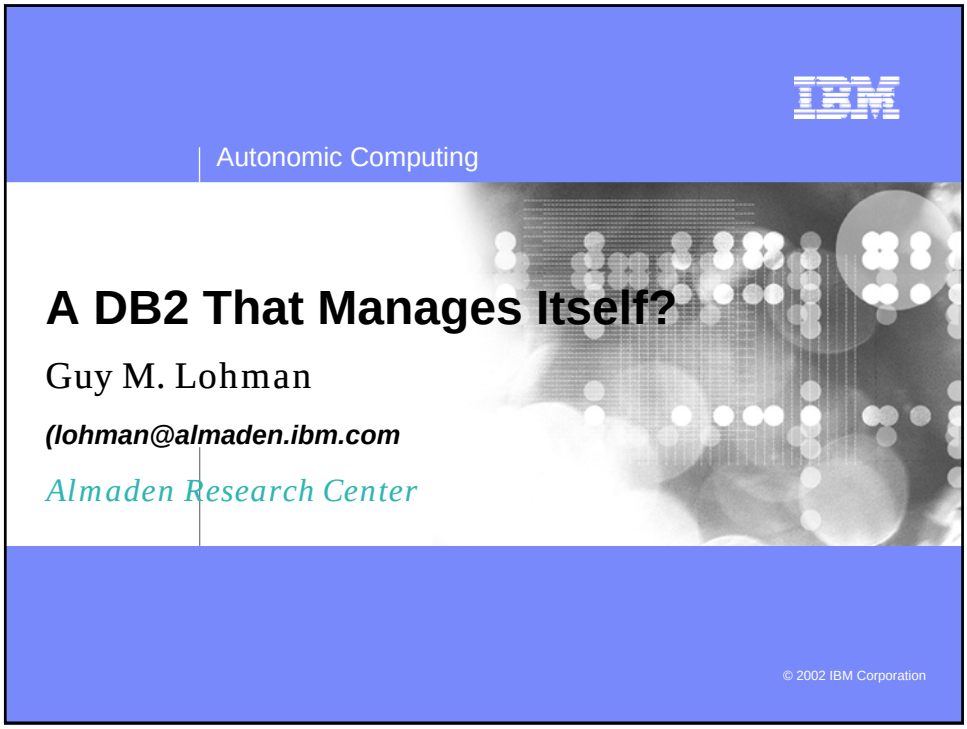
Autonomic Computing
A DB2 That Manages Itself?
Guy M. Lohman
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Almaden Research Center
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Autonomic Computing
The Idea
Wouldn't it be great if your
Database (and entire system!)
were as easy to maintain
and as self-controlled
as your
refrigerator?
2
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Agenda

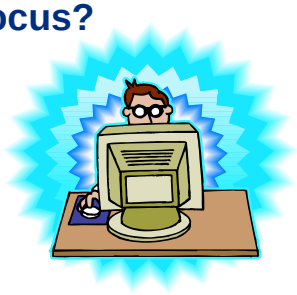
- Introduction & Motivation
- **DB2 Autonomic Computing Project**
- Existing DB2 Autonomic Features
  - Index Advisor
  - Configuration Advisor
  - Health Advisor
- New in "Stinger"
  - Design Advisor
  - Automated Statistics Collection
- Ad. Tech. & Research Projects
  - Progressive Optimization
- Conclusions

DB2 Autonomic Computing

- **Goal** -- Make DB2 Autonomic
- **The Project**:
  - Multi-Platform (Linux, Unix, Windows, mainframe)
  - Multi-Division (Research, Development)
  - Multi-Site (Toronto, Almaden, Silicon Valley, Watson)
  - Part of IBM's company-wide "Autonomic Computing" initiative
- **Leaders**:
  - Toronto Lab: **Sam Lightstone**, Randy Horman, Mark Wilding
  - SVL: Jim Teng (z/OS), Bryan Smith (tools)
  - Research: Guy Lohman (ARC), Joe Hellerstein (Watson)
- **History**:
  - Index Advisor prototyped in 1998
  - Project formed in early 2000
    - **Previously called Self-Managing And Resource Tuning (SMART)**
  - IBM-wide Autonomic Computing initiative
  - Evolutionary: Multi-Release Rollout

- **Refn**: *SMART: Making DB2 (More) Autonomic*, **VLDB 2002**

An Autonomic DB2: What's our Focus?



