



**Tribhuvan University**

**Institute of Science and Technology**

**Evaluating Impact of Pruned Metadata on Low Inter-reference Recency Set (LIRS) Page Replacement Policy**

**Dissertation**

Submitted to:

Central Department of Computer Science and Information Technology  
Kirtipur, Kathmandu, Nepal

In Partial Fulfillment of the Requirements for the Degree Of  
Master of Science in Computer Science and Information Technology

Submitted By

**Dipak Prashad Bhatt**

**July, 2014**



**Tribhuvan University**  
**Institute of Science and Technology**

**Evaluating Impact of Pruned Metadata on Low Inter-reference Recency Set LIRS Page Replacement Policy**

**Dissertation**

Submitted to

Central Department of Computer Science and Information Technology  
Kirtipur, Kathmandu, Nepal

In partial fulfillment of the requirements for the Degree of  
Master of Science in Computer Science and Information Technology

Submitted By

**Dipak Prashad Bhatt**

**July, 2014**

**Supervisor**

**Mr. Arjun Singh Saud**



**Tribhuvan University**

**Institute of Science and Technology**

**Central Department of Computer Science and Information Technology**

Date: - .....

### **Supervisor's Recommendation**

We here by recommend that the dissertation prepared under our supervision by **Mr. Dipak Prashad Bhatt** entitled “**Evaluating Impact of Pruned Metadata on LIRS Page Replacement Policy**” be accepted as fulfilling in partial requirements for the degree of Master of Science in Computer Science and Information Technology. In my best knowledge this is an original work in computer science.

-----  
**Mr. Arjun Singh Saud**

Lecturer

Central Department of Computer Science and

Information Technology

Kirtipur, Kathmandu

**(Supervisor)**



**Tribhuvan University**  
**Institute of Science and Technology**  
**Central Department of Computer Science and Information Technology**

**LETTER OF APPROVAL**

We certify that we have read this dissertation work and in our opinion it is satisfactory on the scope and quality as a dissertation in the partial fulfillment for the requirement of Master of Science in Computer Science and Information Technology.

**Evaluation Committee**

---

**Asst. Prof. Nawaraj Paudel**  
**Head of Department**  
Central Department of Computer Science  
and Information Technology  
Tribhuvan University  
Kirtipur, Kathmandu

---

**Mr. Arjun Singh Saud**  
Lecturer  
Central Department of Computer Science  
and Information Technology  
Tribhuvan University  
Kirtipur, Kathmandu  
**(Supervisor)**

---

**(External Examiner)**

---

**(Internal Examiner)**

## Acknowledgement

First of all, I would like to express my heartfelt gratitude to my supervisor **Mr. Arjun Sing Saud**, Faculty member of the Central Department of Computer Science and Information Technology (CDCSIT), Tribhuvan University, Kirtipur for providing me invaluable suggestions, encouragement and strong guidelines throughout the research period. Without his cooperation and suggestions, this dissertation could not be completed.

This dissertation would not have been possible without the advice and support of my respected teachers, colleagues, friends and family members. Therefore, I would also like to express my special gratitude to all my honorable teachers of CDCSIT, TU, for providing me such a broad knowledge and inspirations within the time period of two years which definitely helped me to live independently in this competitive world of IT.

My special thanks go to my family, especially my respected parents, brothers and sister for their continuous encouragement, motivation and support. I really feel myself a lucky person for being a part of such a caring and loving family.

Lastly, but not the least, I wish to thank my friends Mr. Prakash Datt Bhatt, Mr. Bhupendra Sing Saud and Hari Sing Karki for their kind co-operation during my work.

I have done my best to complete this research work but there may be some errors as well. Thus, suggestions regarding the error of this dissertation will always be welcomed.

