C-DAC Four Days Technology Workshop

ON

Hybrid Computing – Co-Processors/Accelerators
Power-aware Computing – Performance of Applications Kernels

hyPACK-2013
(Mode-1:Multi-Core)

Lecture Topic :

Multi-Core Processors :
Algorithms & Applications Overview - Part-II

Venue : CMSD, UoHYD ; Date : October 15-18, 2013

Killer Apps of Tomorrow

Application-Driven Architectures: Analyzing Tera-Scale Workloads

- Workload convergence
  - The basic algorithms shared by these high-end workloads
- Platform implications
  - How workload analysis guides future architectures
- Programmer productivity
  - Optimized architectures will ease the development of software
- Call to Action
  - Benchmark suites in critical need for redress

Emerging "Killer Apps of Tomorrow" Parallel Algorithms Design

- Static and Load Balancing
  - Mapping for load balancing
  - Minimizing Interaction
  - Overheads in parallel algorithms design
- Data Sharing Overheads

Emerging "Killer Apps of Tomorrow" Parallel Algorithms Design (Contd…)

General Techniques for Choosing Right Parallel Algorithm

- Maximize data locality
- Minimize volume of data
- Minimize frequency of Interactions
- Overlapping computations with interactions.
- Data replication
- Minimize construction and Hot spots.
- Use highly optimized collective interaction operations.
  - Collective data transfers and computations
- Maximize Concurrency.

Programming Aspects Examples

Implementation of Streaming Media Player on Multi-Core

- One decomposition of work using Multi-threads
- It consists of
  - A thread Monitoring a network port for arriving data,
  - A decompressor thread for decompressing packets
  - Generating frames in a video sequence
  - A rendering thread that displays frame at programmed intervals

Source : Reference : [4]

Programming Aspects Examples

Implementation of Streaming Media Player on Multi-Core

- The thread must communicate via shared buffers –
  - an in-buffer between the network and decompressor,
  - an out-buffer between the decompressor and renderer
- It consists of
  - Listen to port ……..Gather data from the network
  - Thread generates frames with random bytes (Random string of specific bytes)
  - Render threads pick-up frames & from the out-buffer and calls the display function
  - Implement using the Thread Condition Variables

Types of Parallelism

Types of Parallelism

- Data parallelism
- Task parallelism
- Combination of Data and Task parallelism
- Stream parallelism

Evolving towards model-based Computing

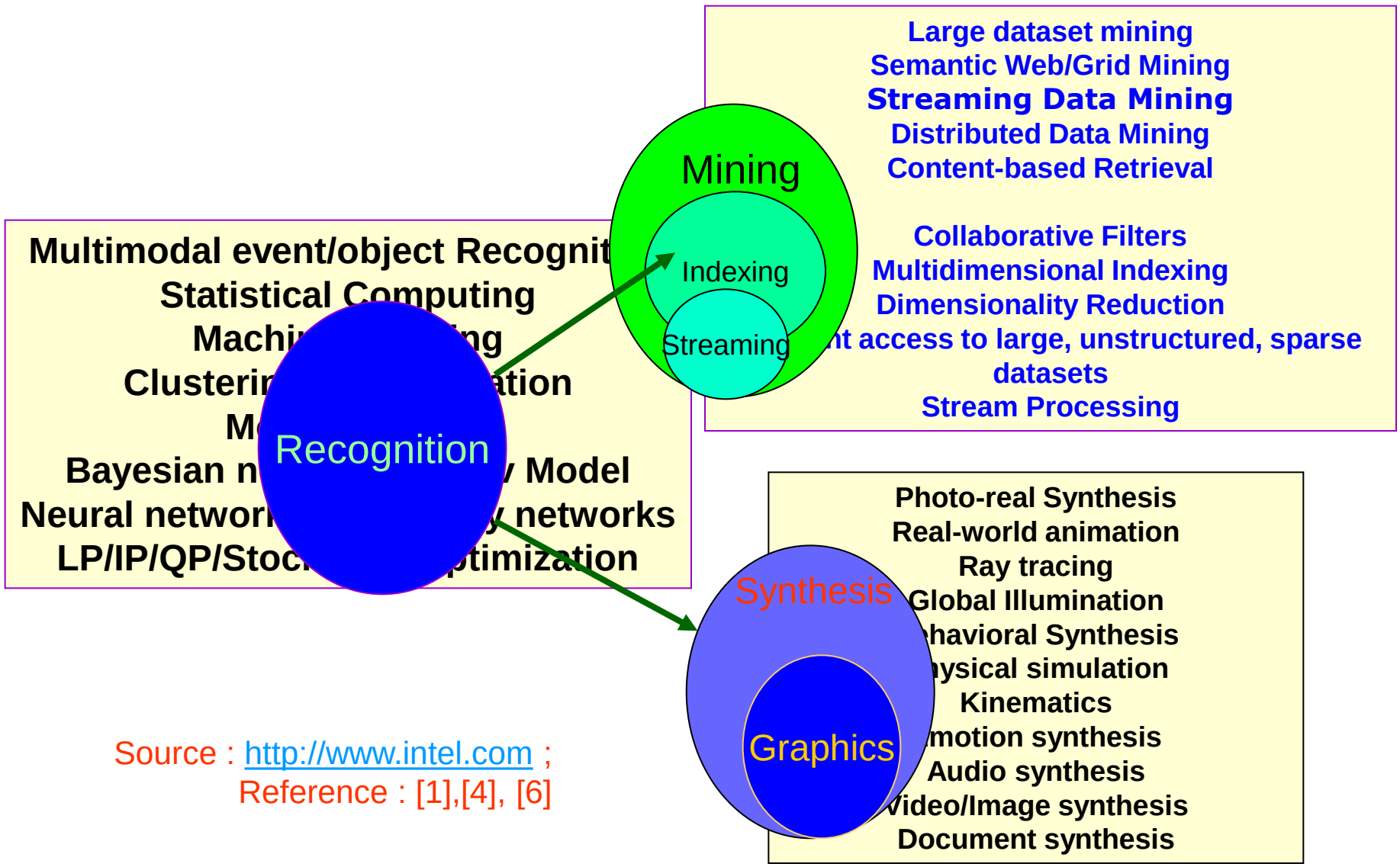
Large dataset mining
Semantic Web/Grid Mining
Streaming Data Mining
Distributed Data Mining
Content-based Retrieval

Collaborative Filters
Multidimensional Indexing
Dimensionality Reduction
Efficient access to large, unstructured, sparse datasets
Stream Processing

Multimodal event/object Recognition
Statistical Computing
Machine Learning
Clustering / Classification
Model-based:
Bayesian network/Markov Model
Neural network / Probability networks
LP/IP/QP/Stochastic Optimization

Photo-real Synthesis
Real-world animation
Ray tracing
Global Illumination
Behavioral Synthesis
Physical simulation
Kinematics
Emotion synthesis
Audio synthesis
Video/Image synthesis
Document synthesis

Evolving towards model-based Computing



Source : http://www.intel.com ;
Reference : [1],[4], [6]