- Up and Running
  - pre-purchase capacity planning tools
  - automate install and initial configuration
- Design
  - advise on logical and physical design
- Maintenance
  - automatic tuning for queries, resources
  - physical maintenance (statistics collection, reorganization, ...)
- Problem Determination and Resolution
  - detecting existing, and predicting future
  - user notification
  - self-correcting features
- Availability and Disaster Recovery
  - availability
  - backup and log management

Approach

- **LOTS of ideas & prototypes underway!**
- **Leverage existing infrastructure in DB2**
  - **Optimizer's detailed model of run-time environment**
  - **Monitoring tools**
  - **Workload captured for DB2 Index Advisor**
  - **DB2 Control Center GUIs, Data Management Tools**
- **Exploit IBM's strength in software research**
  - **Tough problems in: Database, Control Theory, Optimization, Operations Research, Artificial Intelligence, Operating Systems, Usability.**
- **Get something out there, & improve it over time!**
  - **Where the need is greatest**
  - **Where we have ideas/skills**
- **Earn the DBA's trust**
  - **Create tools that speed/simplify/improve DBA's job**
  - **"Free the DBA!" -- DBA retains ultimate decision power**
  - **Longer-term goal is complete automation**

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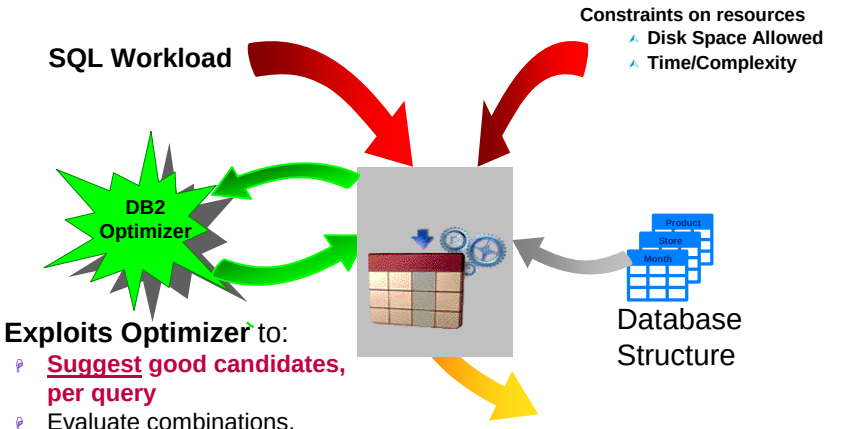
Index Selection: The Problem

- **Huge number of possible indexes**
  - **Dependent upon workload (queries) anticipated**
  - **For each query, user has to trade off:**
    - **Benefits:**
      - **Apply predicates efficiently (save reading entire table)**
      - **Provide a row ordering needed by query for certain operations**
      - **Index-only access (avoid fetching data pages)**
      - **Enforce uniqueness (e.g., primary keys)**
    - **Costs:**
      - **Storage space**
      - **Updating**
      - **More plans for the optimizer to evaluate**
- **Time-consuming trial & error process to choose the best set of indexes**
  1. **Create index (system sorts entire table on key of the index)**
  2. **Collect statistics on it (system scans entire table AND all indexes)**
  3. **Re-optimize all queries in all apps that might benefit**
  4. **See if**
     1. **Index was used**
     2. **Performance improves**
  5. **Iterate!**

Solution(1): DB2 Index Advisor (V6, 1999)



Exploits Optimizer to:

- **Suggest good candidates, per query**
- Evaluate combinations, for entire workload

Indexes Designed by DB2 for Your Environment & Workload

Index Advisor (DB2 V6) – The Math

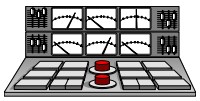
- Variant of well-known "Knapsack" Problem
- Greedy "bang-for-buck" solution is optimal, when integrality of objects (indexes) is relaxed

- For each query Q:
  - Baseline: Explain each query w/ existing indexes, to get cost E(Q)
  - Unconstrained: Explain each query in RECOMMEND INDEXES mode, to get cost U(Q)
  - Improvement ("benefit") B(Q) = E(Q) - U(Q)
- For each index I used by one or more queries:
  - If query Q used index I, assign "benefit" B(Q) to index I: B(I) = B(I) + B(Q)
  - Assign "cost" C(I) = size of index in bytes
  - Order indexes by decreasing B(I) / C(I) ("bang for buck")
  - Cut off where cumulative C(I) exceeds disk budget
- Iterative improvement: exchange handfuls of "winners" with "losers"

- **REFN: "DB2 Advisor: An Optimizer Smart Enough to Recommend its Own Indexes", ICDE 2000 (San Diego), Valentin, Zuliani, Zilio, Lohman, et al.**

Configuration Parameters

- **The Problem:**
  - Almost 150 configuration parameters in DB2 UDB
  - Users didn't know:
    - How to choose the right values
    - Possible interactions between them
  - Had to stop and restart DB2 to have them go into effect
    - Bad for availability, too!



