# Do We Need to Handle Every Temporal Violation in Scientific Workflow Systems?

Yun Yang (& Xiao Liu) – 杨耘 (yyang@swin.edu.au)
http://www.ict.swin.edu.au/personal/yyang
SUCCESS
Swinburne University of Technology
Melbourne, Australia

# SUCCESS – A Brief Introduction

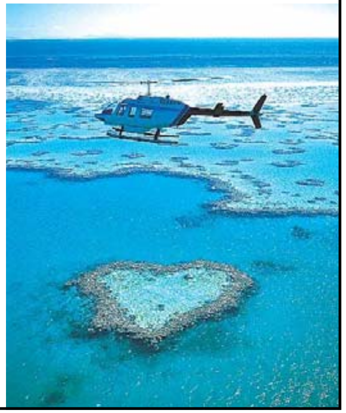
## Swinburne University Centre for Computing and Engineering Software Systems

- Swinburne is one of top 400 universities in the world
  - 2nd smallest one (only some 400 academic staff)
  - No 1 technological university in Australia
- SUCCESS has the strongest SE group in Australia
- SUCCESS 2011 figures on two top SE journals:
  - TSE – IEEE Trans. on Software Engineering
    4 (2+2) (world total: 48)
  - ToSEM – ACM Trans. on Software Engineering and Methodology
    2 (1+1) (world total: 18)

SWINBURNE UNIVERSITY OF TECHNOLOGY

# Melbourne – Capital City of Victoria


- a very dynamic city
- population over 4 million
- Australia’s cultural capital
- famous for parks and gardens
- “The Most Liveable City in the World”
- Welcome for (joint) PhD program etc.

# Outline

- Related Publications (and Acknowledgement)
- Temporal Violation Handling Point Selection
- Evaluation
- Conclusions

4

# Related Publications for This Talk

Acknowledgement: Assoc. Prof. Jinjun Chen; Dr Xiao Liu (two former PhD graduates)


- X. Liu, Y. Yang, Y. Jiang and J. Chen, *Preventing Temporal Violations in Scientific Workflows: Where and How*. IEEE Transactions on Software Engineering, 37(6):805-825, Nov./Dec. 2011
- J. Chen and Y. Yang, *Temporal Dependency based Checkpoint Selection for Dynamic Verification of Temporal Constraints in Scientific Workflow Systems*. ACM Transactions on Software Engineering and Methodology, 20(3):Article 9, Aug. 2011.
- J. Chen and Y. Yang, *Adaptive Selection of Necessary and Sufficient Checkpoints for Dynamic Verification of Temporal Constraints in Grid Workflow Systems*. ACM Transactions on Autonomous and Adaptive Systems, 2(2):Article 6, June 2007


SWINBURNE UNIVERSITY OF TECHNOLOGY

- Based on TOSEM Submission (under revision)

# Outline

- Related Publications (and Acknowledgement)
- Temporal Violation Handling Point Selection
- Evaluation
- Conclusions

# Functional Exceptions vs Non-Functional Temporal Violation

- Question: “Do we need to handle every temporal violation?”
  - Equivalent: “is every necessary and sufficient checkpoint a violation handling point?”
- Answer 1: “Yes”, we need to handle every temporal violation when it is detected in the first place
- Answer 2: “No”, we can further select a subset from the necessary and sufficient checkpoints
  - Cost effectiveness: the overall violation handling cost is huge
  - Self-recovery: auto recovery with future time redundancy