Killer Apps of Tomorrow

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Target For

Bigger *OR* Smaller Cores

Performance *OR* Scalability

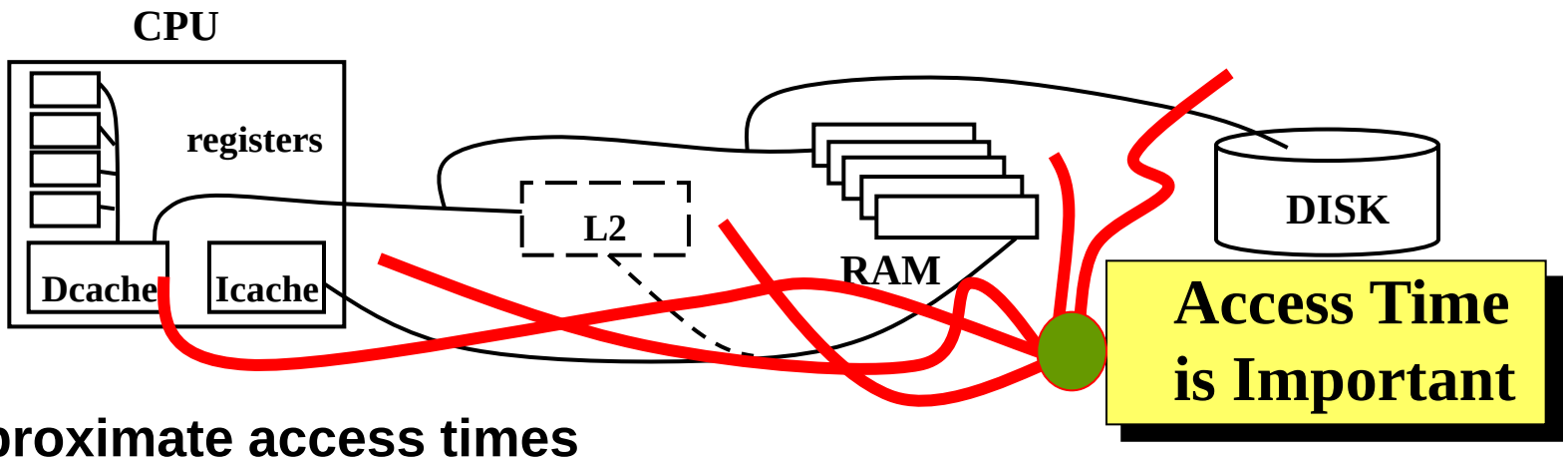
Compute *OR* I/O Intensive

Cache Friendly OR Memory Intensive

Source : http://www.intel.com ; Reference : [6]

The Memory sub-system : Access time

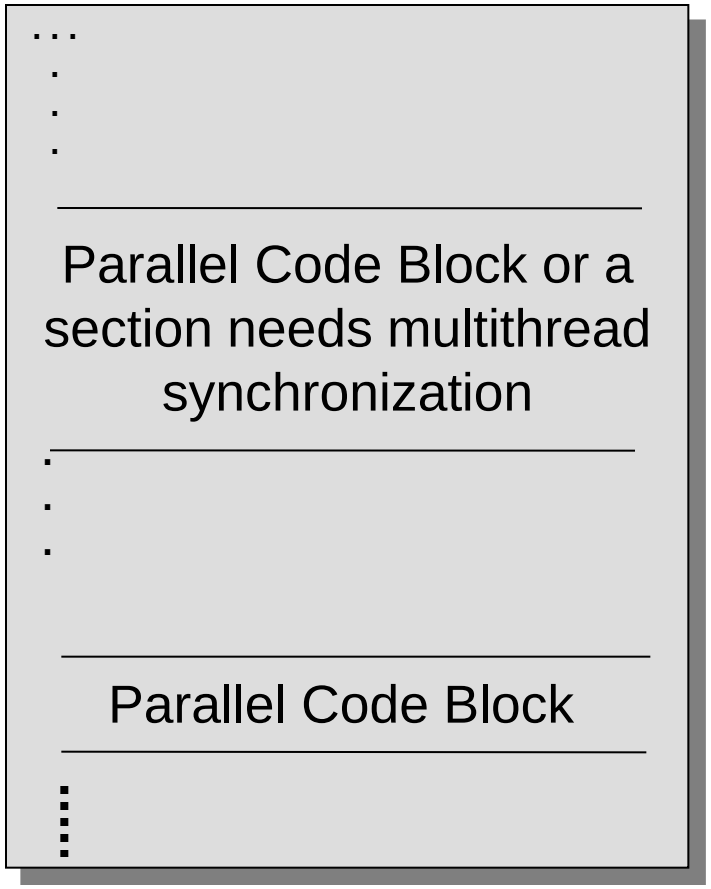
- A lot of time is spent accessing/storing data from/to memory. It is important to keep in mind the relative times for each memory types:



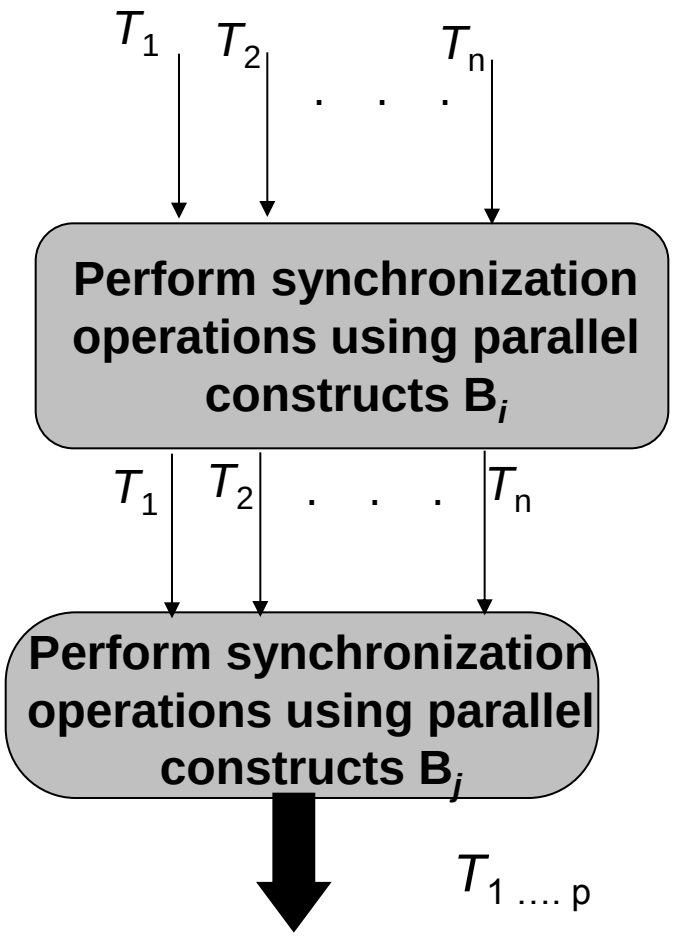
- **Approximate access times**
  - CPU-registers: 0 cycles (that's where the work is done!)
  - L_1 Cache: 1 cycle (Data and Instruction cache). Repeated access to a cache takes only 1 cycle
  - L_2 Cache (static RAM): 3-5 cycles?
  - Memory (DRAM): 10 cycles (Cache miss);
  - 30-60 cycles for Translation Lookaside Buffer (TLB) update
  - Disk: about 100,000 cycles!
  - connecting to other nodes - depending on network latency