- **Solution(1):**
  - Make many configuration parameters dynamic!
  - No need to stop and restart DB2 to change them
  - Not easy to implement, e.g. shrinking buffer pool
  - Shipped in DB2 UDB V8.1 (2002)
  - Prerequisite to automatically tuning them

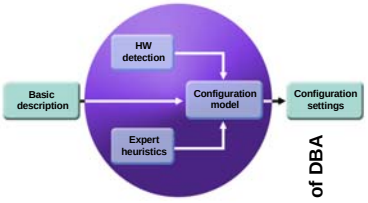
Solution(2): Configuration Advisor (V8.1, 2002)

- **What is it?**
  - Sets ~36 configuration parameters key to performance, including:
    - Memory heaps (buffer pool, sort heap, statement cache)
    - Connections (max and average, remote/local)
  - Based upon answers to 7 high-level questions
  - Equations from performance experts relate parameters
- **Enhanced in V8.1:**
  - Available in V7 as "Performance Configuration Wizard"
  - More sophisticated model in V8.1
  - Easier to invoke via:
    - CREATE DATABASE command extension
    - AUTOCONFIGURE command
  - Better decisions for OLTP and DSS workloads
  - Surprising benchmark results
    (well-known, industry-standard OLTP workload)

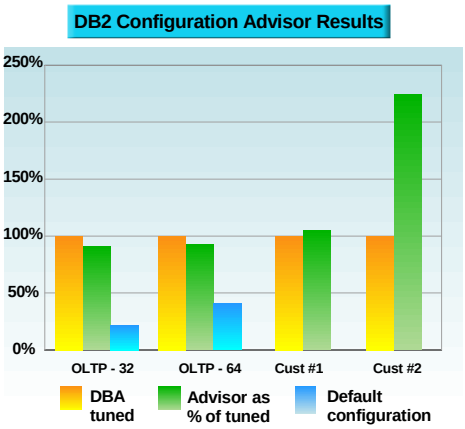
Configuration Advisor: The Questions

- Percentage of Real Memory to dedicate to DBMS
- OLTP vs. Complex query vs. Mixed
- Length of Transaction (typical # of SQL queries per transaction)
- Relative priority of Recovery vs. Query speed
- Number of Local and Remote Connections
- Whether the database is populated or not
- Isolation Level

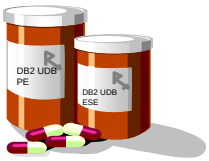
DB2 Configuration Advisor vs. Human Experts



- ***Speeds deployment***
- ***Improves performance***
- ***Frees up resource***

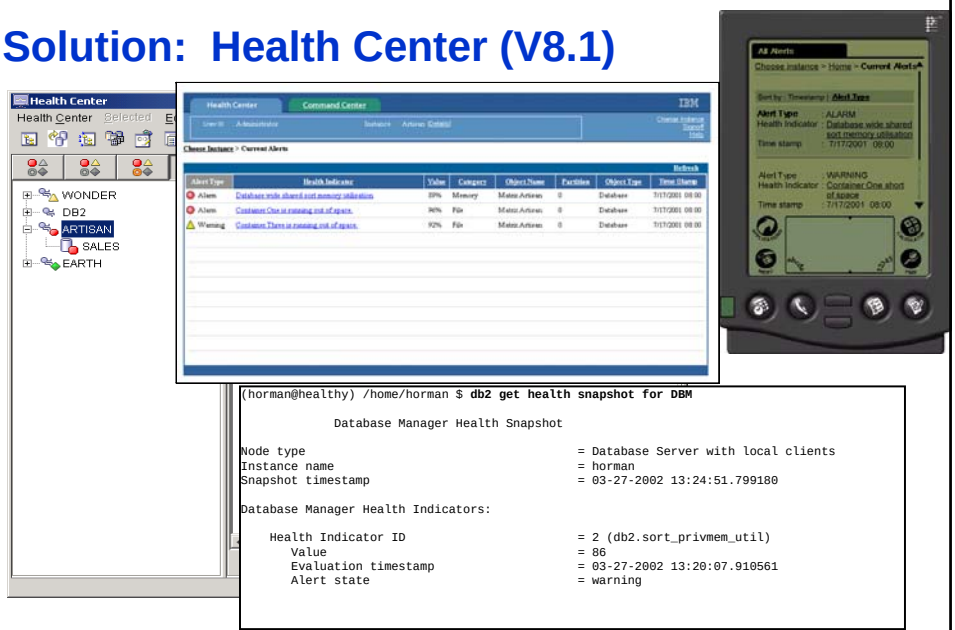


Health Monitoring



- **The Problem:**
  - How do you know if DB2 is running okay, performing well?
  - What do you do if you do manage to figure out it's "unhealthy"?
  - Too difficult to determine what to monitor and when to monitor it
  - Need to set up monitors, notification & resolution mechanisms
- **The Solution: Health Center**
  - DB2 monitors its own health right out of the box
  - Notifies user upon encountering unhealthy conditions
  - Advises on severity of condition, and suggests resolutions
  - Initiates corrective action if required, requested
  - Easy installation: just provide an e-mail or pager address
  - User can modify thresholds for notification