SWINBURNE UNIVERSITY OF TECHNOLOGY

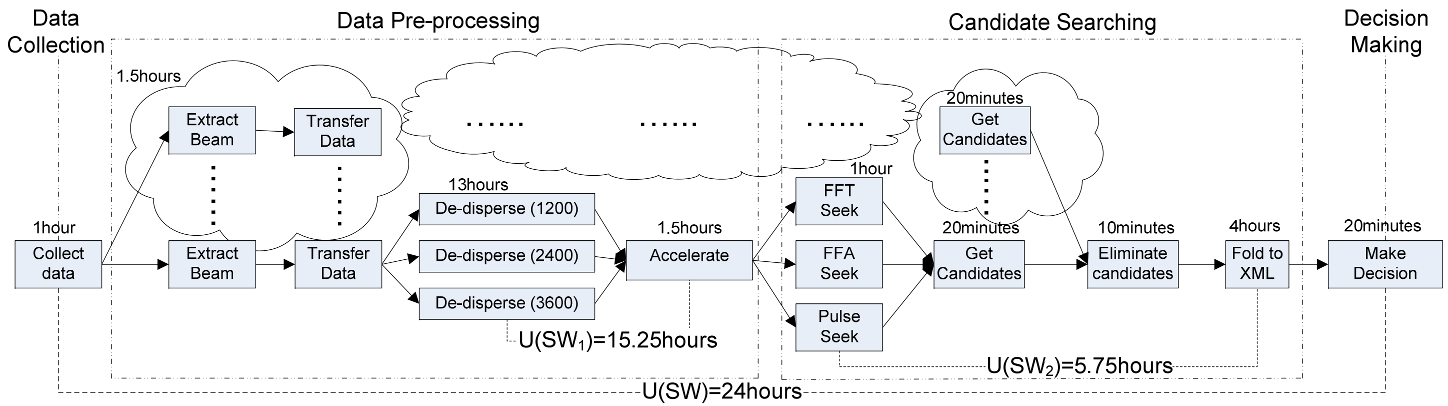
# Motivating Example

- Astrophysics: pulsar searching
- Pulsars: the collapsed cores of stars that were once more massive than 6-10 times the mass of the Sun
- http://astronomy.swin.edu.au/cosmos/P/Pulsar
- Parkes Radio Telescope (http://www.parkes.atnf.csiro.au/)

- Swinburne Astrophysics group (http://astronomy.swinburne.edu.au/) has been conducting pulsar searching surveys (http://astronomy.swin.edu.au/pulsar/) based on the observation data from Parkes Radio Telescope.
- Typical scientific workflow which involves a large number of data and computation intensive activities. For a single searching process, the average data volume (not including the raw stream data from the telescope) is over 4 terabytes and the average execution time is about 23 hours on Swinburne high performance supercomputing facility (http://astronomy.swinburne.edu.au/supercomputing/).

SWIN BUR NE SWINBURNE UNIVERSITY OF TECHNOLOGY

# Pulsar Searching




SWINBURNE UNIVERSITY OF TECHNOLOGY

9

# Problem Analysis

- Fundamental requirements:
  - Temporal conformance: the lower the violation rate, the better the temporal conformance is.
  - Cost effectiveness: the smaller the number of selected handling points, the better the cost effectiveness is.
- *Problem 1) How to measure temporal violations in a quantitative fashion*
  - *Solution: Probability based temporal consistency model*
- *Problem 2) How to decide whether a checkpoint needs to be selected as a handling point or not*
  - *Solution:* Adaptive temporal violation handling point selection strategy