Operational Flow of Threads for an Application

Implementation Source Code



Operational Flow of Threads



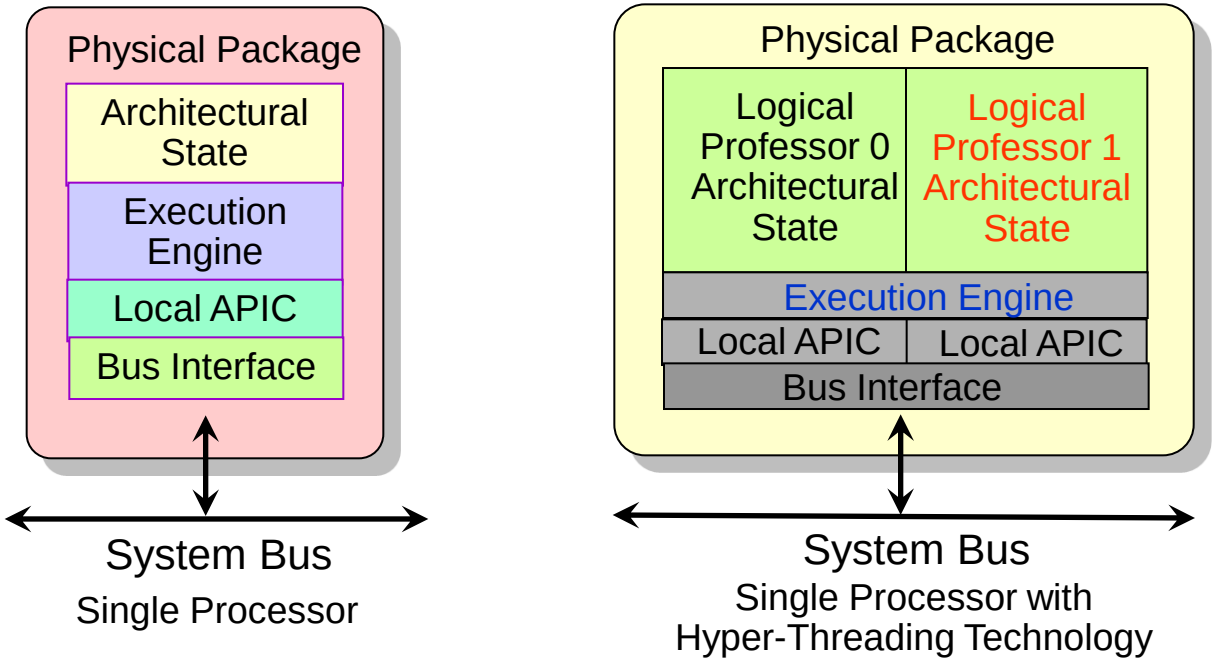
Source : http://www.intel.com ; Reference : [6]

Multi Core : Programming Issues

- Out of Order Execution
- Preemptive and Co-operative Multitasking
- SMP to the rescue
- Super threading with Multi threaded Processor
- Hyper threading the next step (Implementation)
- Multitasking
- Caching and SMT

Hyper-threading : Partitioned Resources

- Hyper-threading (HT) technology is a hardware mechanism where multiple independent hardware threads get to execute in a single cycle on a single super-scalar processor core.

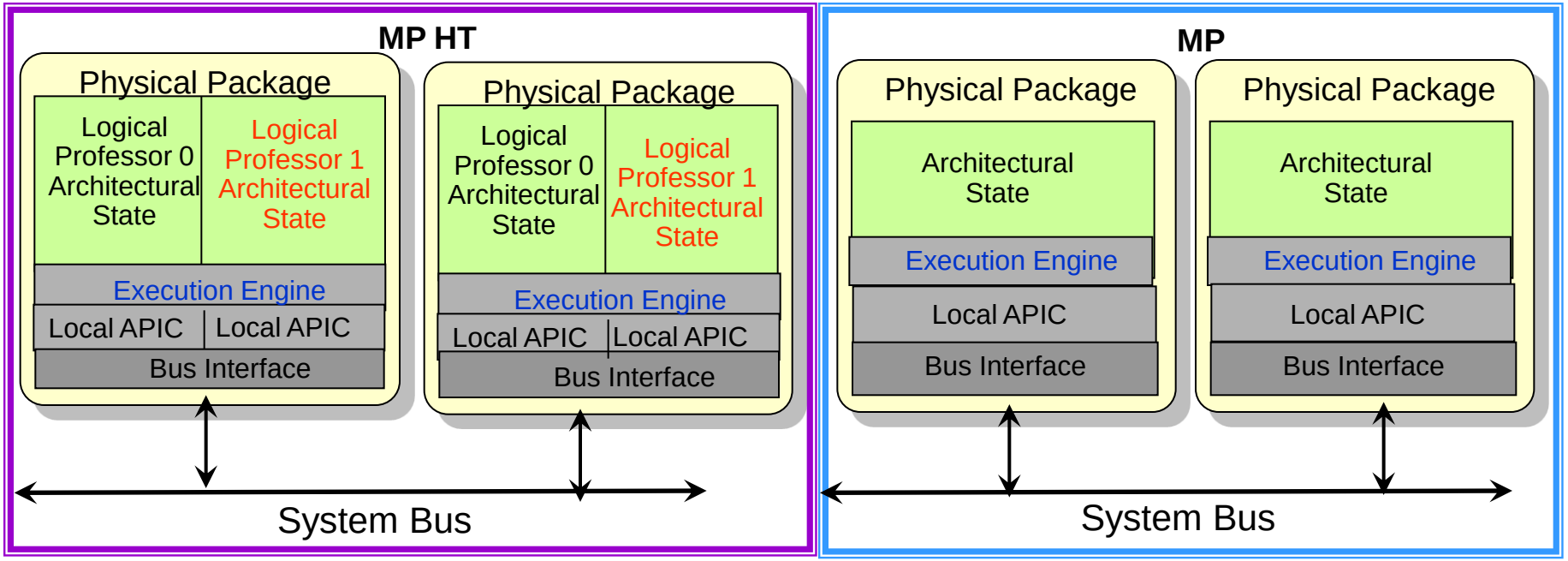


Single Processor System without Hyper-Threading Technology and Single Processor System with Hyper-Threading Technology

Source : http://www.intel.com ; Reference : [6], [10], [19], [23], [24],[29], [31]

