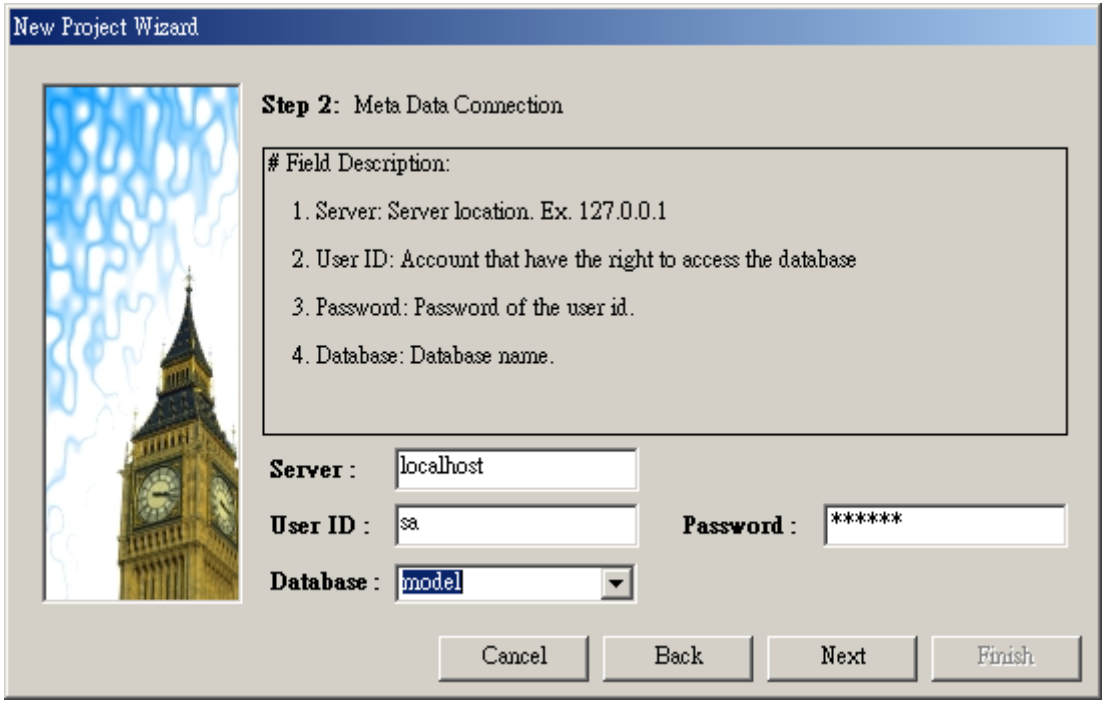
Step 1 of 5:



DPH System – New Project Wizard

New Project Wizard (cont.)

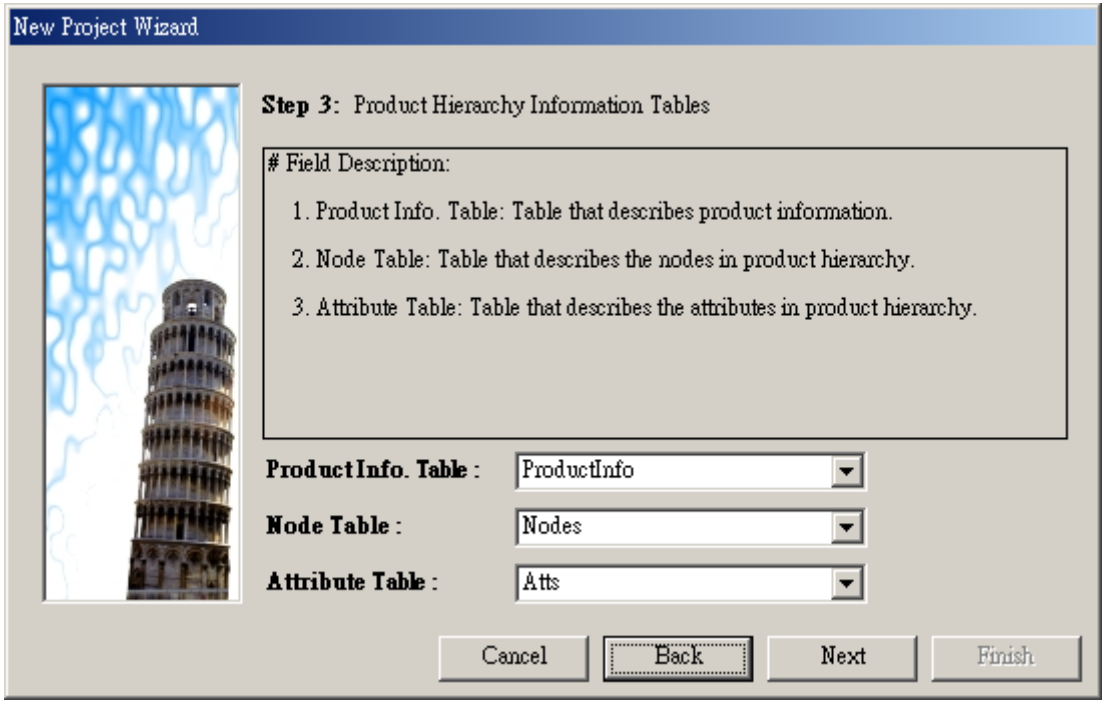
Step 2 of 5:



