Adaptive Tuning of Parallel Programs with CnC

Concurrent Collections (CnC) 2016

Murali Emani

LLNL-PRES-XXXXXX
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

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Computing Landscape is Dynamic

- Parallel systems are continuously evolving

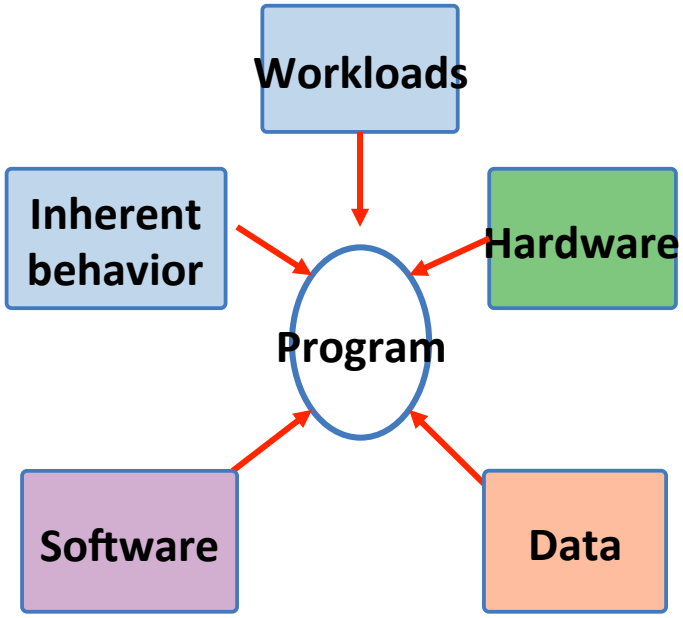
- Diverse architectures, workloads and data

Computing Landscape is Dynamic

- Parallel systems are continuously evolving
- Diverse architectures, workloads and data
- Execution environment is dynamic !
- Need adaptive parallelism partitioning and mapping.

Adaptive Parallelism Mapping

- Co-executing programs
- Varying degree of resource contention



- Compute/memory/IO bound
- Phased behavior

- Large number of components
- Increased chances of failure

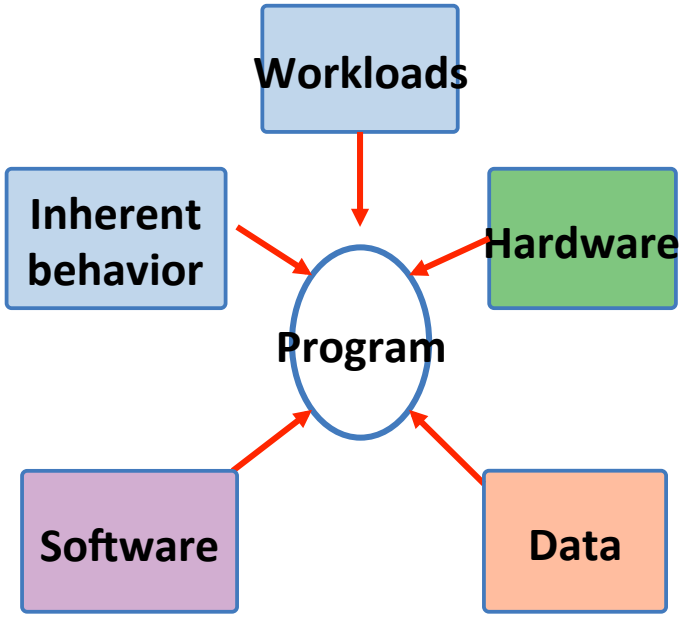
- Recurring upgrades
- Versions compatibility