Hyper-threading Technology

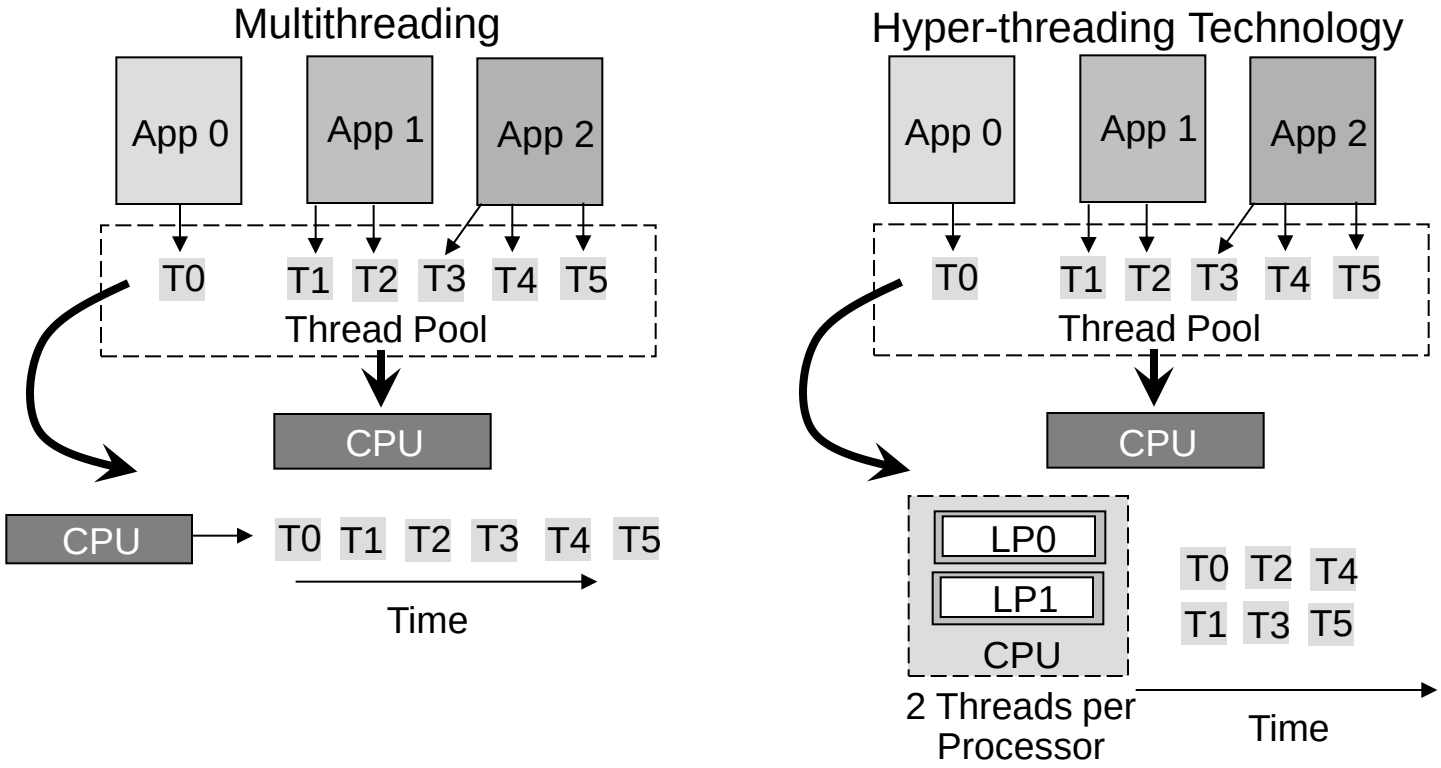
- Multi-processor with and without Hyper-threading (HT) technology



Source : http://www.intel.com ; Reference : [6], [10], [19], [23], [24],[29], [31]

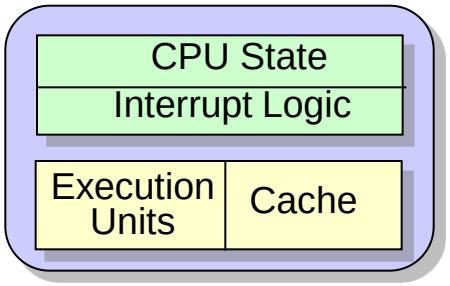
Multi-threaded Processing using Hyper-Threading Technology

- Time taken to process *n* threads on a single processor is significantly more than a single processor system with HT technology enabled.

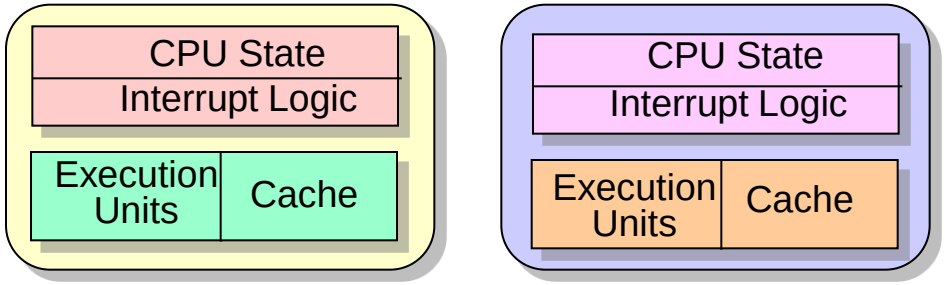


Source : http://www.intel.com ; Reference : [6], [29], [31]

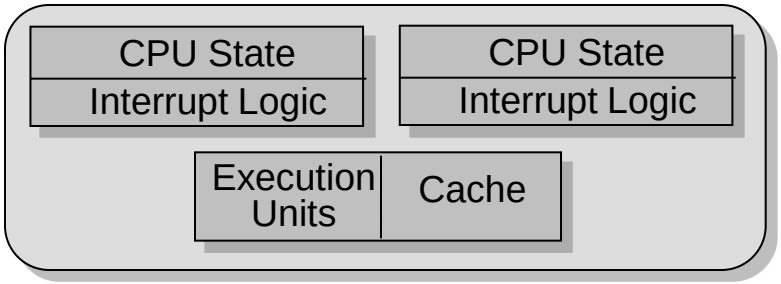
Simple Comparison of Single-core, Multi-processor, and multi-Core Architectures



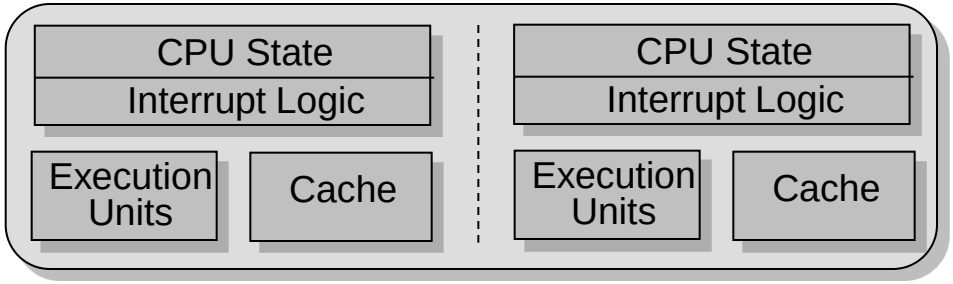
A) Single Core



b) Multi Processor



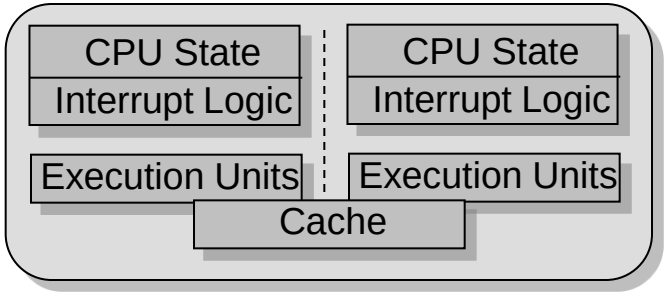
C) Hyper-Threading Technology



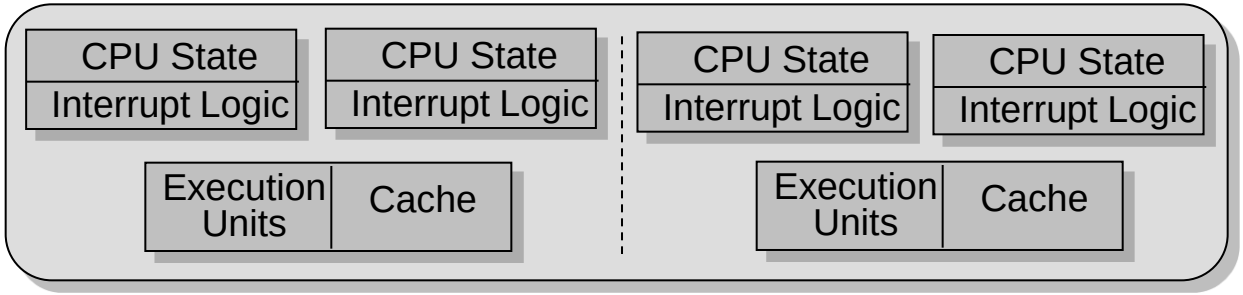
D) Multi-core

Source : http://www.intel.com ; Reference : [6], [29], [31]