SWINBURNE UNIVERSITY OF TECHNOLOGY

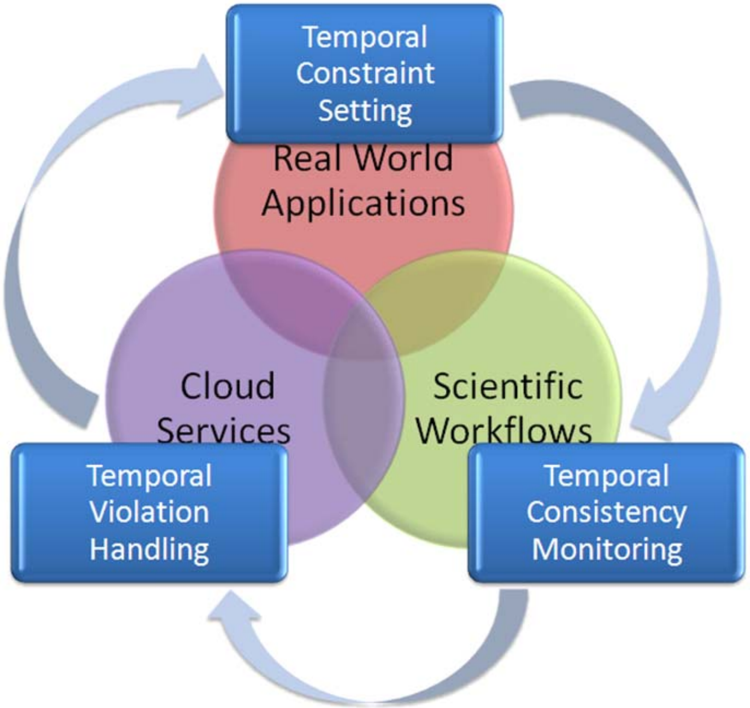
10

# Temporal QoS

- System performance
  - Response time
  - Throughput
- Temporal constraints
  - Global constraints: deadlines
  - Local constraints: milestones, individual activity durations
- Satisfactory temporal QoS
  - High performance: fast response, high throughput
  - On-time completion: low temporal violation rate

SWINBURNE UNIVERSITY OF TECHNOLOGY

# Temporal Framework




12

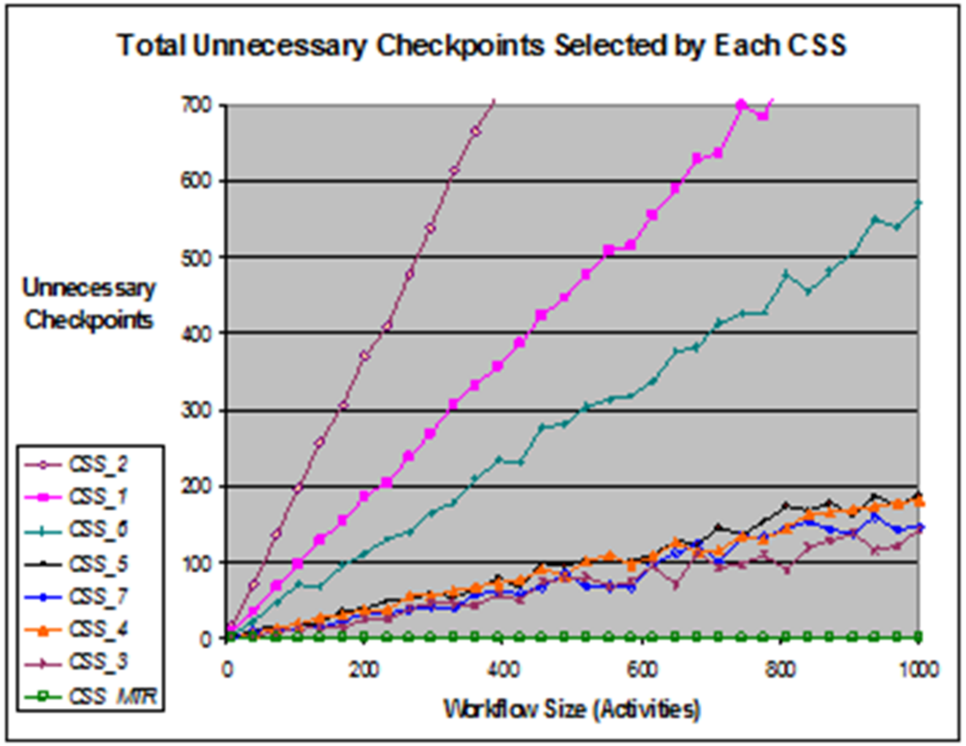
# Temporal Checkpoint Selection - Our Strategy

