



V I R T U A L   M E M O R Y   T E C H N I Q U E S  
F O R  
S M A L L   C O M P U T E R S

John Nguyen Thanh THUY, B.E. (Hons.)

Being a Thesis submitted  
for the  
DEGREE OF MASTER OF ENGINEERING SCIENCE  
in the  
ELECTRICAL ENGINEERING DEPARTMENT  
UNIVERSITY OF ADELAIDE

November, 1976

*Approved April 1978*

To my wife

Catherine-Nuong

## DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University, and to the best of my knowledge and belief it contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

J.N.T. THUY

## ACKNOWLEDGEMENTS

I wish to thank my supervisor, Dr. D.A. Pucknell for his wholehearted help, guidance and encouragement throughout the work of this thesis. I must also acknowledge the valuable assistance from C. Beare, C. Nettle, J. Rogers and especially B. Ackland for making use of his program.

Finally, I would like to thank my wife for her encouragement which has made everything possible.



<u>CHAPTER</u> <u>IV</u>	<u>REPLACEMENT ALGORITHMS</u>	
4.1	Direct Mapping	28
4.2	LRU Stack with Page-Associative Mapping	29
4.3	Simulation Results	30
4.4	Conclusion	35
<u>CHAPTER</u> <u>V</u>	<u>PREDICTION METHODS</u>	
5.1	Introduction	37
5.2	First Prediction Method	38
5.3	Second Prediction Method	40
5.4	Third Prediction Method	43
5.5	Conclusion	46
<u>CHAPTER</u> <u>VI</u>	<u>THE PREVENTION OF PUSHES</u>	
6.1	Introduction	48
6.2	Modified-Page Checking Scheme	49
6.3	Bottom-Page Avoiding Scheme	52
<u>CHAPTER</u> <u>VII</u>	<u>MODELS OF FAULT RATE AND</u> <u>AVERAGE ACCESS TIME FUNCTIONS</u>	
7.1	Introduction	59
7.2	Fault Rate Function	59
7.3	Average Access Time Function	62
<u>CHAPTER</u> <u>VIII</u>	<u>AN EVALUATION OF VIRTUAL MEMORY</u> <u>TECHNIQUES USING SUGGESTED</u> <u>MODELS</u>	
8.1	Introduction	65
8.2	Cost	65
8.3	Time	69
8.4	Limitations	73
8.5	Conclusion	74

<u>CHAPTER IX</u>	<u>SUGGESTIONS FOR FUTURE WORK</u>	
9.1	Introduction	75
9.2	Restructuring of Programs	75
9.3	Expansion of the Virtual Address Space	78
<u>CHAPTER X</u>	<u>CONCLUSION</u>	81
<u>REFERENCES</u>		84
<u>APPENDIX A</u>	<u>FLOW CHARTS OF THE SIMULATION PROGRAM</u>	A-1
<u>APPENDIX B</u>	<u>SIMULATION PROGRAM LISTING</u>	B-1
<u>APPENDIX C</u>	<u>NUMERICAL BACK-UP RESULTS</u>	C-1
<u>APPENDIX D</u>	<u>ADMENDMENT</u>	D-1

This thesis describes an investigation into a cost - effective method of expanding main memory of a computer. The method used is known as Virtual Memory which has the significant advantage of being transparent to programmers. Special attention is paid to small computers in a single - user environment. This is the focus of the study.

Basically this thesis consists of four main parts. Part 1 (Chapter 1 and 2) is a literature survey of the virtual memory concept for the last 15 years since it came to existence. Part 2 (Chapter 3, 4, 5 and 6) presents the results of the investigation in 3 main areas: Replacement algorithms, Prediction methods and the Prevention of Pushes. In Part 3 (Chapter 7,8), mathematical models of the virtual memory system are derived. An evaluation is made on all the techniques investigated using the suggested models. Part 4 (Chapter 9 and 10), discusses possible extensions of this project for future study which includes: Program restructuring and the expansion of the Virtual Address Space. Proper conclusions are then drawn.

Appendices contain the Listing and Flow Charts of the Simulation Program. Tables of Back-up numerical results are also included.



KEYWORDS AND SYMBOLS

- virtual memory : virtual storage.
- auxiliary memory : external storage, backing store.
- a page : a block: a group of words.
- page fault : page exception, translation exception.
- pre-paging : lookahead, predictive loading.
- a push : a write back, a paging-out, a transfer of data from main memory to backing store.
- a pull : a paging-in; a transfer of data from backing store to main memory.
- page frame : space in main memory for one page.
- fault rate : ratio of page faults and total number of references expressed in percentage.
- reference pattern : a sequence of page references in a program.
- address space : maximum range in which the CPU is capable of addressing. In V.M. System, it is called Virtual Address Space.

P	:	page size
M	:	main memory size
C	:	No. of page frames in main memory
F	:	total number of page faults of a program
f	:	fault rate
T	:	average access time
n	:	number of references executed in a program
$t_1$	:	access time of main memory
$t_s$	:	settling time of disk head or tape head
$t_t$	:	data transferring time per work of disk or tape
$\alpha$	:	co-efficient of page transfers
R	:	ratio of Pushes over Pulls
HR	:	Hit Rate
HR	=	$1-f$
HR%	=	$100\%-f\%$

Note: The term "memory" in this thesis is meant to be "main memory". For example -  
memory size : main memory size