Dipak Prashad Bhatt  
Kathmandu, Nepal

## Abstract

To combat the problem of growing performance gap between system and rapidly improving CPU performance, virtual memory system has been becoming increasingly important for all memory management system. Virtual memory system needs an efficient page replacement algorithm to decide which page to be swapped out at page fault. Least Recently Used (LRU) is the one, which captures locality of reference but does not exploit frequency effectively. To minimize the deficiencies presented in LRU *Jiang and Zhang* [7] proposed a LIRS algorithm which aims at maintaining two key pieces of data access history- the recency and IRR. In this algorithm, the metadata of all accessed blocks in recent past are not maintained on the cache. And the pruning operation is performed to minimize space overhead. Due to such pruning operation, the algorithm can store only one history information of accessed block and cannot work always correct because of the constraint timing scope.

This dissertation, lets us to exploit the impact of pruned metadata on LIRS algorithm by maintaining metadata about all pages accessed in the past.

When workload has high reference locality, Derived LIRS has significantly superior performance than LIRS in terms of hit rate. Derived LIRS has higher hit rate up to 32.22% in comparison to LIRS. This is because Derived LIRS employs several history information items whereas the LIRS scheme uses only one history information item. However, Revised LIRS shows poorer performance on same traces due to the dominance of unused blocks in the cache.

# Table of Contents

<b>Details</b>	<b>Page No.</b>
<b>CHAPTER 1</b>	
<b>1. BACKGROUND AND PROBLEM FORMULATION</b>	<b>1-10</b>
1.1 Background	1
1.1.1 Memory Management	1
1.1.2 Virtual Memory	2
1.1.3 Paging	3
1.1.4 Page Replacement Algorithms	4
1.1.5 Working Set	4
1.1.6 Locality of Reference	5
1.1.7 Typical Memory Reference Pattern	5
1.1.7.1.1 Cyclic Pattern	5
1.1.7.1.2 Probabilistic Access Pattern	6
1.1.7.1.3 Temporally Clustered Pattern	6
1.1.7.1.4 Mixed Pattern	6
1.1.8 Performance Metrics	6
1.2 Rationale of the Study	7
1.2.1 Problem Statement	9
1.2.2 Objectives	9
1.3 Motivation	10
1.4 Thesis Organization	10
<b>CHAPTER 2</b>	
<b>2. LITERATURE REVIEW &amp; METHODOLOGY</b>	<b>11-18</b>
2.1 Literature Review	11
2.1.1 Optimal Page Replacement Algorithm	11
2.1.2 Random Page Replacement Algorithm	11
2.1.3 FIFO Page Replacement Algorithm	12
2.1.4 NRU Page Replacement Algorithm	12
2.1.5 Recency/Frequency Based Page Replacement Algorithms	12
2.1.5.1 LRU Page Replacement Algorithm	12

2.1.5.2	LFU Page Replacement Algorithm	13
2.1.5.3	MRU Page Replacement Algorithm	13
2.1.5.4	LRFU Page Replacement Algorithm	14
2.1.5.5	EELRU Page Replacement Algorithm	14
2.1.6	Enhanced LRU Algorithm	14
2.1.6.1	LRU-K Page Replacement Algorithm	14
2.1.6.2	2Q Page Replacement Algorithm	15
2.1.6.3	ARC Page Replacement Algorithm	15
2.1.7	CLOCK Based Page Replacement Algorithm	15
2.1.7.1	CLOCK	16
2.1.7.2	CAR	16
2.1.7.3	CAR with Temporal Filtering (CART)	16
2.1.7.4	CLOCK-Pro	16
2.1.8	Fuzzy Logic Based Page Replacement Algorithm	16
2.2	Research Methodology	17

## **CHAPTER 3**

<b>3.</b>	<b>PROGRAM DEVELOPMENT &amp; IMPLEMENTATION</b>	<b>19-39</b>
3.1	Development Methodology & Tools	19
3.1.1	Programming Language Used	19
3.1.2	Data Structure Used	19
3.2	LIRS	21
2.2.1	Pruning Operation	22
2.2.2	Algorithm	22
2.2.3	Flowchart	23
2.2.4	Tracing	24
3.3	Revised LIRS	26
3.3.1	Algorithm	27
3.3.2	Flowchart	29
3.3.3	Tracing	30
3.4	Derived LIRS	32
3.4.1	Algorithm	33
3.4.2	Flowchart	37