Necessary and Sufficient Checkpoint Selection Strategy

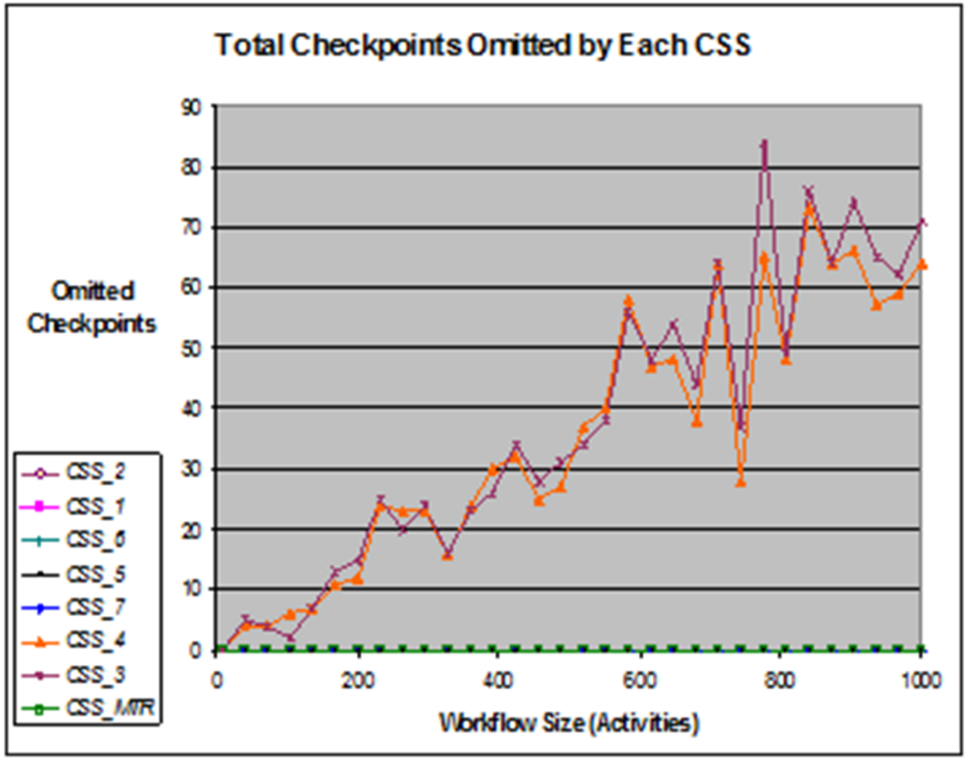
- Probability Time Redundancy
- Minimum Probability Time Redundancy
- DOMTR: Dynamically Obtaining Minimum Time Redundancy
- Theorem of Checkpoint Selection
- Proof of Necessity and Sufficiency