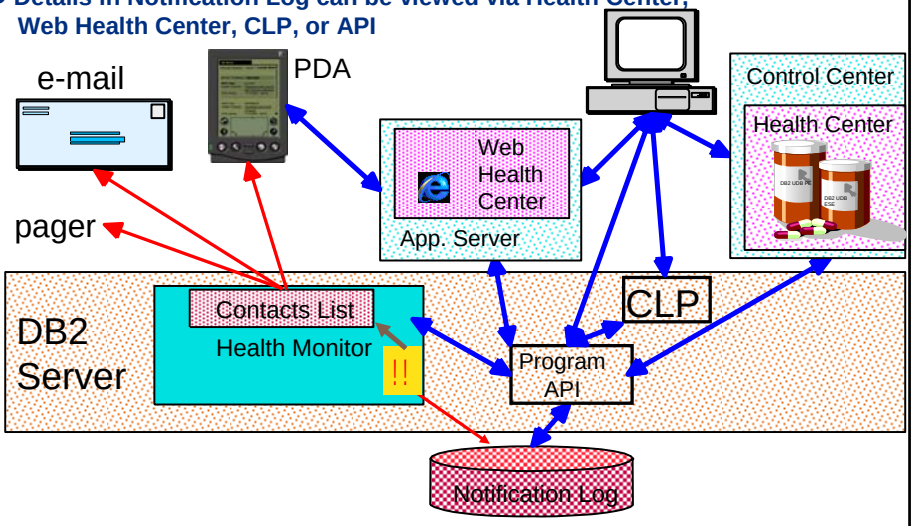
Solution: Health Center (V8.1)




```
(horman@healthy) /home/horman $ db2 get health snapshot for DBM

             Database Manager Health Snapshot

Node type                                      = Database Server with local clients
Instance name                                  = horman
Snapshot timestamp                             = 03-27-2002 13:24:51.799180

Database Manager Health Indicators:

    Health Indicator ID                        = 2 (db2.sort_privmem_util)
       Value                                   = 86
       Evaluation timestamp                    = 03-27-2002 13:20:07.910561
       Alert state                             = warning
```

Health Monitor and Health Center

- **Alerts sent by Health Monitor to Contacts on Contacts List**
- **Details in Notification Log can be viewed via Health Center, Web Health Center, CLP, or API**



Health Center: "Drilling Down"

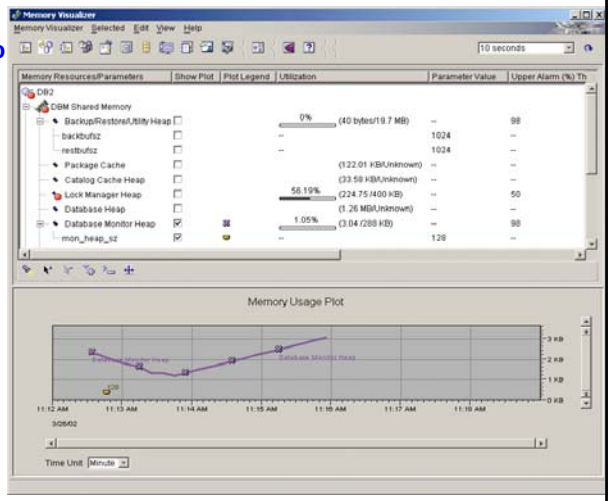
- If you need to do some digging/investigation before choosing an appropriate action, Health Center launches tools in context

e.g. **Use Memory Visualizer to consider "competitors" of a constrained resource**

Other investigative actions include:

- **Storage Management**
- **Indoubt Transaction Manager**
- **Event Monitor**

NOTE: for many corrective actions, DB/DBM cfg parms can be dynamically updated!!!