DPH System – New Project Wizard

New Project Wizard (cont.)

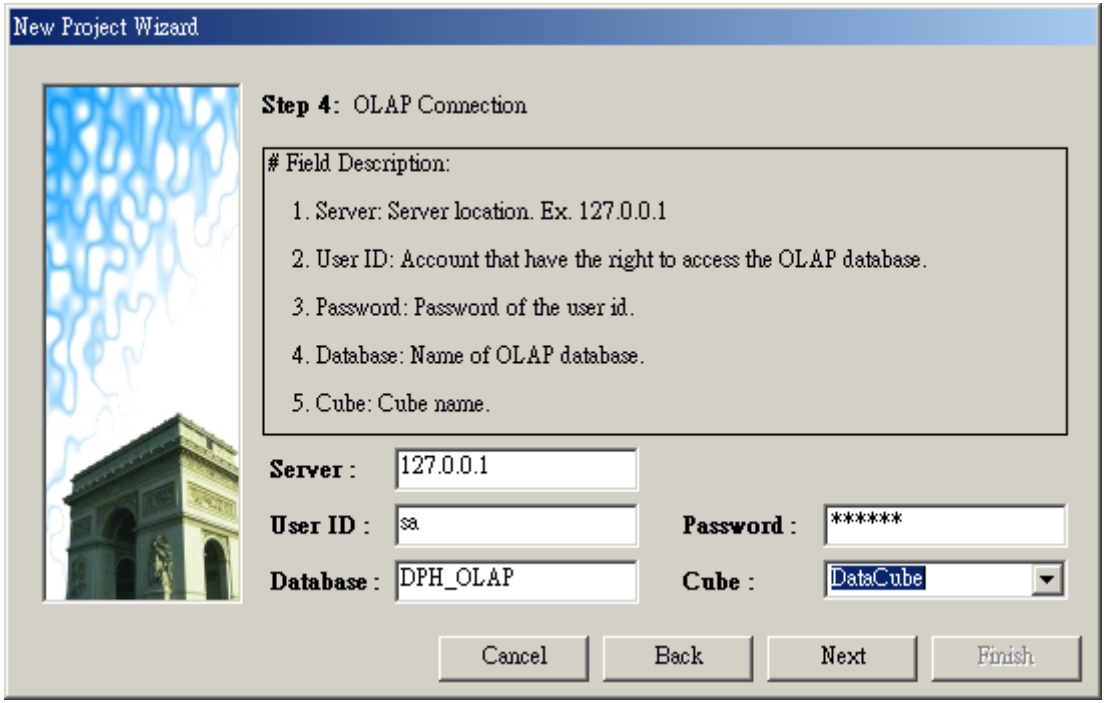
Step 3 of 5:



DPH System – New Project Wizard

New Project Wizard (cont.)