SWINBURNE UNIVERSITY OF TECHNOLOGY

# Results (1)

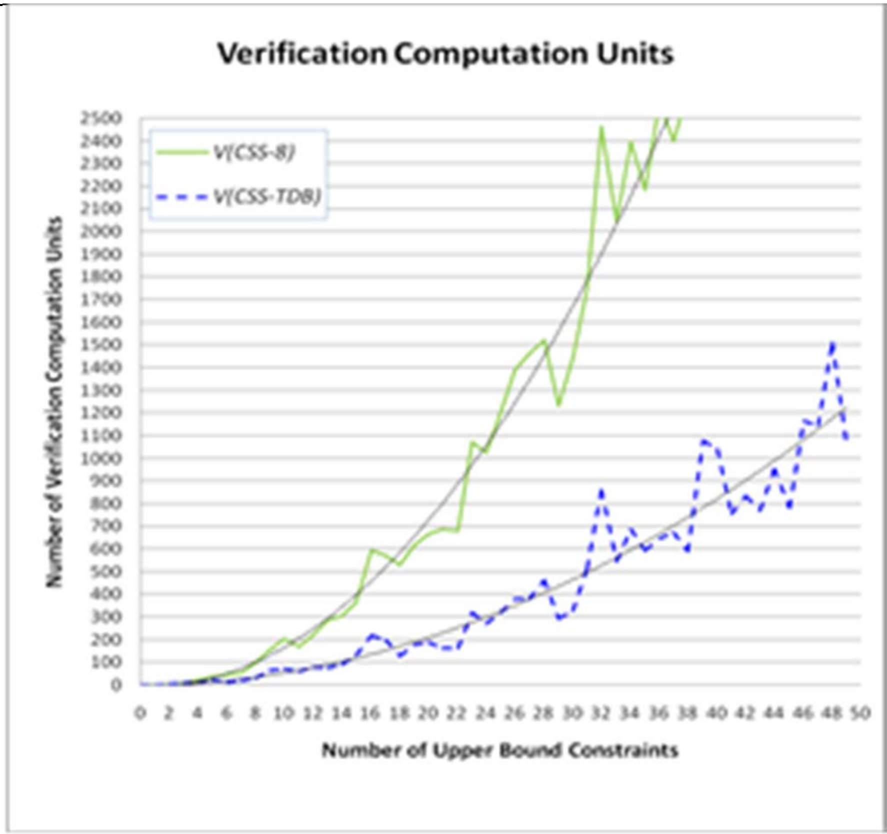

Total Unnecessary Checkpoints Selected by Each CSS
Unnecessary Checkpoints
700
600
500
400
300
200
100
0
0
200
400
600
800
1000
Workflow Size (Activities)
CSS_2
CSS_1
CSS_6
CSS_5
CSS_7
CSS_4
CSS_3
CSS_MTR

# Results (2)



Total Checkpoints Omitted by Each CSS
Omitted Checkpoints
Workflow Size (Activities)
0
10
20
30
40
50
60
70
80
90
0
200
400
600
800
1000
CSS_2
CSS_1
CSS_6
CSS_5
CSS_7
CSS_4
CSS_3
CSS_MTR

# Results (3)



Verification Computation Units
V(CSS-8)
V(CSS-TDB)
Number of Verification Computation Units
Number of Upper Bound Constraints

# Basic Idea (1)

- Strategy overview
  - Input:
    - A necessary and sufficient checkpoint $a_p$ selected by $CSS_{TD}$;
    - The maximum probability time deficit $MPTD(a_p)$;
    - The minimum probability time redundancy $MPTR(a_p)$;
    - The probability threshold for self-recovery *PT*;
    - The result of last temporal violation handling *Success* in *[true, false]* .
  - Output:
    - True or False $a_p$ as a temporal violation handling point
  - Steps:
    - Step 1: Adaptive modification of PT
    - Step 2: Temporal violation handling point selection

SWINBURNE UNIVERSITY OF TECHNOLOGY

17

# Basic Idea (2)

- Temporal Violation Handling Point Selection Rule
  - At activity $a_p$, with the probability of self-recovery $P(T)$ and the probability threshold $PT$, the rule for temporal violation handling point selection is as follows: if $P(T) > PT$, then the current checkpoint is not selected as a handling point; otherwise, the checkpoint is selected as a handling point.
- Quantitatively measure the probability of self-recovery $P(T)$
  - The model for "Probability of Self-Recovery": a probability distribution model, the maximum probability time deficit, the minimum probability time redundancy

SWINBURNE UNIVERSITY OF TECHNOLOGY

# Basic Idea (3)

- Adaptive Modification Process for Probability Threshold *PT*
  - Given current probability threshold *PT* and checkpoint $a_p$ , i.e. a temporal violation is detected at $a_p$, *PT* is updated as *PT*(1+r)*. Afterwards, based on our handling point selection rule, if $a_p$ is not selected as a handling point, then *PT* is updated as *PT*(1-r)*. Otherwise, *PT* remains unchanged. Here, *r* stands for the update rate.
  - The adaptive modification process is to increase the probability threshold , i.e. the probability of violation handling, where violation handling is triggered; or to decrease where violation handling is skipped if self-recovery applies.