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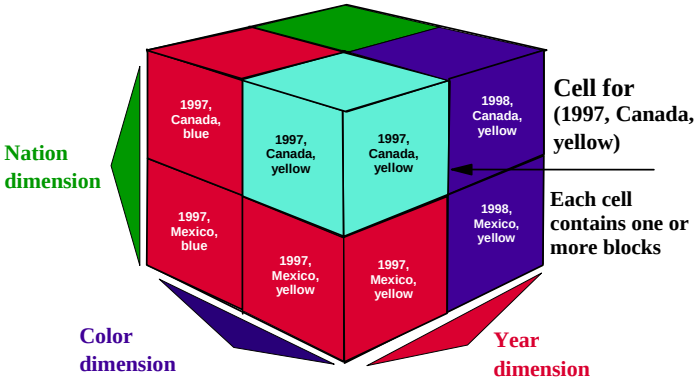
Design Advisor ("Stinger")

- An extension of existing Index Advisor (V6)
- Headquarters for all physical database design
- Recommends any combination of:
  - **Indexes**
  - **Materialized Views (Materialized Query Tables (MQTs))**
    - **Called Automatic Summary Tables (ASTs) before V8.1**
  - **Partitioning of tables (in partitioned environment)**
  - **Multi-Dimensional Clustering (MDC) storage method (New in V8.1)**
- Takes interactions of these into consideration
- Status:
  - **Coming soon ("Stinger")!**
  - **Beta testing on customer databases now!**

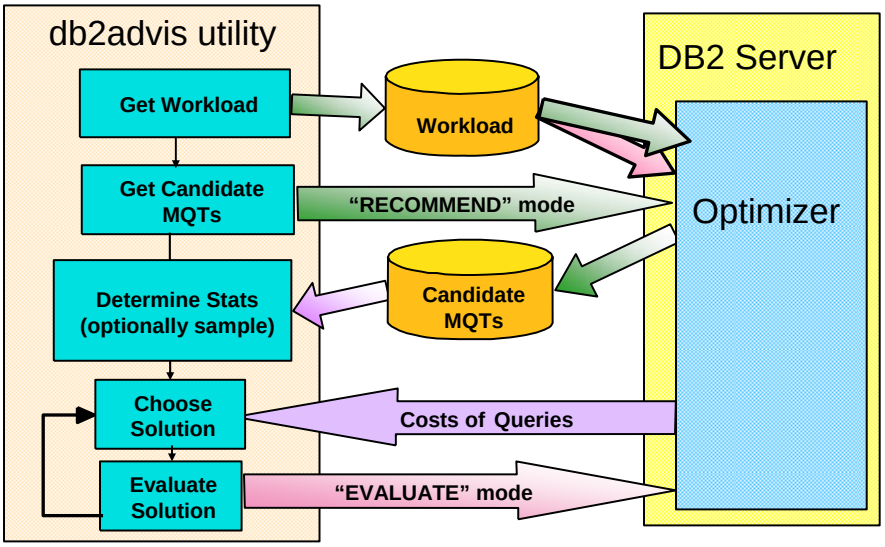
- **REFNS:**
  - **"**DB2 Design Advisor: Integrated Automatic Physical Database Design", **VLDB 2004**
  - "Recommending Materialized Views and Indexes with IBM's DB2 Design Advisor", **IEEE Intl. Conf. on Autonomic Computing (ICAC 2004)**
  - **"**Trends in Automating Database Physical Design", **IEEE 2003 Workshop on Autonomic Computing Principles and Architectures**, Banff, Alberta, August 2003

Multi-Dimensional Clustering (MDC) – V8.1

Cells are the portion of the table containing data having a unique set of dimension values; the intersection formed by taking a slice from each dimension.
Blocks are the storage units that compose each cell.

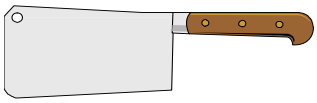


Design Advisor Architecture (MQTs only)



Design Advisor: Partition Advisor

- **Scope:**
  - DB2 "partitioned environment" (was called EEE prior to V8.1)
  - "Shared-nothing" parallelism
  - Data stored horizontally partitioned
    - In a partition group, spread across specified partitions
    - Based upon hashing of partitioning column(s)
    - May be replicated across all partitions of partition group
  - Need to co-locate similar values for joins, aggregation in queries
  - Partitioning required for a given table may be different
    - Between queries
    - Even within a query (joined on different columns)!

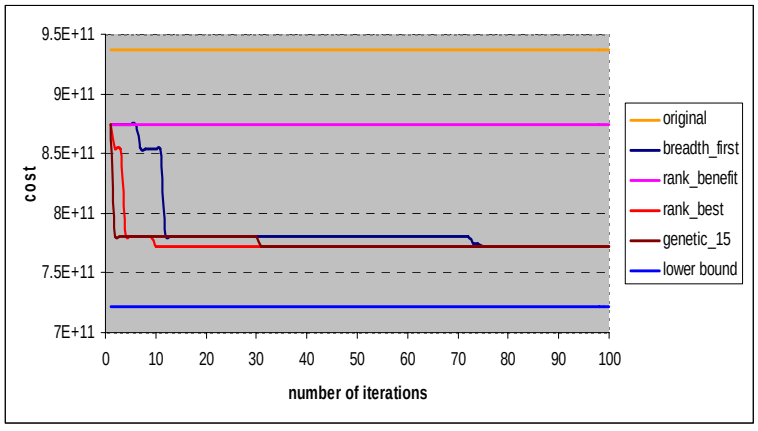


- **Problem:** What is optimal partitioning for each table, given:
  - Workload of queries
  - Schema, including set of partition groups & tablespaces
  - Statistics on database