- Varying amount of I/O
- Scalability issues

Adaptive Parallelism Mapping

Program performance is sensitive to the environment

- Co-executing programs
- Varying degree of resource contention



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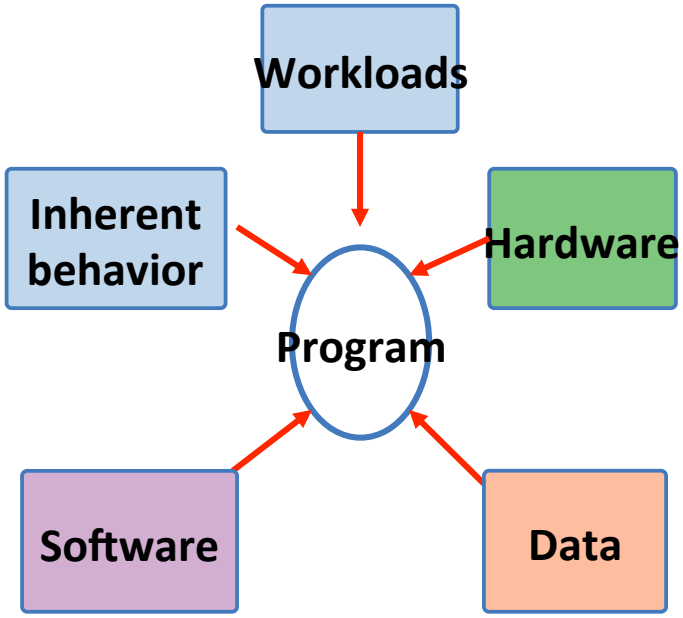
Adaptive Parallelism Mapping

Tune program for better performance

- Co-executing programs
- Varying degree of resource contention



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Tuners

- Is it enough to tune once and leave as-is ?
- Execution environment might change
- Tuning has to adapt to the environment through the program execution

Tuners in CnC

- Several knobs available to tune

- Step priorities
  - Rank steps based on amount / importance of work

    CNC_USE_PRIORITY

- Thread affinity
  - Improve locality and minimize thread movement

    FIFO_AFFINITY / step_tuner::affinity()

    CNC_PIN_THREADS

Tuners in CnC

- Number of threads

  CnC::debug::set_num_threads
  CNC_NUM_THREADS

- Tag-Ranges / Tuning Ranges
  - Group of steps instead of single instances

- Partitioning ranges

- Hierarchical CnC ?

Current work

(1) Optimal Tuner Selection

Determining

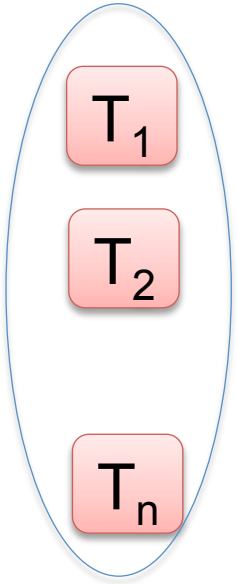
— which parameters to tune and

— how much to tune

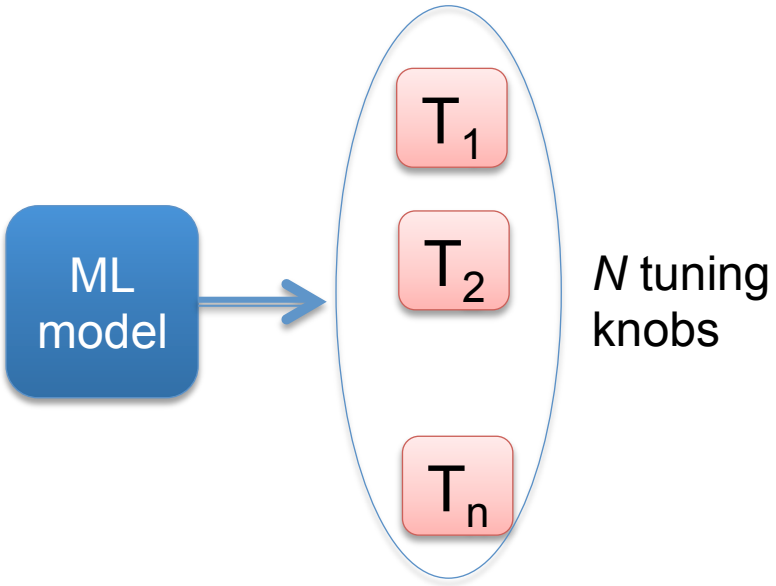
- Each tunable parameter may have different impact
- Strong / Weak Correlation analysis
- For example,
  - (a) #threads (b) affinity and (c) partitioner
  - Fibonacci series, with different combinations gave up to 2x speedup !!