SWINBURNE UNIVERSITY OF TECHNOLOGY

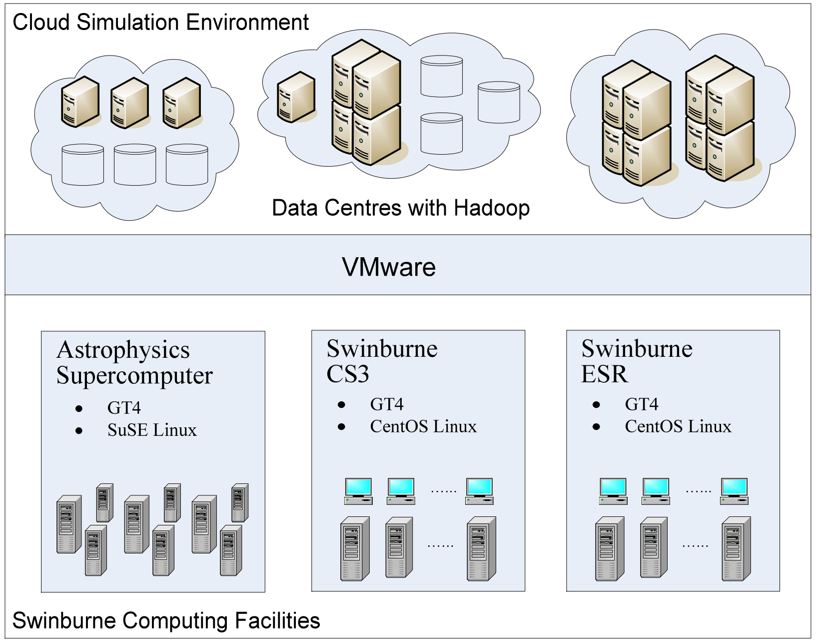
# Outline

- Related Publications (and Acknowledgement)
- Temporal Violation Handling Point Selection
- Evaluation
- Conclusions

SWINBURNE UNIVERSITY OF TECHNOLOGY

# Simulation Environment

- SwinCloud




SWINBURNE UNIVERSITY OF TECHNOLOGY

21

# Experimental Settings

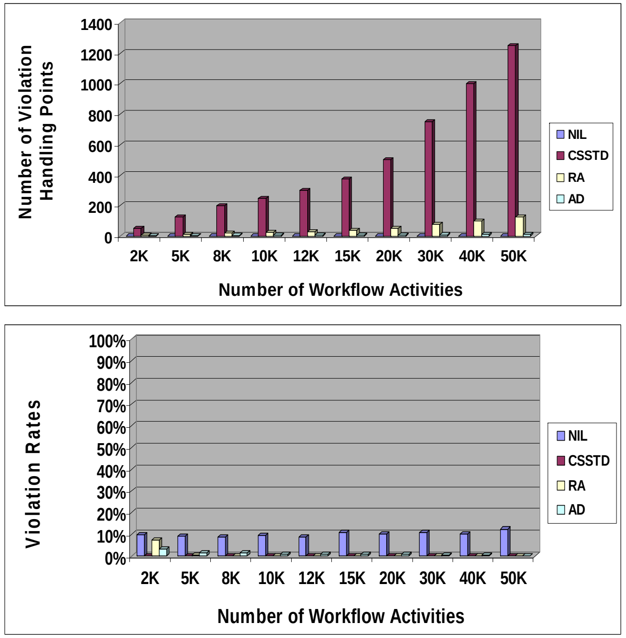
| | |
|---|---|
| **Scientific Workflows** | Scientific workflow size: from 2000 to 50,000 workflow activities;<br>Activity durations: all activity durations follow the normal distribution model. The mean duration is randomly selected from 30 to 3000 time units, and the standard deviation is set as 10% of its mean;<br>Temporal constraints: the initial build time probability for deadlines are set as 90% according to [Liu et al. 2011a];<br>Workflow segments: the average length of the workflow segments for subsequent activities is set as 20;<br>Random noises: the duration of one selected activity in each workflow segment is increased by 5%, 15% or 25% of its mean in different rounds. |
| **Temporal Violation Handling** | Temporal violation handling strategy: a pseudo strategy with 50% time compensation rate;<br>Size of subsequent workflow segment: randomly selected as 3 to 5;<br>Success rate: the success rate for violation handling is set as 80%. |
| $CSS_{TD}$ | Default values as defined in [Chen and Yang 2011]. |
| $RT$ | The fixed confidence threshold: $FT$ is set as 0.9, i.e. select 10% from the total checkpoints as adjustment points in a pure random fashion. |
| $AD$ | The update rate: $\gamma$ is initially set as 0.5 and gradually decreased to 0.05. |
| $NIL$ | Without temporal violation handling. |