Simple Comparison of Single-core, Multi-processor, and multi-Core Architectures



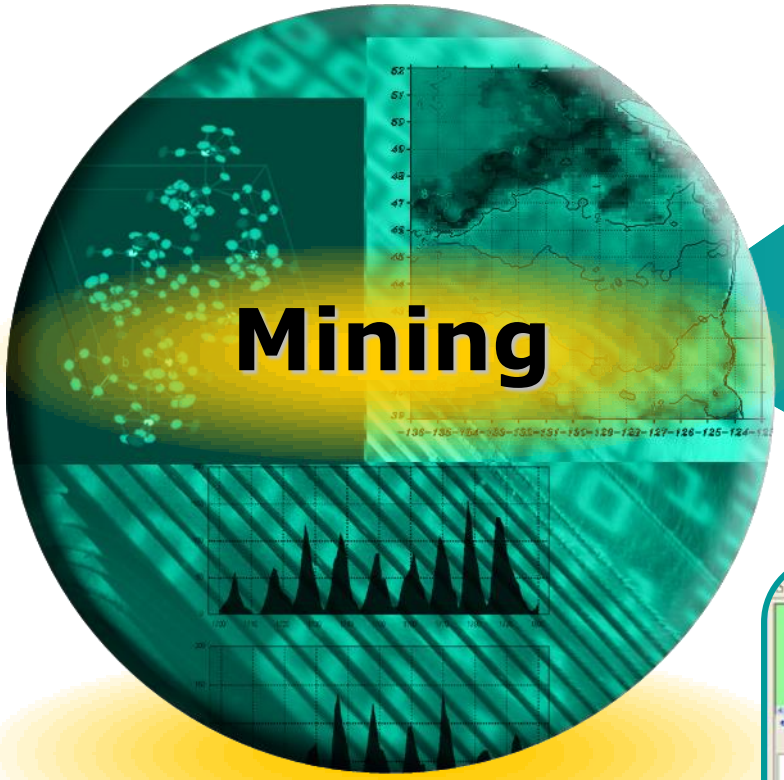
E) Multi-core with Shared Cache



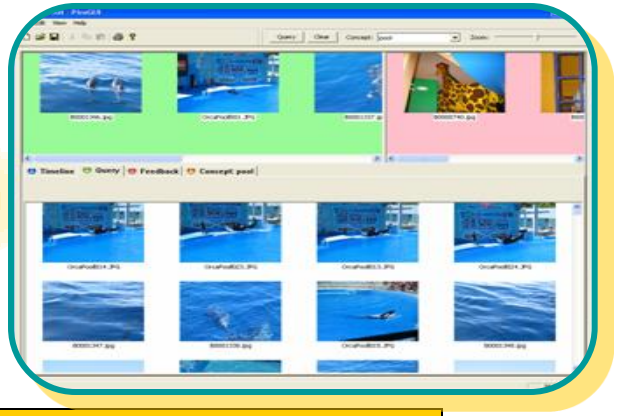
F) Multi-core with Hyper-threading Technology

Source : http://www.intel.com ; Reference : [6], [29], [31]

Emerging "Killer Apps of Tomorrow"



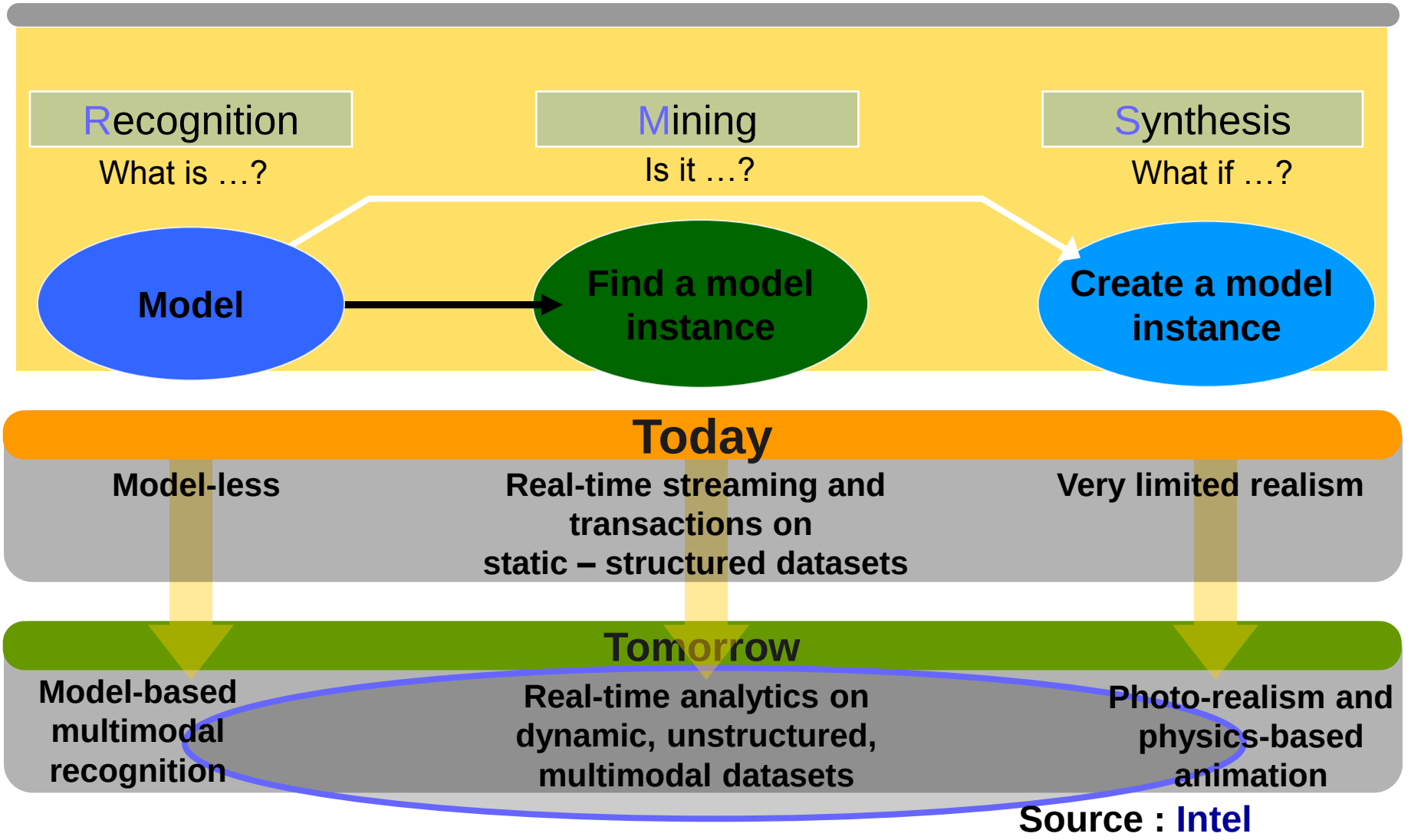
"Where is it?"
Search for a similar instance