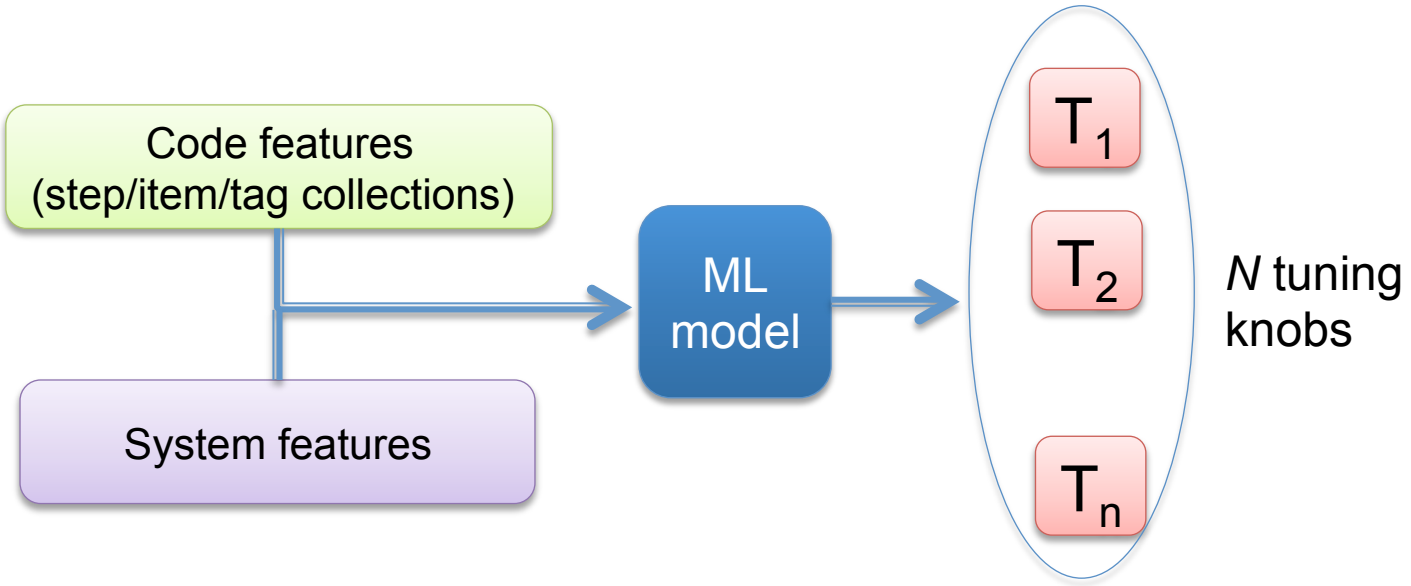
Machine learning could be of help

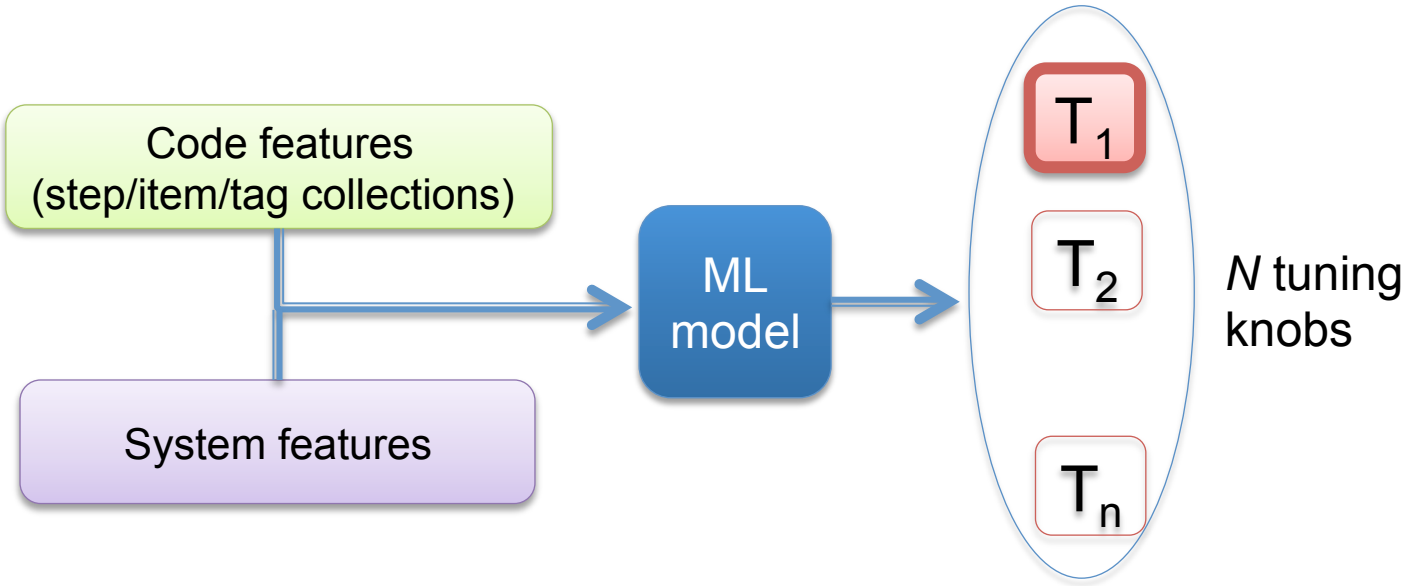
- ICS '06: "**Online power-performance adaptation of multi-threaded programs using hardware event-based prediction**", Curtis-Maury, M., Dzierwa, J., Antonopoulos, C. D., and Nikolopoulos, D. S.
- ISPASS'12: "**Using Utility Prediction Models to Dynamically Choose Program Thread Counts**.", Moore, R. W. and Childers, B. R
- PLDI'12: **" Parcae: A System for Flexible Parallel Execution**", A. Raman, A. Zaks, J. W. Lee, and D. I. August.
- CGO '13: "**Smart, Adaptive Mapping of Parallelism in the Presence of External Workload**", M. Emani, Z. Wang and M. O'Boyle
- PLDI'14: "**Adaptive, Efficient, Parallel Execution of Parallel Programs**", Sridharan, G. Gupta, and G. S. Sohi.
- PLDI'15: "**Celebrating Diversity: A Mixture of Experts Approach for Runtime Mapping in Dynamic Environments**", M. Emani and M. O'Boyle
- LCPC '16: "**Mapping Medley: Adaptive Parallelism Mapping with Varying Optimization Goals**", M.Emani