Reference: "Automating Physical Database Design in a Parallel Database", ACM SIGMOD 2002 (Madison, WI, June 2002)

Performance Improvement on Customer Database (Partitioning only)

- **50 queries and 500 possible configurations**
- **Rank_best algorithm converges the fastest, 22% speedup**



Automating Statistics Collection:

- **Problem:**
  - Optimizer requires that statistics on database be
    - Up to date (after updates)
    - Complete (multi-column)
  - User must invoke RUNSTATS
- **Solution**: Automate RUNSTATS
  - ***Invocation*** scheduled and prioritized
  - ***Run silently*** as a background daemon
    - Throttled based upon workload
  - **LEO** the **LE**arning **O**ptimizer determines which ***statistics needed***
    - Based upon learning from past queries
    - Groups of columns
      - Enables correlation detection
    - Communicated to RUNSTATS via statistical "profiles"
- Shipping in DB2 "Stinger"
- **Refn**: "Automated Statistics Collection in DB2 Stinger", **VLDB 2004**

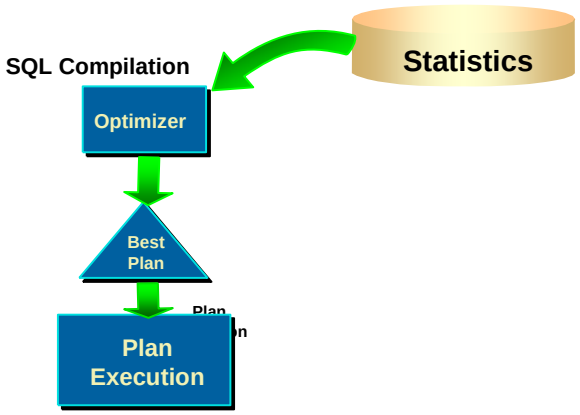
Automating Statistics Collection:
LEO the LEarning Optimizer Determines Statistics Profiles

Refn: "LEO -- DB2's LEarning Optimizer", Intl. Conf. on Very Large Data Bases 2001 (Rome, Sept. 2001)

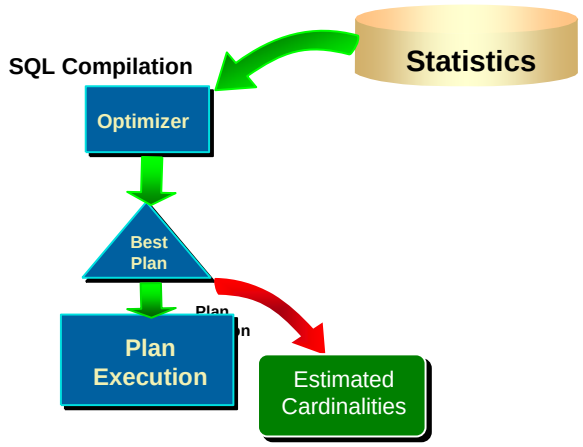
LEO Motivation

- Cost depends heavily on number of rows processed (cardinality)
- Optimizer's model limited by simplifying assumptions
  - Especially due to statistical correlation between columns
  - EXAMPLE: WHERE Make = 'Honda' AND Model = 'Accord'
  - Impossible to know a priori which columns are correlated!
- Why not use actual results from executed queries to
  - Validate statistics and assumptions
  - Advise when/how to run expensive statistics collection
  - Gather statistics that reflect the workload
  - Repair the model for optimizing "similar" future queries
- Could achieve automatically
  - Better quality plans
  - Reduced customer tuning & administration time
  - Reduced IBM support time
- Part of Automated RUNSTATS in “Stinger”