Demo: Personal image search

Source: Intel

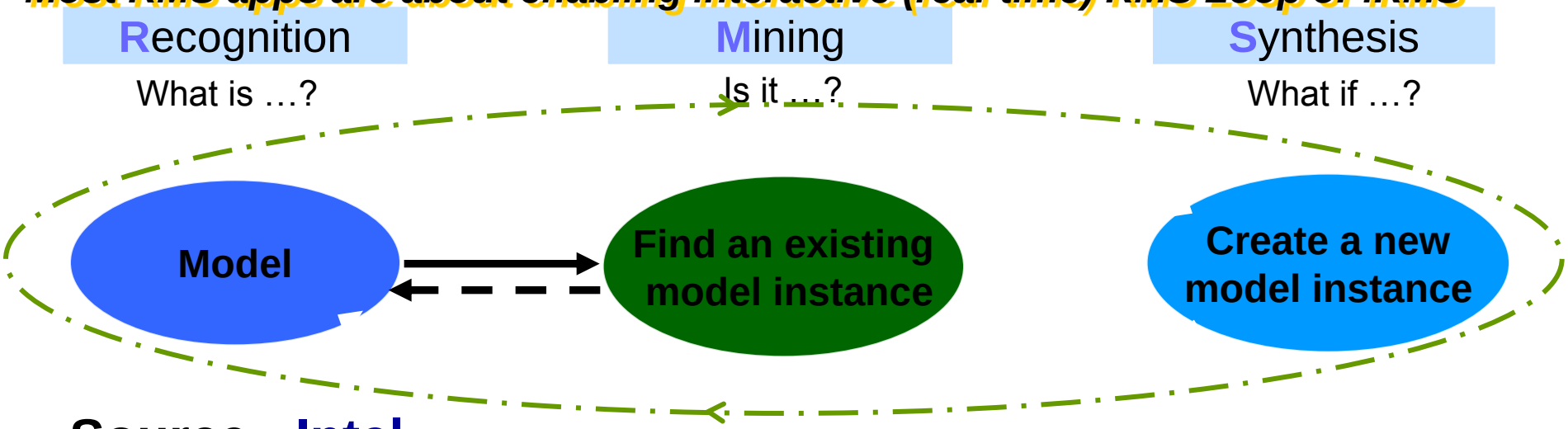
Emerging "Killer Apps of Tomorrow"
RMS: Recognition Mining & Synthesis



Source : Intel

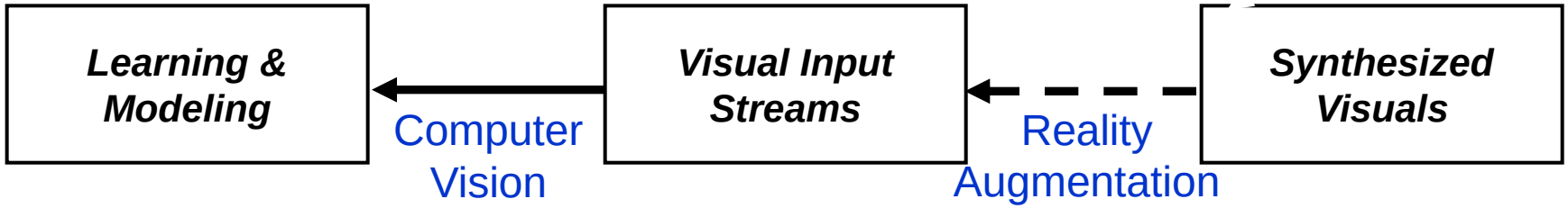
Emerging "Killer Apps of Tomorrow" Interactive Recognition Mining & Synthesis