N tuning knobs


ML model
T_1
T_2
T_n
N tuning knobs


Code features
(step/item/tag collections)
System features
ML
model
T1
T2
Tn
N tuning
knobs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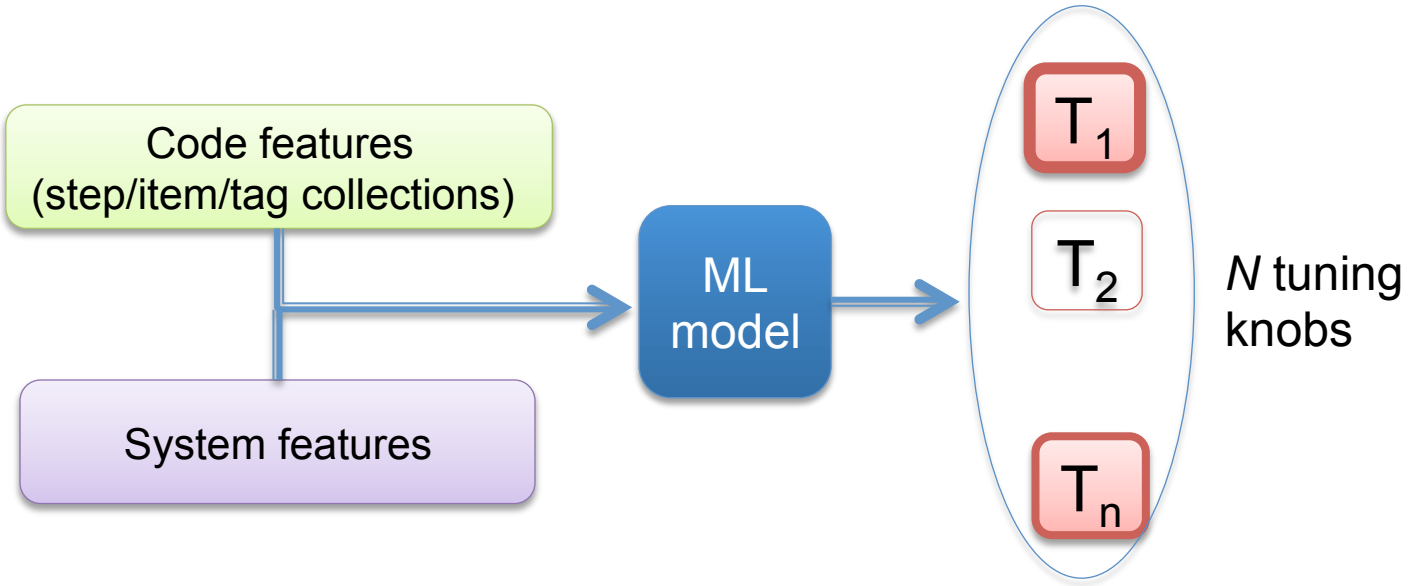
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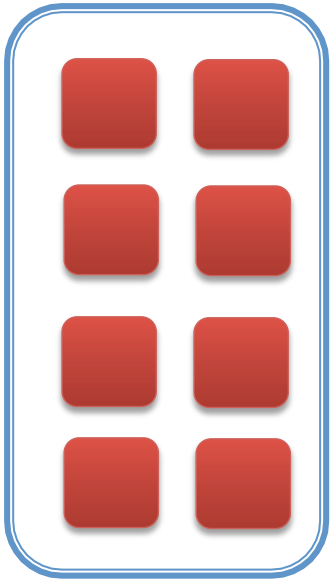
(2) How to determine optimal #threads