3.4.3	Tracing	37
-------	---------	----

## **CHAPTER 4**

<b>4.</b>	<b>DATA COLLECTION &amp; ANALYSIS</b>	<b>40-48</b>
4.1	Trace Data	40
4.2	Testing and Analysis	40
4.2.1	Replacement Performance on Looping Type Reference Pattern	41
4.2.2	Replacement Performance on Probabilistic Type Reference Pattern	43
4.2.3	Replacement Performance on Temporally Clustered Type Reference Pattern	45
4.2.4	Replacement Performance on Mixed Type Reference Pattern	46

## **CHAPTER 5**

<b>5.</b>	<b>CONCLUSION &amp; FUTURE WORK</b>	<b>49-50</b>
5.1	Conclusion	49
5.2	Future Work and Recommendations	50

<b>References</b>	51-53
-------------------	-------

<b>Bibliography</b>	54
---------------------	----

## List of Figures

<b>Details</b>	<b>Page No</b>
Figure 1.1 → Virtual Memory System	2
Figure 1.2 → Mapping process of logical memory to physical cache.	8
Figure 3.1 → Structure of the Linked List	19
Figure 3.2 → Flowchart of LIRS Algorithm	23
Figure 3.3 → Flowchart of Revised LIRS Algorithm	29
Figure 3.4 → Flowchart of Derived LIRS Algorithm	36
Figure 4.1 → Graph Showing Result for CS Pattern of Reference Pages	42
Figure 4.2 → Graph Showing Result for Glimpse Pattern of Reference Pages	43
Figure 4.3 → Graph Showing Result for Cpp Pattern of Reference Pages	44
Figure 4.4 → Graph Showing Result for sprite Pattern of Reference Pages	46
Figure 4.5 → Graph Showing Result for Multi1 Pattern of Reference Pages	47
Figure 4.6 → Graph Showing Result for Multi2 Pattern of Reference Pages	48

## List of Tables

<b>Details</b>	<b>Page No</b>
Table 3.1 → State at Virtual Time 1-9	24-26
Table 3.2 → State at Virtual Time 1-9	30-32
Table 3.3 → State at Virtual Time 1-9	37-39
Table 4.1 → Result for CS Pattern of Reference Pages	41
Table 4.2 → Result for Glimpse Pattern of Reference Pages	42
Table 4.3 → Result for Cpp Pattern of Reference Pages	44
Table 4.4 → Result for sprite Pattern of Reference Pages	45
Table 4.5 → Result for multi1 Pattern of Reference Pages	47
Table 4.6 → Result for multi2 Pattern of Reference Pages	48

## List of Abbreviations

2Q	-	Two Queues
ARC	-	Adaptive Replacement Cache
AFPR	-	Adaptive Fuzzy Page Replacement
CAR	-	Clock with Adaptive Replacement
CLOCK Pro	-	Clock with Pro
CPU	-	Central Processing Unit
EELRU	-	Early Eviction Least Recently Used
FINUFO	-	First In Not Used First Out
FIFO	-	First In First Out
FPR	-	Fuzzy Page Replacement
HIR	-	High Inter-reference Recency
HIRS	-	High Inter-reference Recency Set
IRG	-	Inter- Reference Gap
IRR	-	Inter- Reference Recency
LFU	-	Least Frequently Used
LIR	-	Low Inter-reference Recency
LIRS	-	Low Inter-reference Recency Set
LRFU	-	Least Recently Frequently Used
LRU	-	Least Recently Used
MMU	-	Memory Management Unit
MQ	-	Multi Queue
MRU	-	Most Recently Used
NRU	-	Not Recently Used
OS	-	Operating System
TLB	-	Translation Look-aside Buffer