Most RMS apps are about enabling interactive (real-time) RMS Loop or iRMS



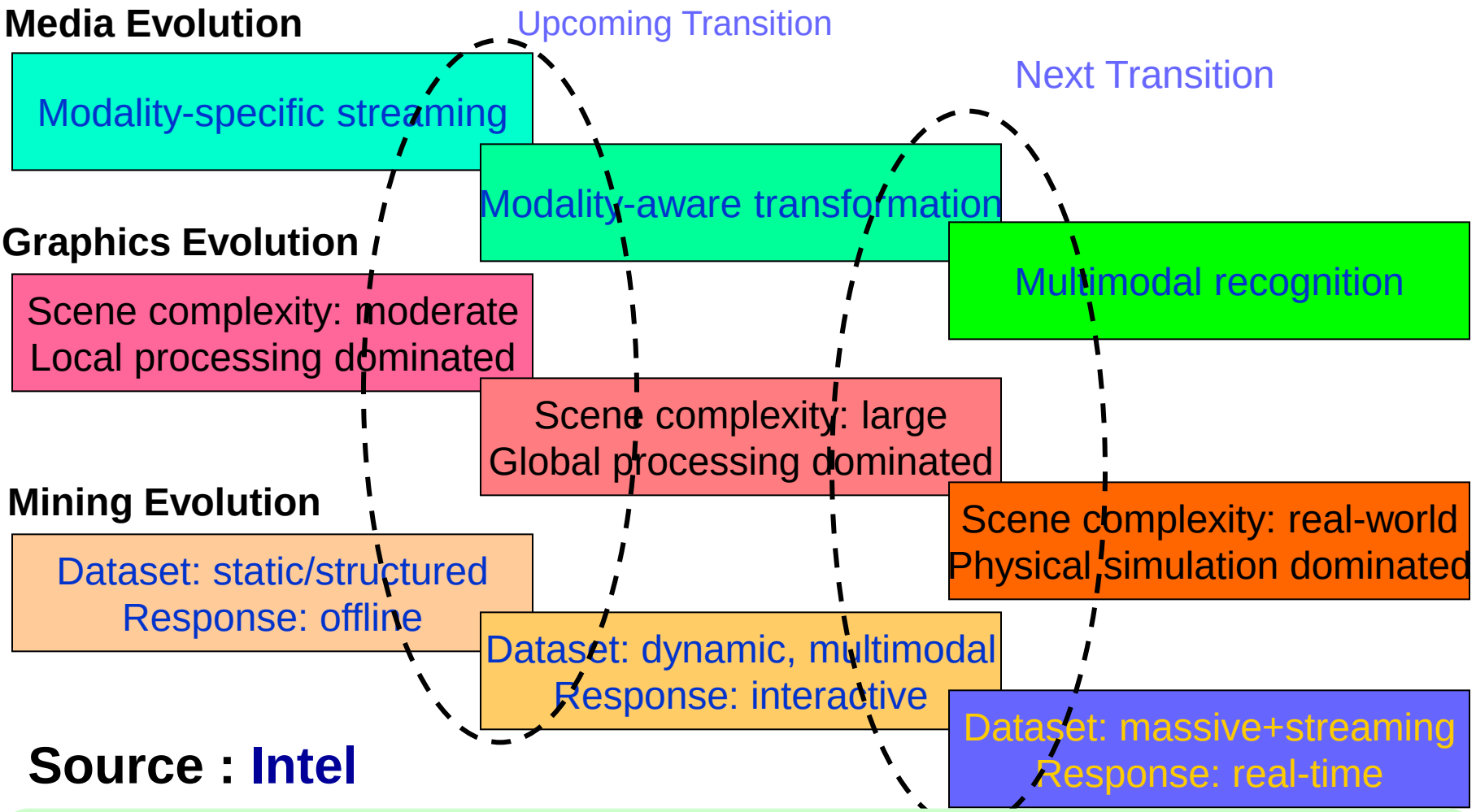
Source : Intel

Graphics Rendering + Physical Simulation



Workload convergence: multimodal recognition and synthesis over complex datasets

Emerging "Killer Apps of Tomorrow"
Interactive Recognition Mining & Synthesis



Source : Intel

Workload convergence: multimodal recognition and synthesis over complex datasets

Emerging "Killer Apps of Tomorrow" Parallel Algorithms Design

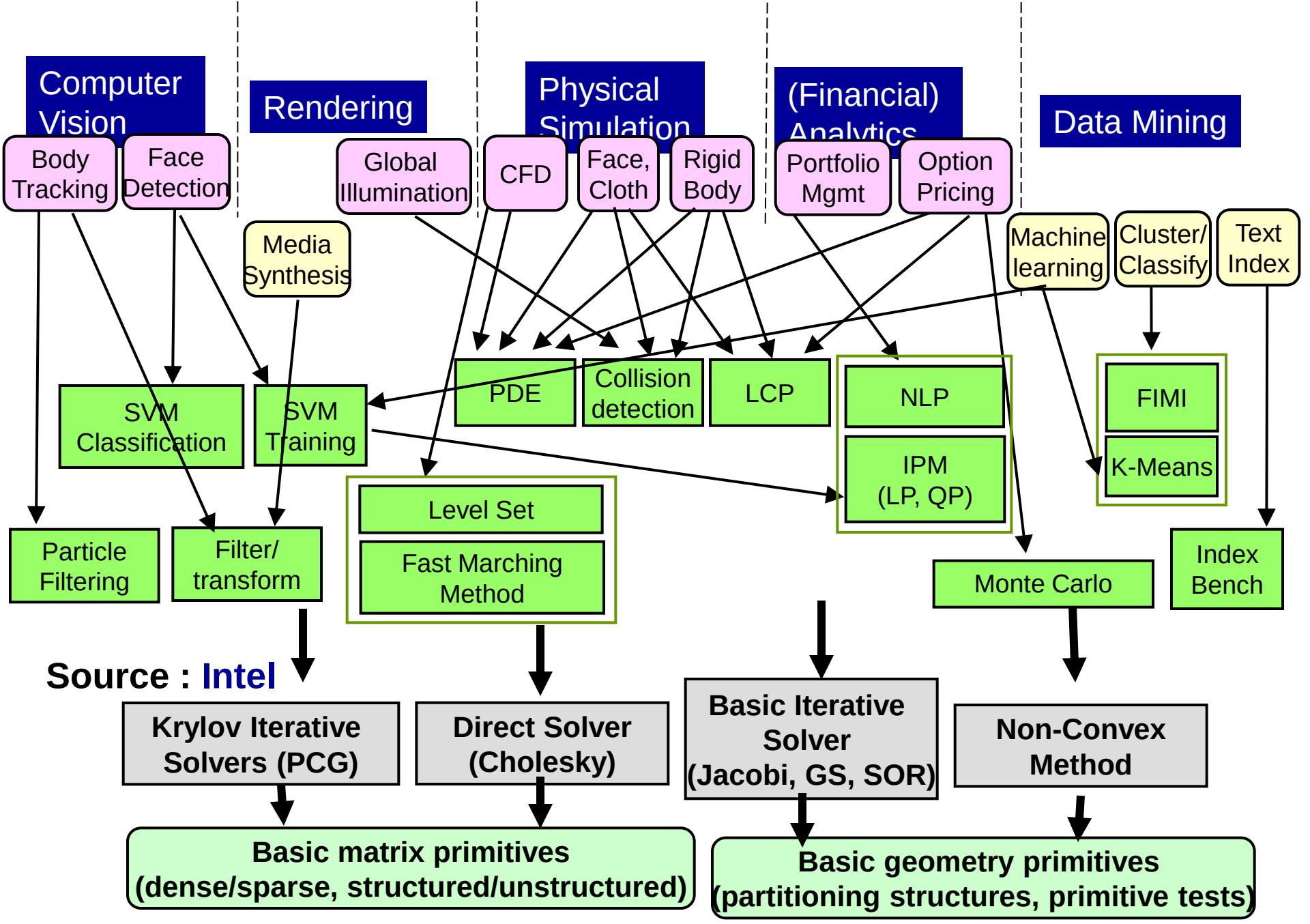
(Contd…)

- Video : Body Tracking and Ray-Tracing
- Search for Video based imaging & Creation of Videos with animation
- Games / Interactive 3D simulation
- Real-time realistic 3D Visualization of body systems
- Wall Street Financial Analysis; Business: Data Mining – Security: Real Time Video surveillance Astrophysics,
- BioInformatics – Pattern Search Algorithms

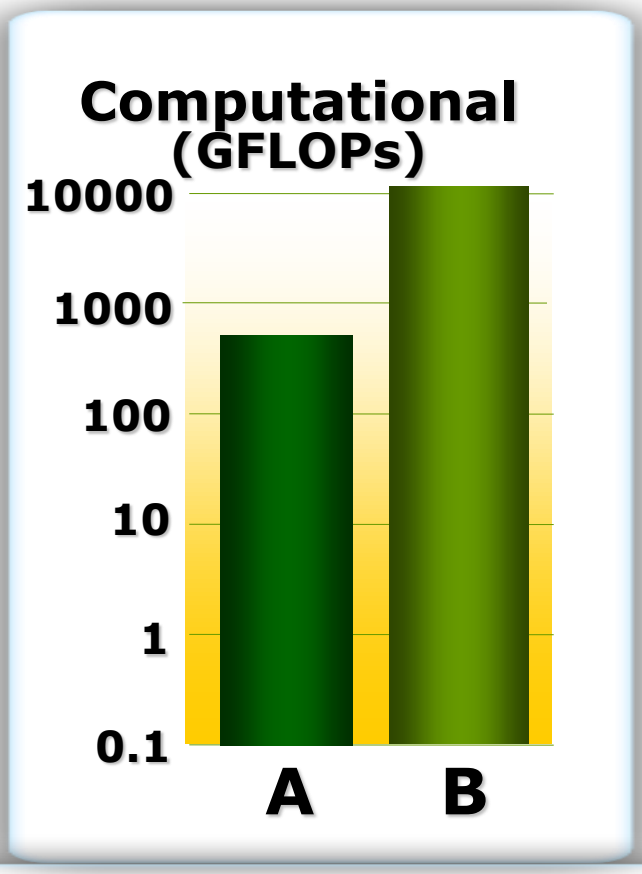
Emerging "Killer Apps of Tomorrow" Parallel Algorithms Design