Query Optimization -- Today

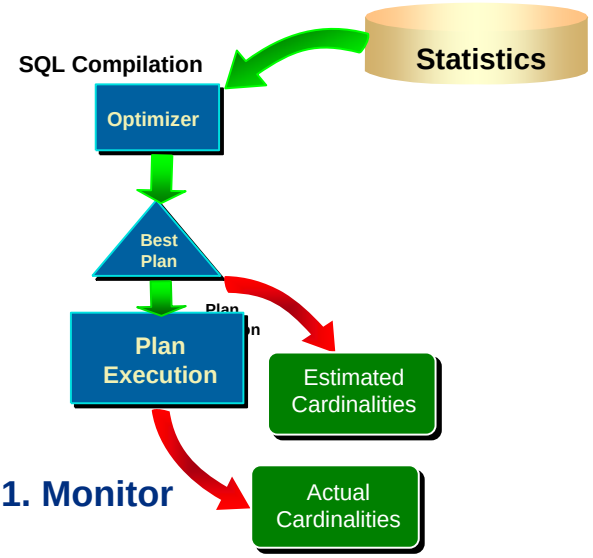


EXPLAIN gives Optimizer's Estimates



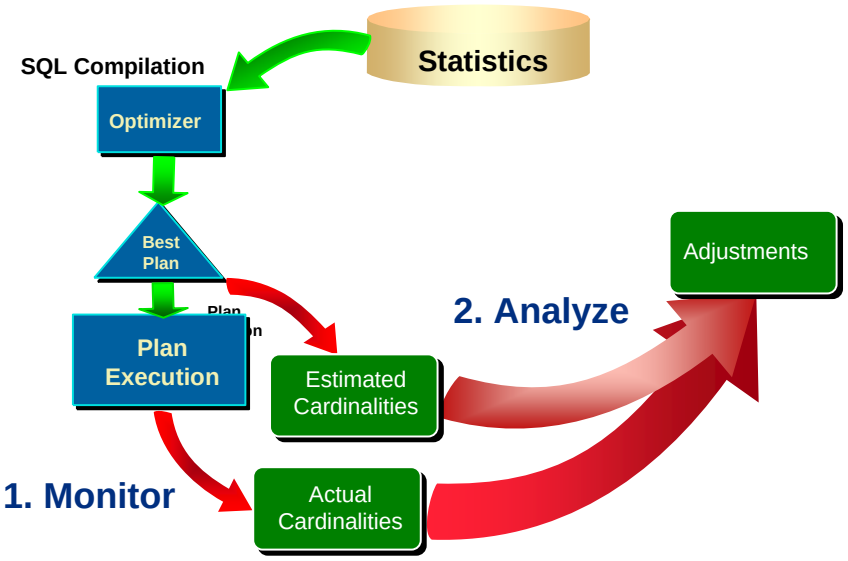
1. Monitor

New: Capture Actual Number of Rows!

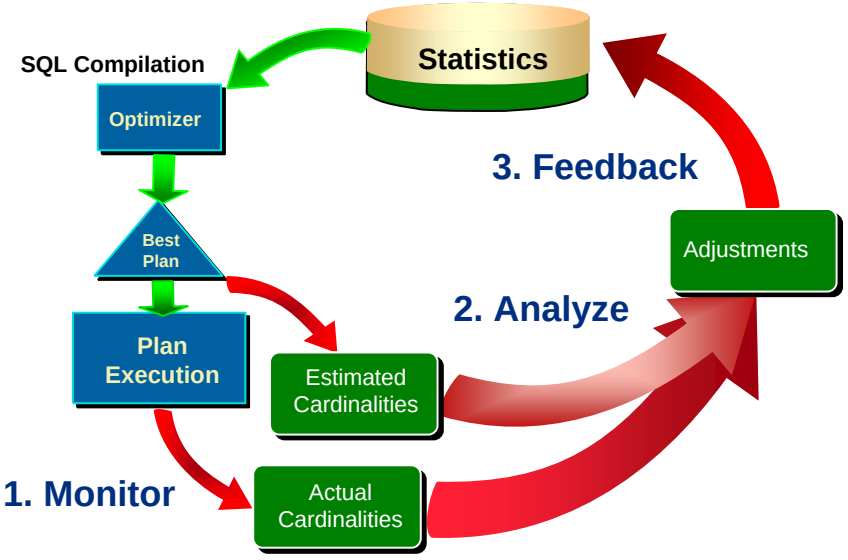


1. Monitor

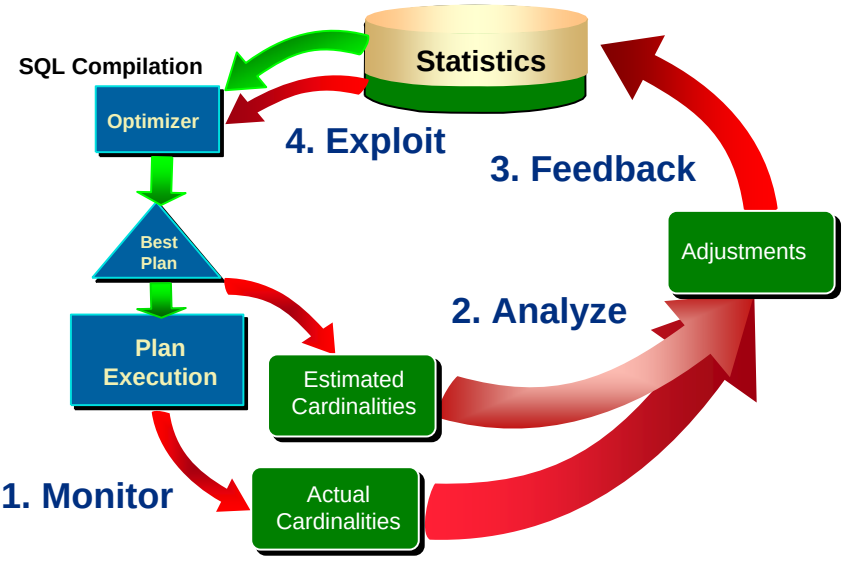
Figure Out Where the Differences Are



Augment Statistics with Adjustments



Exploit: Learning in Query Optimization!