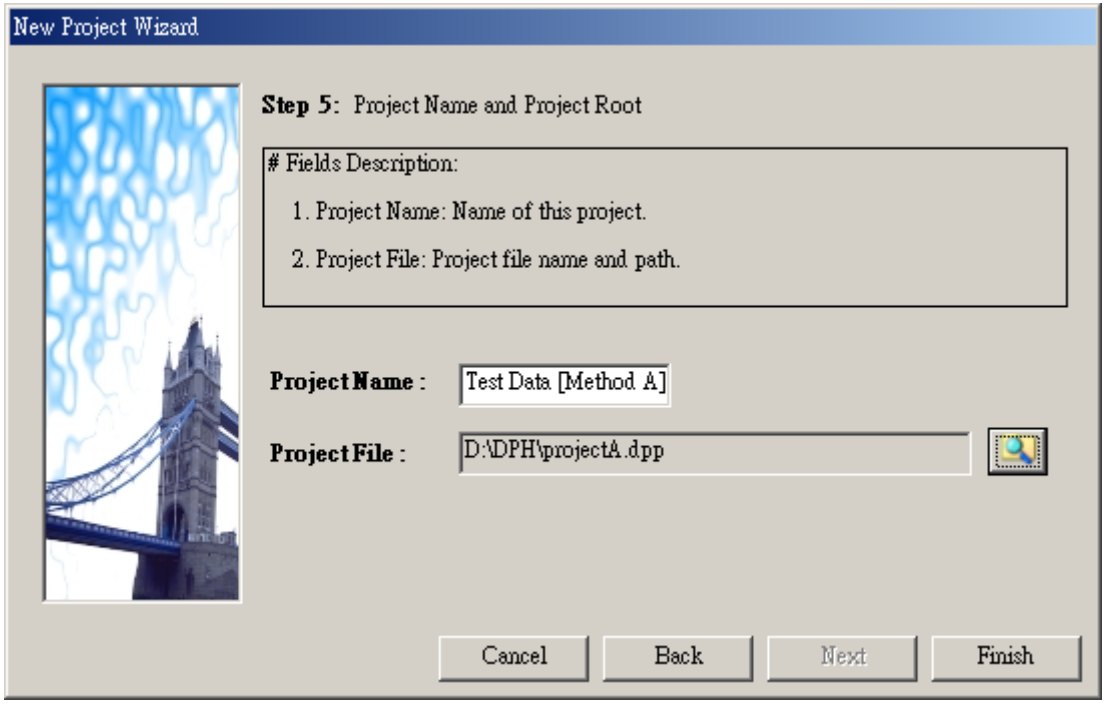
Step 4 of 5:



DPH System – New Project Wizard

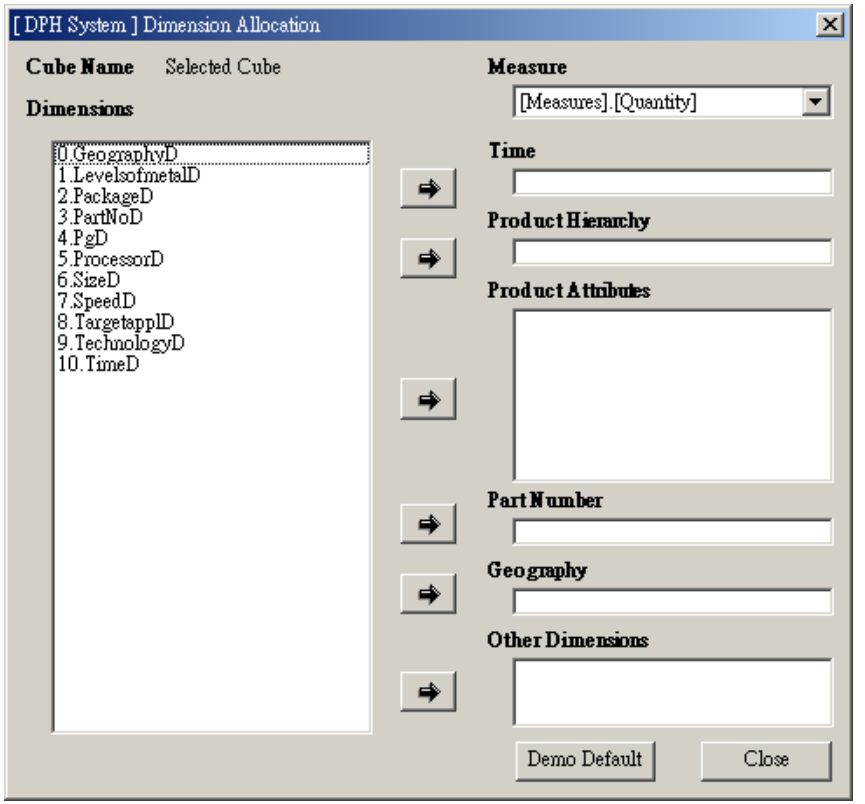
New Project Wizard (cont.)

