Simulator pentru detectia hazardului de date in structurile pipe-line

Se vor considera o structura pipe-line de adincime (lungime) k si 2 instructiuni I si J cu I incarcata in structura pipe-line inaintea lui J.

O instructiune, i, este caracterizata printr-un domeniu D(i) - multimea resurselor necesare executiei si un rang R(i) - multimea rezultatelor obtinute in urma executiei.

Exista 3 tipuri de hazard de date in structurile pipe-line: RAW, WAR si WAW conform urmatoarelor reguli:

$$I : D(I) -> R(I)$$
$$J : D(J) -> R(J)$$
$$daca\ D(J) \cap R(I) \neq \Phi\ atunci\ exista\ hazard\ RAW$$
$$daca\ R(J) \cap D(I) \neq \Phi\ atunci\ exista\ hazard\ WAR$$
$$daca\ R(J) \cap R(I) \neq \Phi\ atunci\ exista\ hazard\ WAW$$

Se vor considera urmatoarele tipuri de instructiuni acceptate in simulator (numite *OPCODE*) :

"ADD", "DIV", "LD", "MUL", "SUB"

si un numar de 32 de registre (denumite *Rd* sau *Rs1* si *Rs2*):

"R1", "R2", "R3", "R4", "R5", "R6", "R7", "R8","R9", "R10", "R11", "R12", "R13", "R14", "R15", "R16","R17", "R18", "R19", "R20", "R21", "R22", "R23", "R24","R25", "R26", "R27", "R28", "R29", "R30", "R31", "R32"

Sintaxa unei instructiuni este (care realizeaza opetatie *Rd=Rs1 OPCODE Rs2*, cu *OPCODE* egal cu *ADD* (adunare), *SUB* – (scadere), *MUL* (inmultire) si *DIV* (impartire) sau *Rd=Rs1,* daca *OPCODE* este *LD*:

OPCODE Rd,Rs1,Rs2

Simulatorul citeste 2 fisiere de intrare:

- un fisier de configurare (numit *config.txt*) care continue 2 linii cu adincimea pipe-line (minim 3, maxim 10) si numarul maxim de instructiuni (minim 2, maxim 50).
- un fisier de instructiuni (*program.txt*) – care continue, pe cite o linie separate, programul analizat, folosindu-se sintaxa anterioara.

Se vor genera 2 fisiere de iesire:

- un fisier de analiza a hazardului – *analiza_hazard.txt* (care va indica ce instructiuni sint dependente una de cealalta)

- un fisier care precizeaza modul de executie a programului prin eliminarea hazardului – *eliminare_hazard.txt* (prin intirzierea minima a incarcarii instructiunilor)

Exemple de fisiere:

Structura pipe_line cu adincimea 5, maxim 15 instructiuni in program:

config.txt
5
15

program.txt

```
ADD R1,R2,R3
SUB R4,R1,R5
ADD R1,R1,R5
MUL R4,R6,R7
DIV R7,R3,R5
LD R1,R3
ADD R32,R1,R5
LD R32,R9
ADD R7,R8,R5
ADD R19,R7,R32
SUB R19,R7,R32
MUL R19,R7,R32
SUB R19,R7,R32
ADD R29,R7,R32
ADD R19,R27,R30
```

analiza_hazard.txt

IN	OPCODE	DEST	SOURCES	DIST	DEPEND	HAZARD
0	ADD	R1	R2,R3			
1	SUB	R4	R1,R5	1	R1	RAW
2	ADD	R1	R1,R5	1	R1	WAR
				2	R1	WAW
3	MUL	R4	R6,R7	2	R4	WAW
4	DIV	R7	R3,R5	1	R7	WAR
5	LD	R1	R3	3	R1	WAW
6	ADD	R32	R1,R5	1	R1	RAW
7	LD	R32	R9	1	R32	WAW
8	ADD	R7	R8,R5			

9	ADD	R19	R7,R32	1	R7	RAW
				2	R32	RAW
				3	R32	RAW
10	SUB	R19	R7,R32	1	R19	WAW
				2	R7	RAW
				3	R32	RAW
11	MUL	R19	R7,R32	1	R19	WAW
				2	R19	WAW
				3	R7	RAW
12	SUB	R19	R7,R32	1	R19	WAW
				2	R19	WAW
				3	R19	WAW
13	ADD	R29	R7,R32			
14	ADD	R19	R27,R30	2	R19	WAW
				3	R19	WAW

eliminare_hazard.txt

IN	OPCODE	DEST	SOURCES	DIST	DEPEND
	HAZARD				
0	ADD	R1	R2,R3		
4	SUB	R4	R1,R5		
8	ADD	R1	R1,R5		
9	MUL	R4	R6,R7		
13	DIV	R7	R3,R5		
14	LD	R1	R3		
18	ADD	R32	R1,R5		
22	LD	R32	R9		
23	ADD	R7	R8,R5		
27	ADD	R19	R7,R32		
31	SUB	R19	R7,R32		
35	MUL	R19	R7,R32		
39	SUB	R19	R7,R32		

```
40      ADD    R29     R7,R32
==========================================================================
43      ADD    R19     R27,R30
==========================================================================
```