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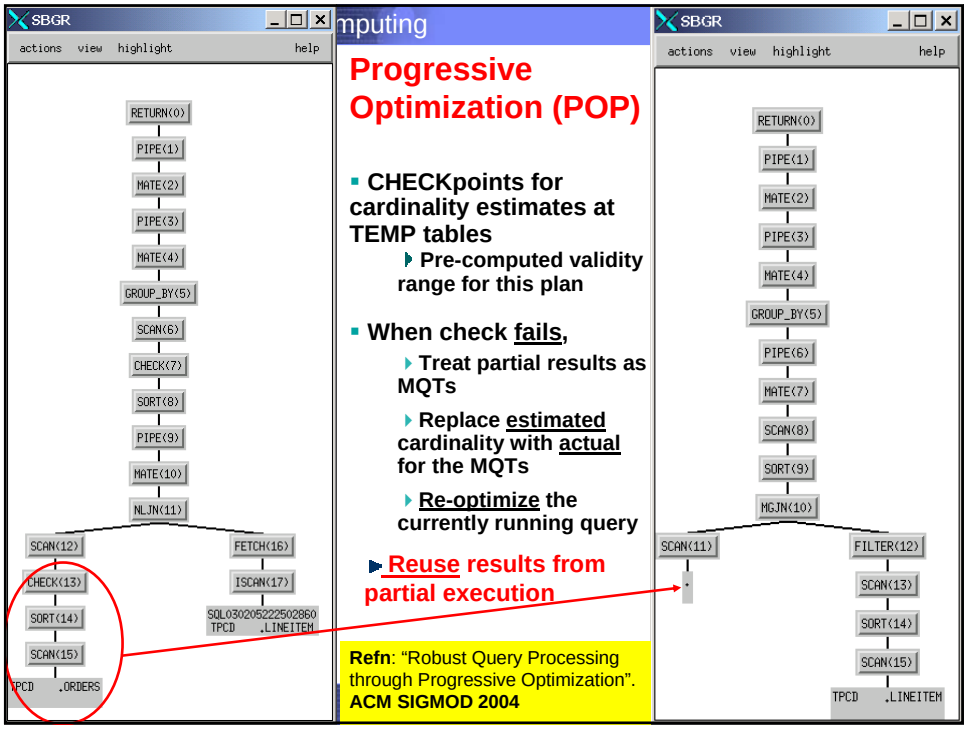
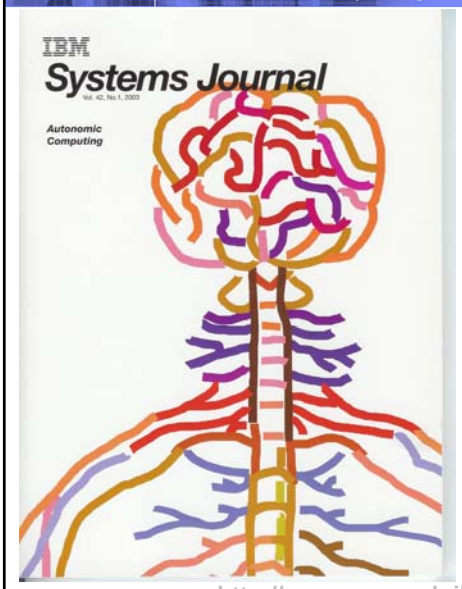


Conclusions & Future Directions

- Autonomic features of DB2:
  - Key to lowering Total Cost of Ownership
  - A major DB2 differentiator
  - Now in DB2 are the "tip of the iceberg"!
  - Many more on the way in technology stream from
    - Development
    - Research
    - Universities
  - Rollout prioritized by Customers ("Free the DBAs!")
  - Beginning to integrate IBM components autonomically
  - Ultimate goal is complete automation!



For more info…

Autonomic computing systems are self-managing and always available, analogous to the human autonomic nervous system depicted abstractly on the cover. Papers in this issue describe a variety of research projects in which the concepts of autonomic computing are being developed.

http://www.research.ibm.com/journal/sj42-1.html

http://www.ibm.com/autonomic

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