Step 5 of 5:



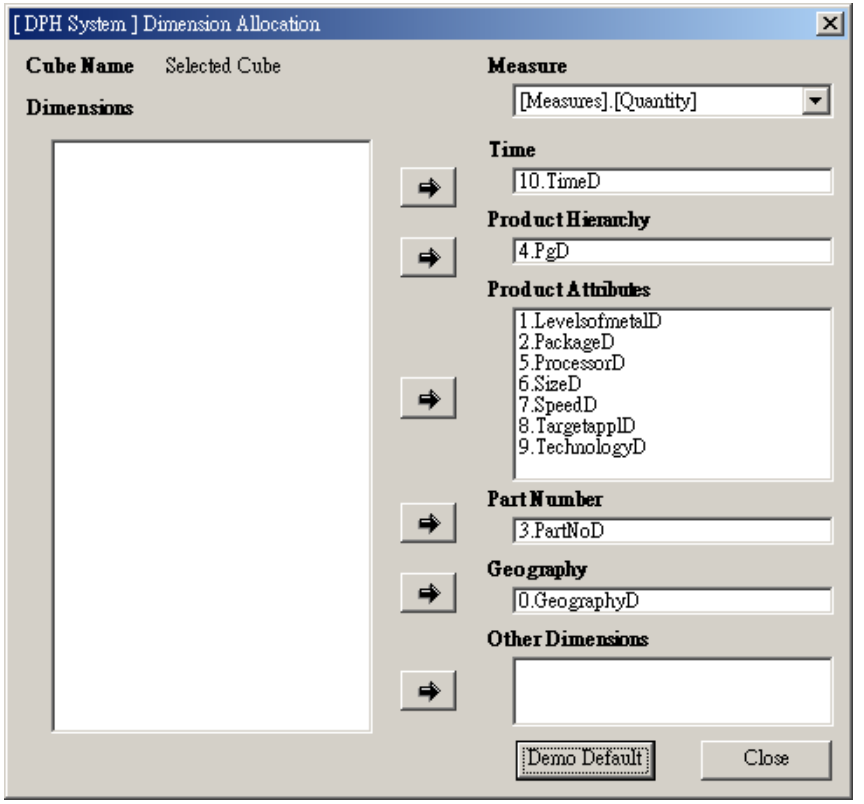
Dimension Allocation

Step 1 of 2:



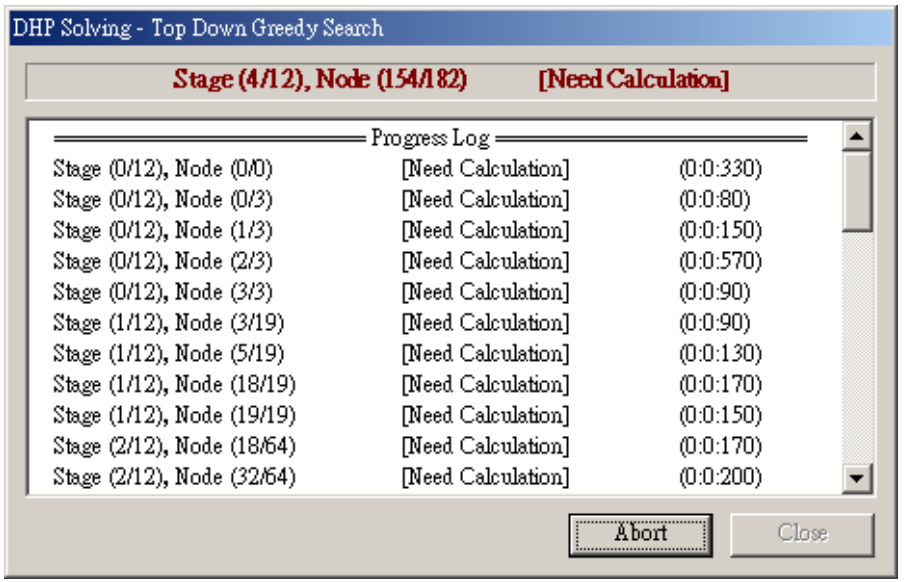
Dimension Allocation (cont.)