Se calculeaza si performanta structurii pipe-line:

$$P = \frac{numarul\ ideal\ de\ tacte\ pentru\ N\ instructiuni}{numarul\ efectiv\ de\ tacte\ pentru\ N\ instructiuni} = \frac{k+N-1}{M}$$

$$N\ numarul\ de\ instructiuni, M\ numarul\ total\ de\ tacte\ pipe-line$$

Exemplu de program

Sa se scrie un program care sa efectueze operatia: $m = \frac{a+b.c}{j} + \frac{d+e.f}{k} + \frac{g+h.i}{l}$ (toate variabilele cor fi stocate in registre) si sa se evalueze performanta structurii pipe-line cu adincimea 3.Se vor aloca cit mai multe registre posibil pentru a evita dependentele.
O alocare posibila este:

Variabila	Registru	Rezultat	Registru
a	R1	$b.c$	R14
b	R2	$a+b.c$	R15
c	R3	$\frac{a+b.c}{j}$	R16
d	R4	$e.f$	R17
e	R5	$d+e.f$	R18
f	R6	$\frac{d+e.f}{k}$	R19
g	R7	$h.i$	R20
h	R8	$g+h.i$	R21
i	R9	$\frac{g+h.i}{l}$	R22
j	R10	$\frac{a+b.c}{j} + \frac{d+e.f}{k}$	R23
k	R11		
l	R12		
m	R13		

Urmarindu-se strict operatiile din expresia aritmetica, rezulta codul:

Instructiune	Semnificatie
`MUL R14,R2,R3`	$b.c$
`ADD R15,R1,R14`	$a+b.c$

`DIV R16,R15,R10`	$\frac{a+b.c}{j}$
`MUL R17,R5,R6`	$e.f$
`ADD R18,R4,R17`	$d+e.f$
`DIV R19,R18,R11`	$\frac{d+e.f}{k}$
`MUL R20,R9,R10`	$h.i$
`ADD R21,R7,R20`	$g+h.i$
`DIV R22,R21,R12`	$\frac{g+h.i}{l}$
`ADD R23,R16,R19`	$\frac{a+b.c}{j}+\frac{d+e.f}{k}$
`ADD R13,R23,R22`	$m=\frac{a+b.c}{j}+\frac{d+e.f}{k}+\frac{g+h.i}{l}$

Fisierul de configurare este:

3
11

Se obtine analiza hazardului:

IN	OPCODE	DEST	SOURCES	DIST	DEPEND	HAZARD
0	MUL	R14	R2,R3			
1	ADD	R15	R1,R14	1	R14	RAW
2	DIV	R16	R15,R10	1	R15	RAW
3	MUL	R17	R5,R6			
4	ADD	R18	R4,R17	1	R17	RAW
5	DIV	R19	R18,R11	1	R18	RAW
6	MUL	R20	R9,R10			
7	ADD	R21	R7,R20	1	R20	RAW
8	DIV	R22	R21,R12	1	R21	RAW
9	ADD	R23	R16,R19			
10	ADD	R13	R23,R22	1	R23	RAW

si modul de executie cu intirzierea instructiunilor:

IN	OPCODE	DEST	SOURCES	DIST	DEPEND	HAZARD
0	MUL	R14	R2,R3			
2	ADD	R15	R1,R14			
4	DIV	R16	R15,R10			
5	MUL	R17	R5,R6			
7	ADD	R18	R4,R17			
9	DIV	R19	R18,R11			
10	MUL	R20	R9,R10			
12	ADD	R21	R7,R20			
14	DIV	R22	R21,R12			
15	ADD	R23	R16,R19			
17	ADD	R13	R23,R22			

Executia instructiunilor se desfasoara astfel:

S3			0		1		2	3		4		5	6		7		8	9		10
S2		0		1		2	3		4		5	6		7		8	9		10	
S1	0		1		2	3		4		5	6		7		8	9		10		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

tactul pipe-line

Performanta pipe-line va fi:

$$P = \frac{k+N-1}{M+k-1} = \frac{3+11-1}{18+3-1} = \frac{13}{20} = 65\%$$

Se pot realiza o reamplasare a instructiunilor pentru a mari distanta intre instructiunile dependente (fara a modifica logica programului) astfel:

Instructiune	**Semnificatie**
`MUL R14,R2,R3`	$b.c$
`MUL R17,R5,R6`	$e.f$
`MUL R20,R9,R10`	$h.i$
`ADD R15,R1,R14`	$a+b.c$
`ADD R18,R4,R17`	$d+e.f$

`ADD R21,R7,R20`	$g+h.i$
`DIV R16,R15,R10`	$\frac{a+b.c}{j}$
`DIV R19,R18,R11`	$\frac{d+e.f}{k}$
`DIV R22,R21,R12`	$\frac{g+h.i}{l}$
`ADD R23,R16,R19`	$\frac{a+b.c}{j}+\frac{d+e.f}{k}$
`ADD R13,R23,R22`	$m=\frac{a+b.c}{j}+\frac{d+e.f}{k}+\frac{g+h.i}{l}$

Se obtine noua analiza hazardului:

IN	OPCODE	DEST	SOURCES	DIST	DEPEND	HAZARD
0	MUL	R14	R2,R3			
1	MUL	R17	R5,R6			
2	MUL	R20	R9,R10			
3	ADD	R15	R1,R14			
4	ADD	R18	R4,R17			
5	ADD	R21	R7,R20			
6	DIV	R16	R15,R10			
7	DIV	R19	R18,R11			
8	DIV	R22	R21,R12			
9	ADD	R23	R16,R19			
10	ADD	R13	R23,R22	1	R23	RAW

si noul modul de executie cu intirzierea instructiunilor:

IN	OPCODE	DEST	SOURCES	DIST	DEPEND	HAZARD
0	MUL	R14	R2,R3			
1	MUL	R17	R5,R6			

==========
2 MUL R20 R9,R10
==========
3 ADD R15 R1,R14
==========
4 ADD R18 R4,R17
==========
5 ADD R21 R7,R20
==========
6 DIV R16 R15,R10
==========
7 DIV R19 R18,R11
==========
8 DIV R22 R21,R12
==========
9 ADD R23 R16,R19
==========
11 ADD R13 R23,R22
==========

Cu reamplasarea instructiunilor, executia instructiunilor se desfasoara astfel:

S3			0	1	2	3	4	5	6	7	8	9		10						
S2		0	1	2	3	4	5	6	7	8	9		10							
S1	0	1	2	3	4	5	6	7	8	9		10								
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

tactul pipe-line

Performanta pipe-line va fi acum:

$$P = \frac{k+N-1}{M+k-1} = \frac{3+11-1}{12+3-1} = \frac{13}{14} = 92.86\%$$

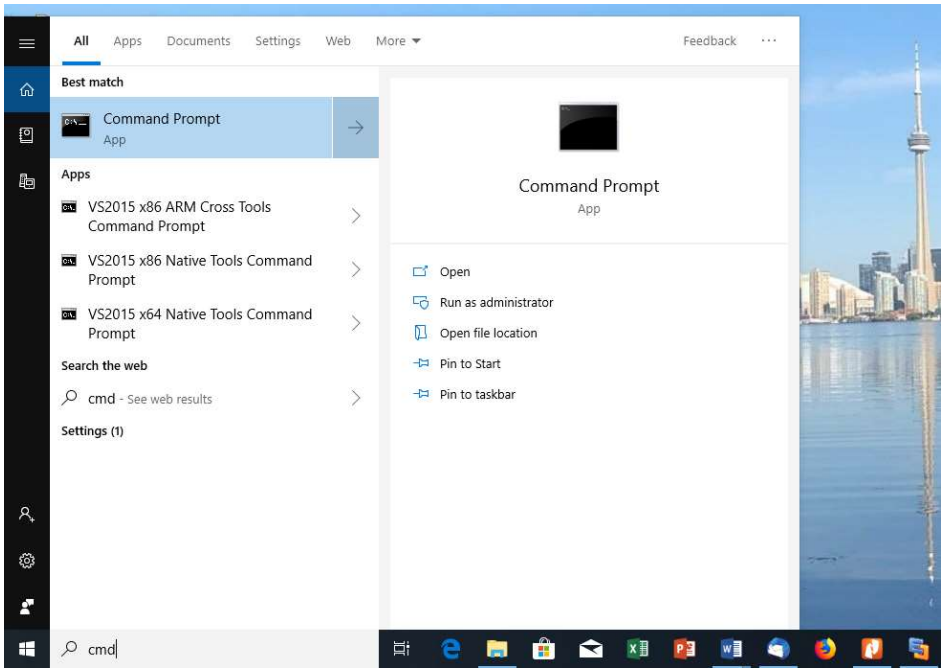
Desfasurarea lucrarii

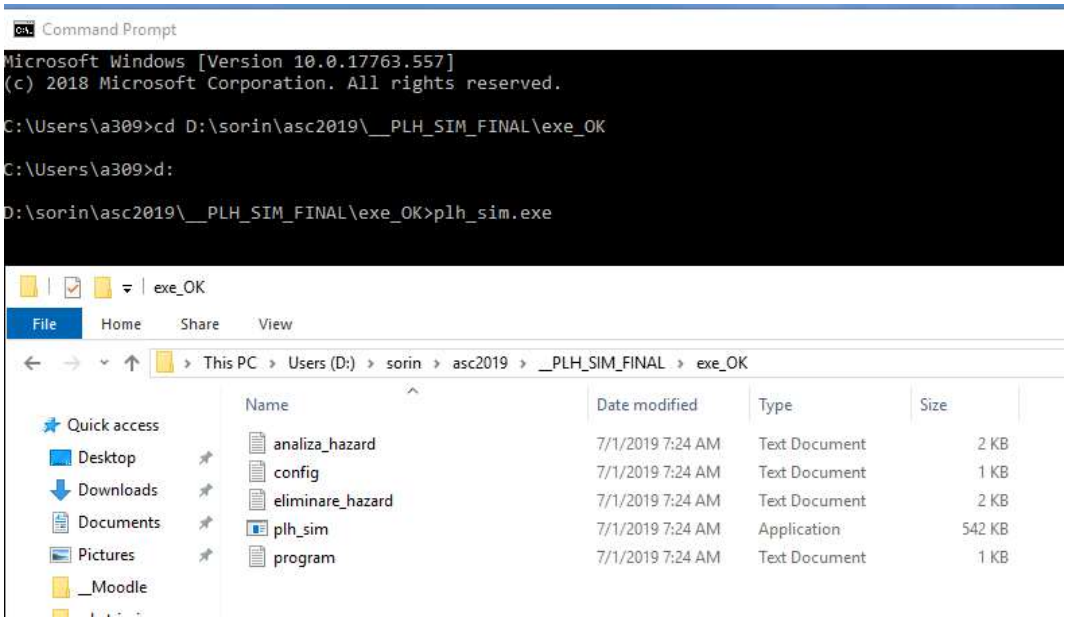
Se vor crea fisiere de configurare si de instructiuni pentru a se masura performantele pipe-line-lui urmarindu-se:

- determinarea dependentei dintre performanta si lungimea pipe-line
- determinarea dependentei dintre performanta si modul de scriere a programului (reamplasarea instructiunilor)

Lansarea in executie a simulatorului se face astfel:

- Se creaza fisierele **config.txt** si **program,txt** in acelasi subdirector cu programul **pl_haz_sim.exe**.
- Se deschide o fereastra de comanda (consola) cu comanda cmd (din meniul Windows)
- Se schimba calea in mod corespunzator caii subdirectoruli unde se afla fisierele de la primul punct
- Se executa in linia de comanda programul **pl_haz_sim.exe**





- Se vizualizeaza fisierele rezultate (analiza_hazard.txt si eliminare_hazard.txt) si performanta afisata in consola.

```
Command Prompt

D:\sorin\asc2019\__PLH_SIM_FINAL\exe_OK>plh_sim.exe
Se citeste fisierul de configurare ...
Adincimea pipe-line: 3
Numarul de instructiuni din program: 11
Se citeste fisierul de instructiuni ...
S-au citit 11 linii din fisierul de instructiuni, nu exista erori de sintaxa

Se scriu fisierele de rezultate ...

Analiza hazardului
==============================================================================
IN      OPCODE  DEST    SOURCES         DIST            DEPEND          HAZARD
==============================================================================
0       MUL     R14     R2,R3
==============================================================================
1       MUL     R17     R5,R6
==============================================================================
2       MUL     R20     R9,R10
==============================================================================
3       ADD     R15     R1,R14
==============================================================================
4       ADD     R18     R4,R17
==============================================================================
5       ADD     R21     R7,R20
==============================================================================
6       DIV     R16     R15,R10
==============================================================================
7       DIV     R19     R18,R11
==============================================================================
8       DIV     R22     R21,R12
==============================================================================
9       ADD     R23     R16,R19
==============================================================================
10      ADD     R13     R23,R22         1               R23             RAW
==============================================================================
Terminare analiza hazard


Corectia hazardului (prin intirzierea minima a instructiunilor)
==============================================================================
IN      OPCODE  DEST    SOURCES         DIST            DEPEND          HAZARD
==============================================================================
0       MUL     R14     R2,R3
==============================================================================
1       MUL     R17     R5,R6
==============================================================================
2       MUL     R20     R9,R10
==============================================================================
3       ADD     R15     R1,R14
==============================================================================
```

Se interpreteaza rezultatele si se modifica fisierele de intrare (configurarea si program) pentru a obtine, daca e posibil, o performanta mai buna prin indepartarea instructiunilor dependente (fara a modifica logica programului).