SWINBURNE UNIVERSITY OF TECHNOLOGY

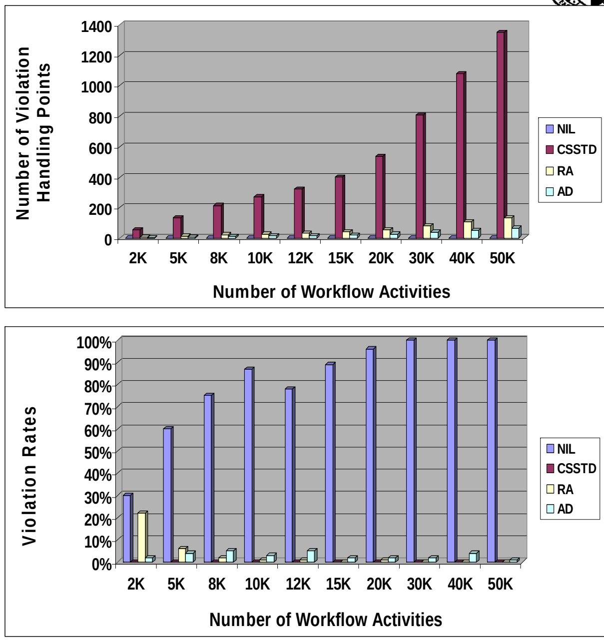
* Note that we have also applied our strategy with different distribution models, and the conclusions are consistent

22

# Experimental Results




Experimental results (Noise=0%).

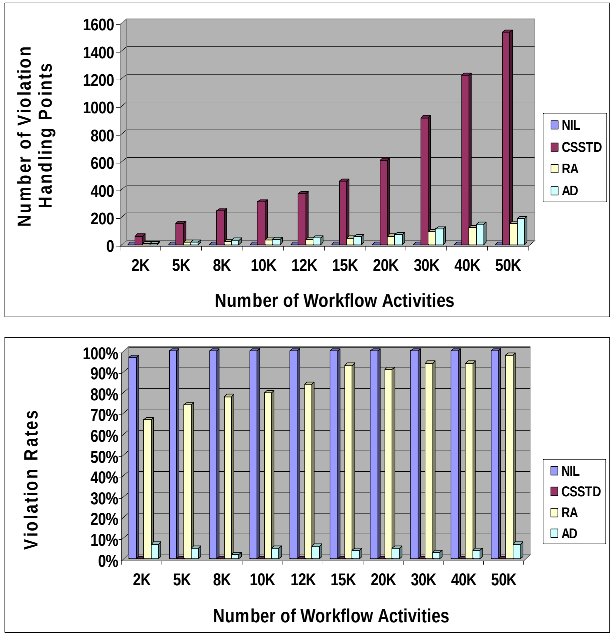



Experimental results (Noise=5%).

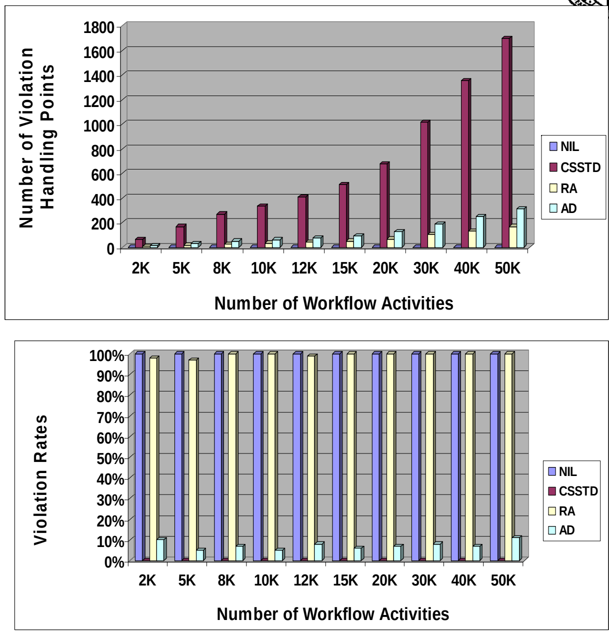
SWINBURNE UNIVERSITY OF TECHNOLOGY

23

# Experimental Results




Experimental results (Noise=15%).