Step 2 of 2:



Solve DPH Network

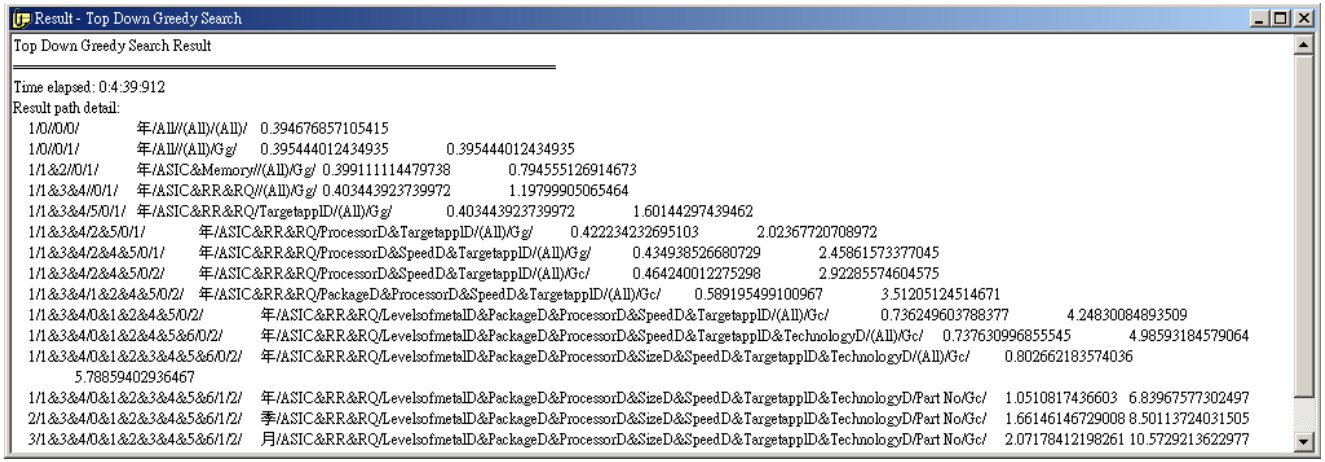
UI 1 of 2:



DPH System – Top-Down Search: Calculation

Solve DPH Network (cont.)

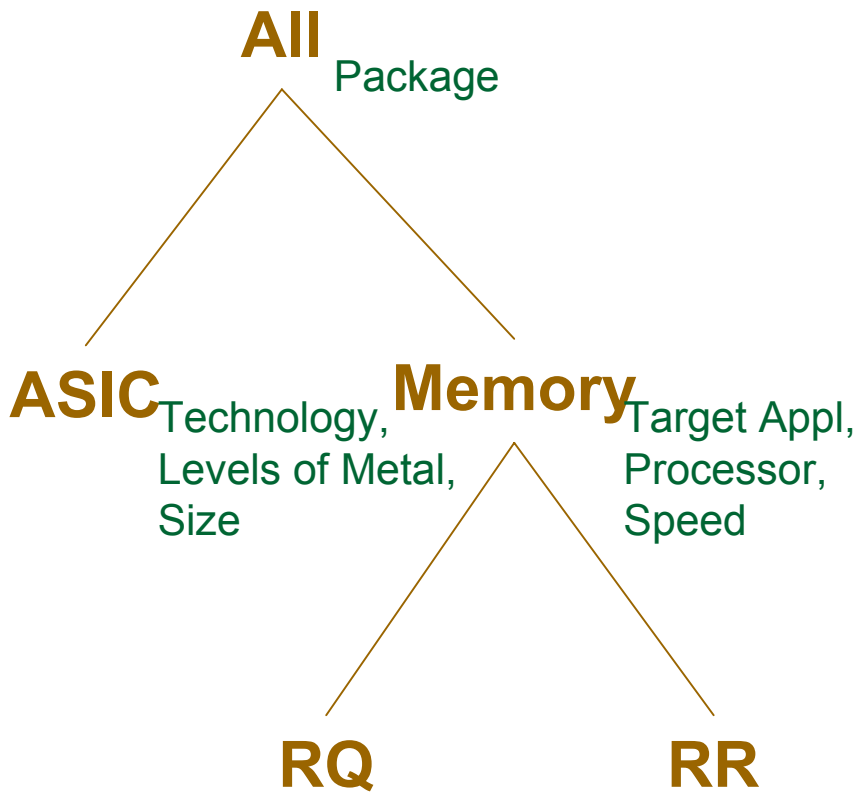
UI 2 of 2:



DPH System – Top-Down Search: Result

Case Study

- Dimension Considered:
  - Product
  - Time
  - Customer / Geography
- Product Dimension
  - Total number of attributes*1: 8
    - Prior case: 4
  - Possible attribute combination: 1,126,182,528
    - One-product case: 325,863