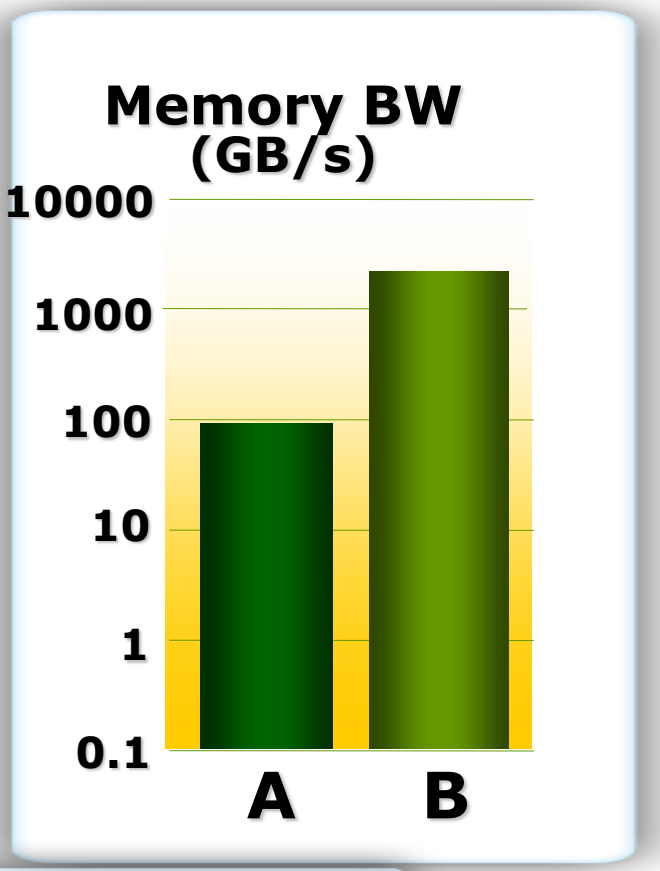
(Contd…)

- Speech Recognition & Speech Analysis – Modelling and Identifying using multi-modal data
- Large Scale image searches Audi /Video Control Systems
- Ray Tracing Algorithms – Video & Physical Simulation
- Overlapping computations with interactions.
- Data Mining Algorithms


Computer Vision
Rendering
Physical Simulation
(Financial) Analytics
Data Mining
Body Tracking
Face Detection
Global Illumination
CFD
Face, Cloth
Rigid Body
Portfolio Mgmt
Option Pricing
Machine learning
Cluster/ Classify
Text Index
Media Synthesis
SVM Classification
SVM Training
PDE
Collision detection
LCP
NLP
IPM (LP, QP)
FIMI
K-Means
Particle Filtering
Filter/ transform
Level Set
Fast Marching Method
Monte Carlo
Index Bench
Source : Intel
Krylov Iterative Solvers (PCG)
Direct Solver (Cholesky)
Basic Iterative Solver (Jacobi, GS, SOR)
Non-Convex Method
Basic matrix primitives (dense/sparse, structured/unstructured)
Basic geometry primitives (partitioning structures, primitive tests)

Emerging “Killer Apps of Tomorrow” Simulation



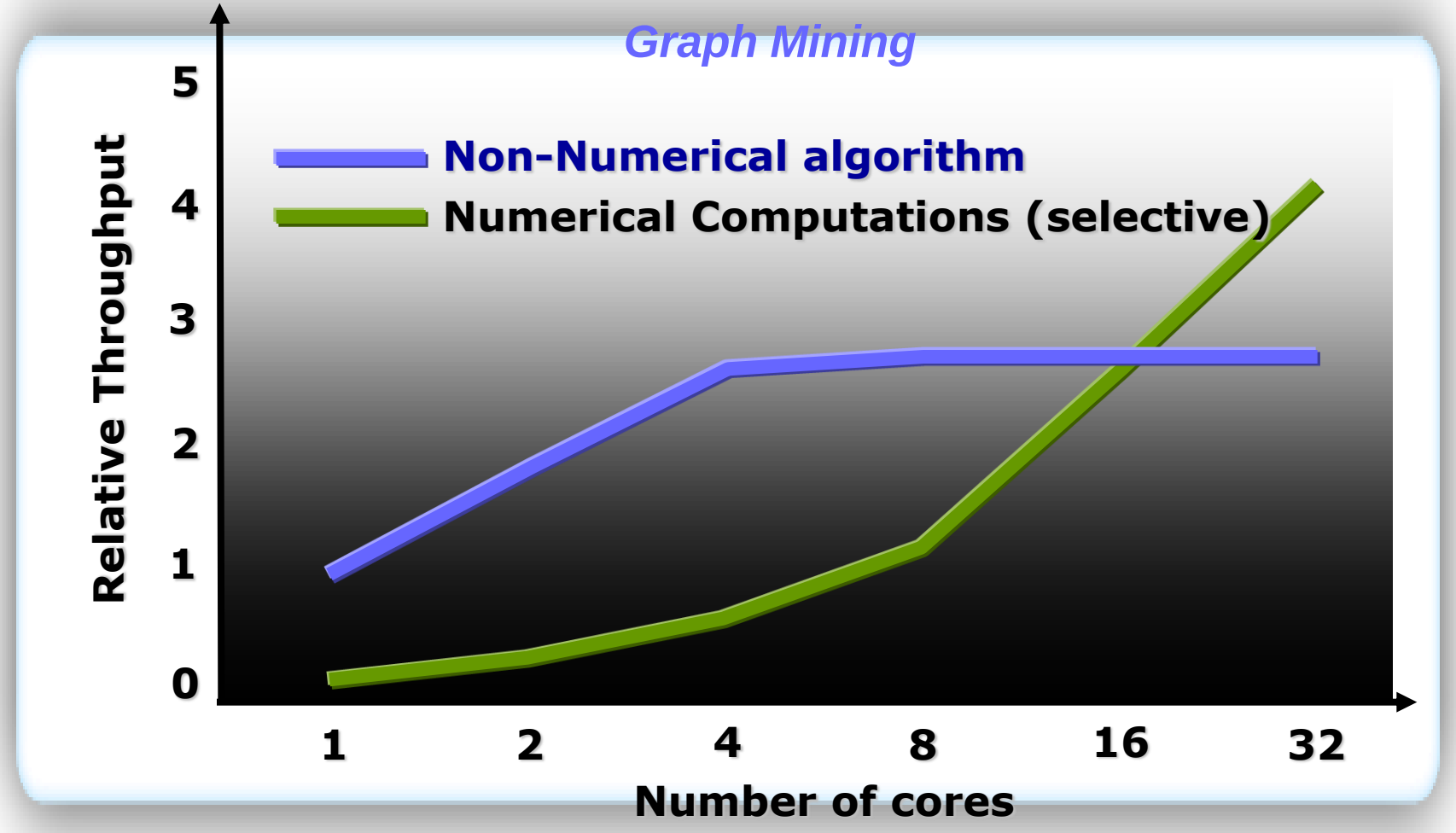


A: CFD, 75x50x50, 10 fps

B: CFD, 150x100x100, 30 fps

Source : Intel

Performance Analysis



Emerging "Killer Apps of Tomorrow":Summary

- RMS applications require significant increase in compute density
  - often non-linear extensions of existing usages
- RMS apps have a *converged common core of computing*
  - Workload convergence implies platform convergence
- Programmer productivity can be enhanced by platform
  - significant opportunity for silicon differentiation
- RMS apps will drive most future technology vectors
  - Programming to processor to memory technology
- Existing benchmarks are a poor proxy for these apps
  - Current popular suites must *evolve or go extinct!*

Emerging "Killer Apps of Tomorrow":References

- More web based info:
  - Justin Rattner, CTO, Intel, blog on "Cool Codes" http://blogs.zdnet.com/OverTheHorizon/
  - RMS Intro: http://www.intel.com/technology/magazine/computing/recognition-mining-synthesis-0205.htm
  - Platform 2015:
    - http://www.intel.com/technology/architecture/platform2015/

Source : Reference : [6]
http://www.intel.com

Summary

- An overview of Application Requirements for Multi-Core Systems
- An Overview of Threading

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- **Thank You**
- *Any questions ?*