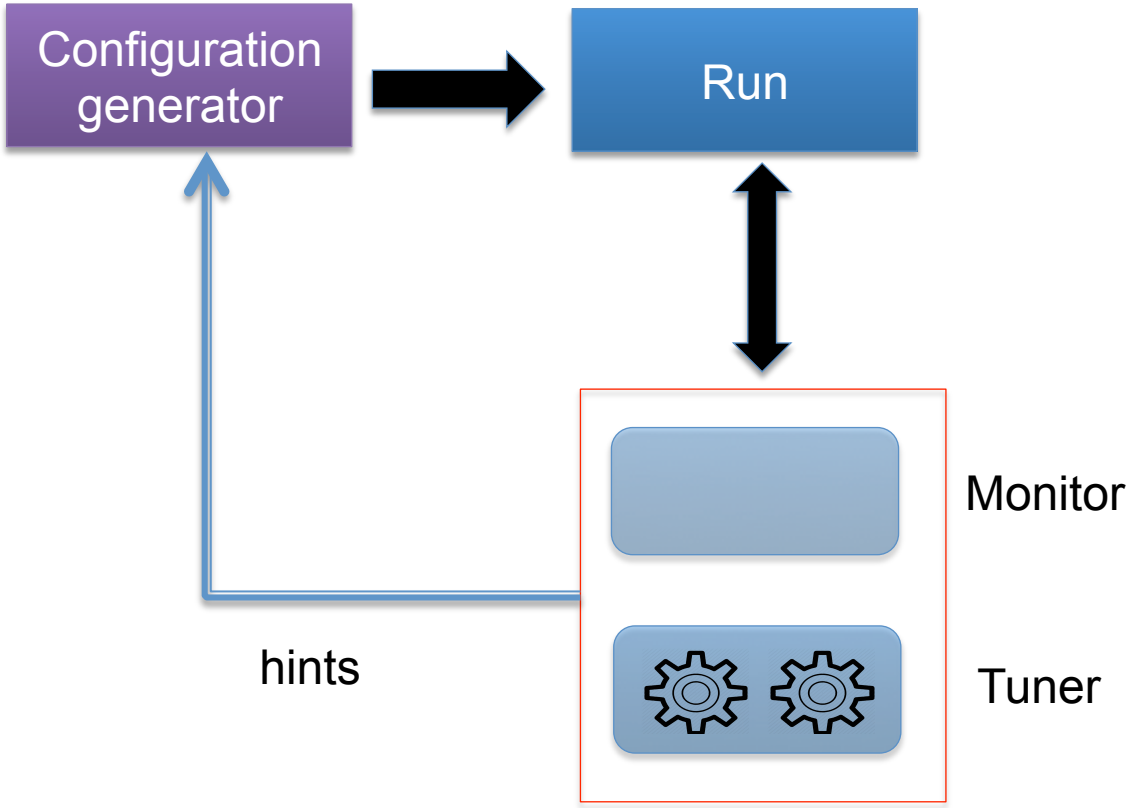
Step collection

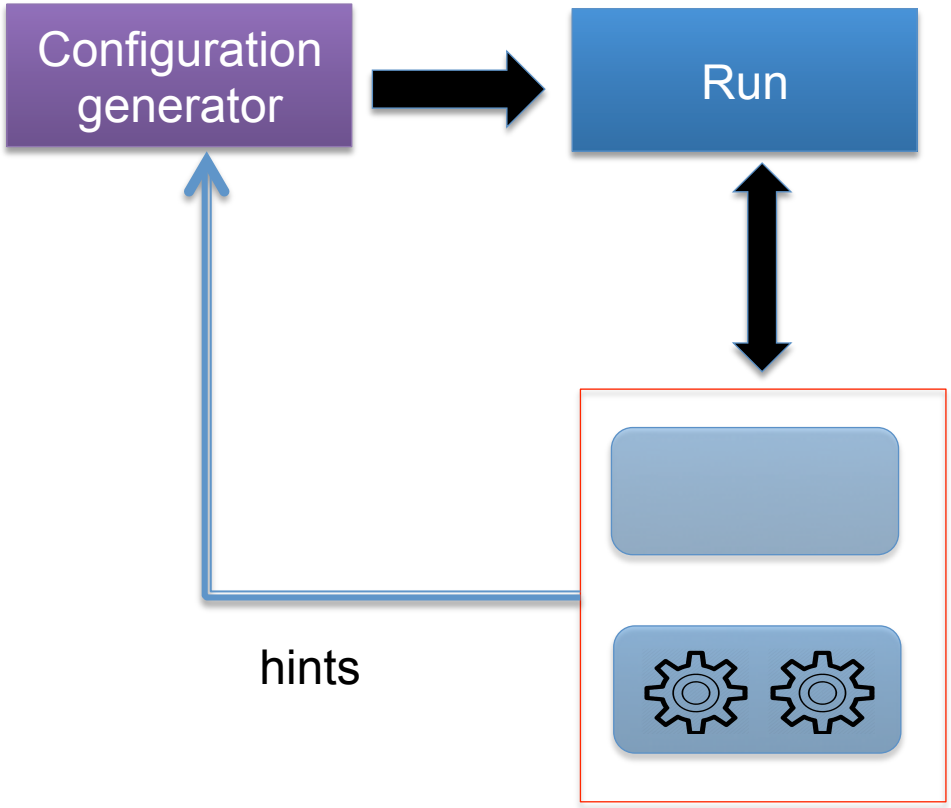


Schedule all instances

Schedule range of instances

How it works

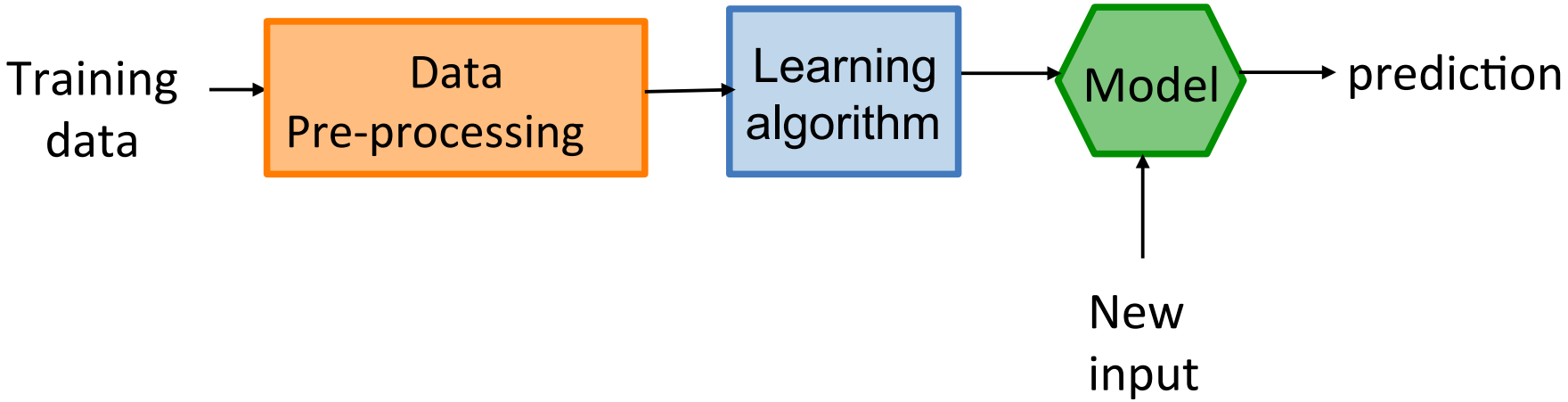




- May take time to reach optimal configuration
- Machine Learning can help reach quicker

Approach – Machine Learning

- Hand crafted solutions infeasible



- Train offline, deploy online

Challenges

- Training Data
  - Experiment Design space
  - Prune data

- Supervised / Unsupervised
  - Semi-supervised ?
  - Start with a learned heuristic,
  - update and re-learn as and when required

- Active / Passive invoke
  - *Heartbeat* mode – monitor at regular intervals, or
  - As and when required

- Ensure no additional overhead

Summary

- Tuning needs to be adaptive
- Faster decision to tune can deeply impact performance
- Machine Learning could be one way forward.

Murali Emani,
Lawrence Livermore National Laboratory,
emani1@llnl.gov