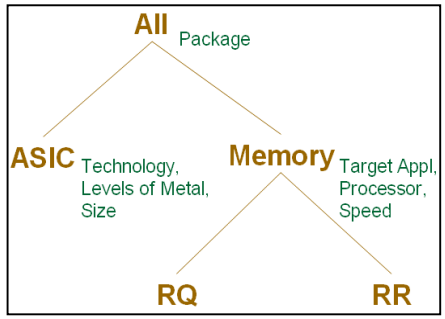
Case Study – Product Hierarchy

*1. Part Number is also considered

Case Study – Performance

- System Architecture: stand along
  - CPU: Pentium 4-m, 1.4G
  - Memory: 512MB
- Planning Strategy: Balanced DPH
- Solving Time Cost (H:M:S):
  - Weekly demand plan:
    - Top-down search: 0:3:19
    - Button-up search: 0:11:55
    - Dynamic programming search: 0:28:9
  - Daily demand plan:
    - Top-down search: 0:4:26
    - Button-up search: 1:15:50
    - Dynamic programming search: 2:22:22

Case Study – DP Search



$Product_{All} \times Time_{Year} \times Customer_{All}$

$Product_{All} \times Time_{Year} \times Customer_{GG}$

Left Sub-Tree

Right Sub-Tree

$Product_{ASIC} \times Time_{Year} \times Customer_{GG}$

$Product_{ASIC} \times Time_{Year} \times Customer_{GG \cdot GC}$

$Product_{ASIC(Package)} \times Time_{Year} \times Customer_{GG \cdot GC}$

$roduct_{ASIC(Package,\ Levls\ of\ Metal)} \times Time_{Year} \times Customer_{GG \cdot GC}$

$oduct_{ASIC(Package,\ Levls\ of\ Metal,\ Technology)} \times Time_{Year} \times Customer_{GG \cdot GC}$

$luct_{ASIC(Package,\ Levls\ of\ Metal,\ Technology,\ Size)} \times Time_{Year} \times Customer_{GG \cdot GC}$

$Product_{Memory} \times Time_{Year} \times Customer_{GG}$

$Product_{Memory} \times Time_{Year} \times Customer_{GG \cdot GC}$

$Product_{Memory(Package)} \times Time_{Year} \times Customer_{GG \cdot GC}$

$Product_{Memory(Package,\ Target\ Appl)} \times Time_{Year} \times Customer_{GG \cdot GC}$

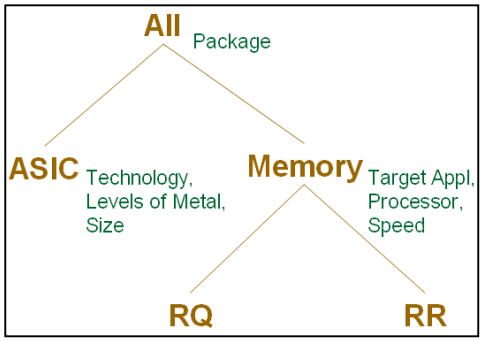
$Product_{RR(Package,\ Target\ Appl)} \times Time_{Year} \times Customer_{GG \cdot GC}$

$Product_{RR(Package,\ Target\ Appl,\ Processor)} \times Time_{Year} \times Customer_{GG \cdot GC}$

$Product_{RQ(Package,\ Target\ Appl)} \times Time_{Year} \times Customer_{GG \cdot G}$

$Product_{RQ(Package,\ Target\ Appl,\ Processor)} \times Time_{Year} \times Customer_{G}$

Case Study – DP Search (cont.)



- Left sub-tree

$$\text{Product}_{\text{ASIC(Package, Levls of Metal, Technology, Size)}} \times \text{Time}_{\text{Year}} \times \text{Customer}_{\text{GG} \cdot \text{GC}}$$

$$\text{Product}_{\text{ASIC(Package, Levls of Metal, Technology, Size)}} \times \text{Time}_{\text{Year}} \times \text{Customer}_{\text{GG} \cdot \text{GC}}$$