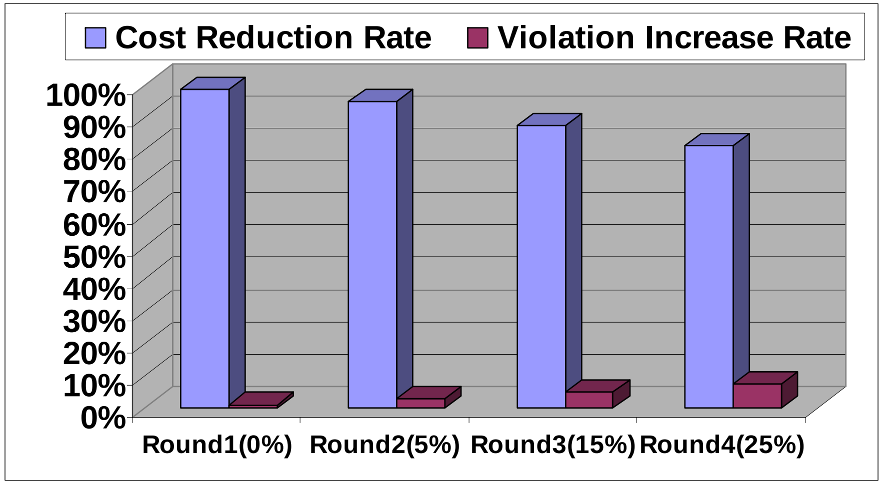



Experimental results (Noise=25%).

SWINBURNE UNIVERSITY OF TECHNOLOGY

24

# Experimental Results

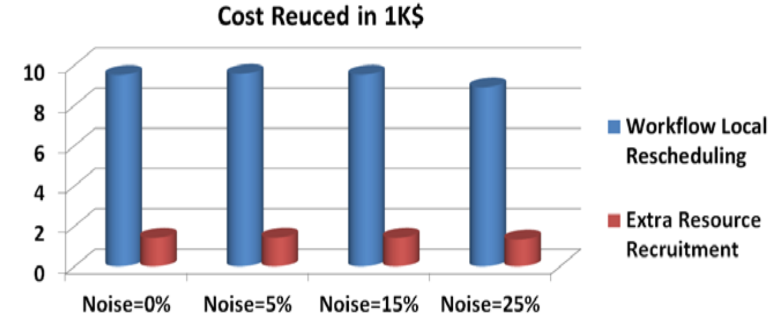



Cost reduction rate vs. violation increase rate

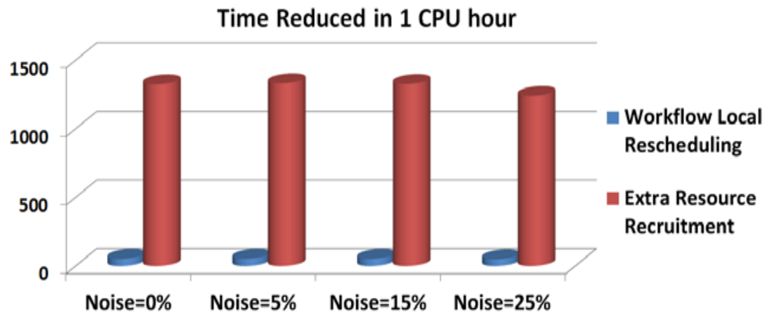
SWINBURNE UNIVERSITY OF TECHNOLOGY

25

# Experimental Results




Yearly cost reduction for the pulsar searching workflow.




Yearly time reduction for the pulsar searching workflow.

SWINBURNE UNIVERSITY OF TECHNOLOGY

26

# Outline

- Related Publications (and Acknowledgement)
- Temporal Violation Handling Point Selection
- Evaluation
- Conclusions

SWINBURNE UNIVERSITY OF TECHNOLOGY

# Conclusions

- Temporal conformance vs. cost effectiveness
- Not every necessary and sufficient checkpoint needs to be selected as a violation handling point
- Saving a lot of time and cost (e.g. over 98% under normal circumstance) while maintaining satisfactory temporal conformance (close to 0 violations)

# Future Work

Move from computation-intensive scientific workflows to instance-intensive business workflows

- Fast response time vs. high system throughput
- Different temporal consistency model
- Different monitoring strategies
- Different violation handling strategies

# End - Q&A

- Thanks for your attention!

SWINBURNE UNIVERSITY OF TECHNOLOGY

30