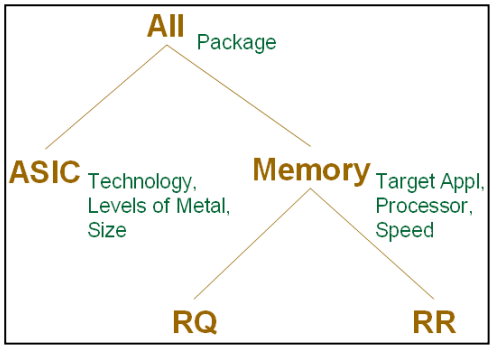
$$\text{Product}_{\text{ASIC((Package, Levls of Metal, Technology, Size)} \cdot \text{PartNo)}} \times \text{Time}_{\text{Year}} \times \text{Customer}_{\text{GG} \cdot \text{GC}}$$

$$\text{Product}_{\text{ASIC((Package, Levls of Metal, Technology, Size)} \cdot \text{PartNo)}} \times \text{Time}_{\text{Year} \cdot \text{Quarter}} \times \text{Customer}_{\text{GG} \cdot \text{GC}}$$

$$\text{Product}_{\text{ASIC((Package, Levls of Metal, Technology, Size)} \cdot \text{PartNo)}} \times \text{Time}_{\text{Year} \cdot \text{Quarter} \cdot \text{Month}} \times \text{Customer}_{\text{GG} \cdot \text{GC}}$$

$$\text{Product}_{\text{ASIC((Package, Levls of Metal, Technology, Size)} \cdot \text{PartNo)}} \times \text{Time}_{\text{Year} \cdot \text{Quarter} \cdot \text{Month} \cdot \text{Day}} \times \text{Customer}_{\text{GG} \cdot \text{GC}}$$

Case Study – DP Search (cont.)



- Right sub-tree

$Product_{Memory(Package,\ Target\ Appl)}$ x $Time_{Year}$ x $Customer_{GG \cdot GC}$

$Product_{RR(Package,\ Target\ Appl)}$ x $Time_{Year}$ x $Customer_{GG \cdot GC}$

$Product_{RR(Package,\ Target\ Appl,\ Processor)}$ x $Time_{Year}$ x $Customer_{GG \cdot GC}$

$Product_{RR(Package,\ Target\ Appl,\ Processor,\ Speed)}$ x $Time_{Year}$ x $Customer_{GG \cdot GC}$

$Product_{RR((Package,\ Target\ Appl,\ Processor,\ Speed) \cdot PartNo)}$ x $Time_{Year}$ x $Customer_{GG \cdot GC}$

$Product_{RR((Package,\ Target\ Appl,\ Processor,\ Speed) \cdot PartNo)}$ x $Time_{Year \cdot Quarter}$ x $Customer_{GG \cdot GC}$

$Product_{RR((Package,\ Target\ Appl,\ Processor,\ Speed) \cdot PartNo)}$ x $Time_{Year \cdot Quarter \cdot Month}$ x $Customer_{GG \cdot GC}$

$Product_{RR((Package,\ Target\ Appl,\ Processor,\ Speed) \cdot PartNo)}$ x $Time_{Year \cdot Quarter \cdot Month \cdot Day}$ x $Customer_{GG \cdot GC}$

$Product_{RQ(Package,\ Target\ Appl)}$ x $Time_{Year}$ x $Customer_{GG \cdot GC}$

$Product_{RQ(Package,\ Target\ Appl,\ Processor)}$ x $Time_{Year}$ x $Customer_{GG \cdot GC}$

$Product_{RQ(Package,\ Target\ Appl,\ Processor,\ Speed)}$ x $Time_{Year}$ x $Customer_{GG \cdot GC}$

$Product_{RQ((Package,\ Target\ Appl,\ Processor,\ Speed) \cdot PartNo)}$ x $Time_{Year}$ x $Customer_{GG \cdot GC}$

$Product_{RQ((Package,\ Target\ Appl,\ Processor,\ Speed) \cdot PartNo)}$ x $Time_{Year \cdot Quarter}$ x $Customer_{GG \cdot GC}$

$Product_{RQ((Package,\ Target\ Appl,\ Processor,\ Speed) \cdot PartNo)}$ x $Time_{Year \cdot Quarter \cdot Month}$ x $Customer_{GG \cdot GC}$

$Product_{RQ((Package,\ Target\ Appl,\ Processor,\ Speed) \cdot PartNo)}$ x $Time_{Year \cdot Quarter \cdot Month \cdot Day}$ x $Customer_{GG \cdot GC}$

Feature Works

- DPH - what-if analysis
- Computation time improvement