Microprocessor & Computer Architecture (µpCA)

UE19CS252

Dr. D. C. Kiran

Department of
Computer Science and Engineering

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Pipeline Processor: Branch Prediction 2

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Syllabus

~~Unit 1: Basic Processor Architecture and Design~~

Unit 2: Pipelined Processor and Design
- ~~3-Stage ARM Processor~~
- ~~5-Stage Pipeline Processor~~
- ~~Introduction to Pipeline Processor~~
- ~~What May Go Wrong?~~
- ~~Introduction to Hazards, Stalls,~~
- ~~Structural Hazards~~
- ~~Data Hazard~~
  - ~~RAW, WAR, WAW Hazards~~
- ~~Attacking Data Hazard~~
  - ~~Software Approach vs ardware Approach~~
- ~~Control Hazards~~
- ~~Branch History Table~~
- ~~1 bit Branch Prediction~~
- 2 bit Branch Prediction

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Text 1: "Computer Organization and Design", Patterson, Hennessey, 5th Edition, Morgan Kaufmann, 2014.

Reference 1:"Computer Architecture: A Quantitative Approach", Hennessey, Patterson, 5th Edition, Morgan Kaufmann, 2011.

Towards 2-Bit Predictor

What is the problem with 1-Bit predictor

- **Aliasing Problem**
  - branches with same lower order bits will reference the same entry, causing mutual prediction

- **Shortcomings with loops**
  - Always mispredict twice for every loop
    - Mispredict upon exiting a loop, since this is a surprise
    - If we repeat the loop, we'll miss again since we'll predict, branch not taken

What is the problem with 1-Bit predictor

```
for(i=0 ; i < m ; i++)
    for(j=0; j<n ; j++)
        begin S1; S2; ...; Sk end;
```

i	j	1-bit	
		Pred	**Outc**
0	0	NT	T
0	1	T	T
0	n	T	NT
1	0	NT	T
1	1	T	T

If m= 100 & n=10

2 miss prediction per Iteration

2 × *m* miss predictions for iterations

2x100= 200 miss predictions

8 x n Correct Predictions (Single Iteration)

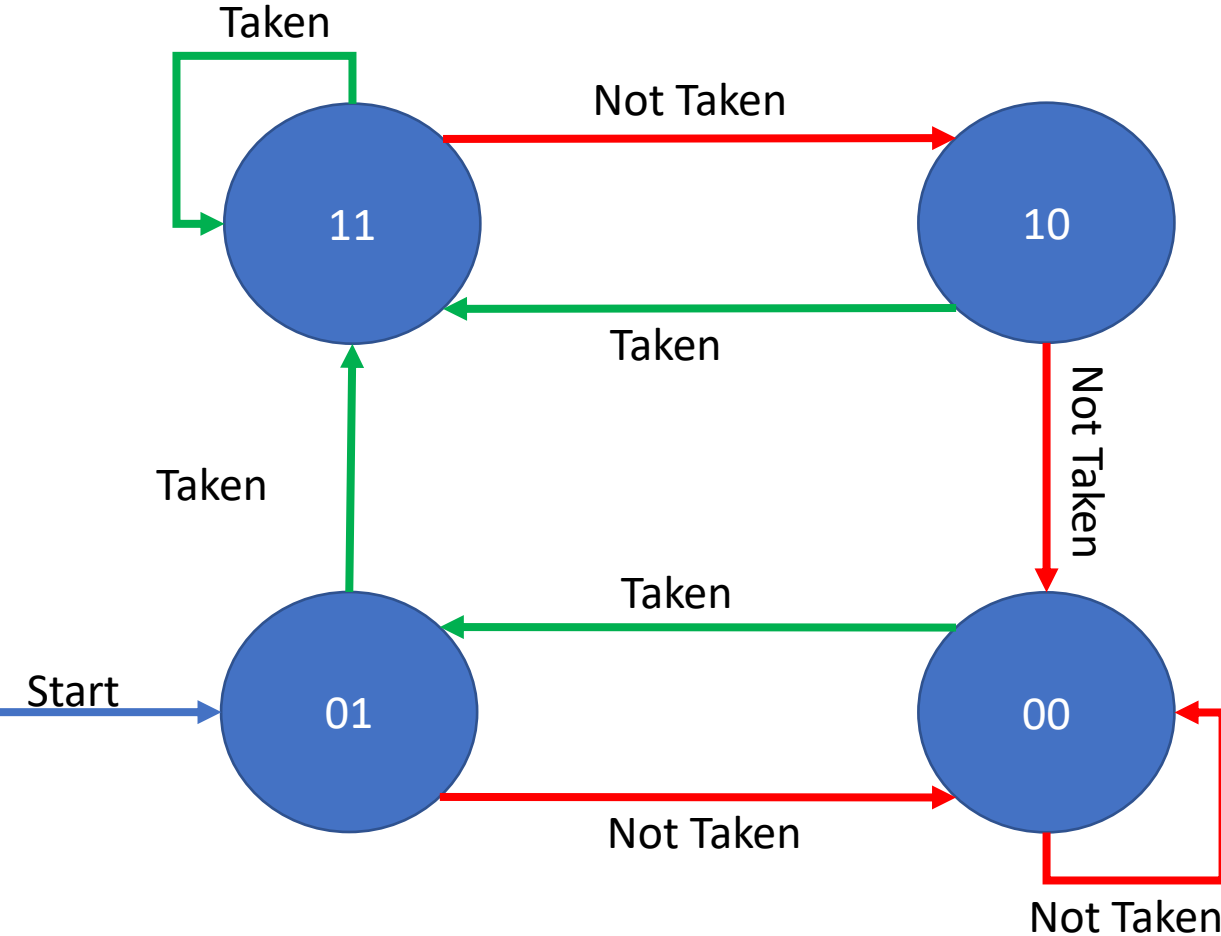8x10x100= 8000 Correct Predictions for nxm iterations

Accuracy of Correct Predictions = 8000/100= 80%
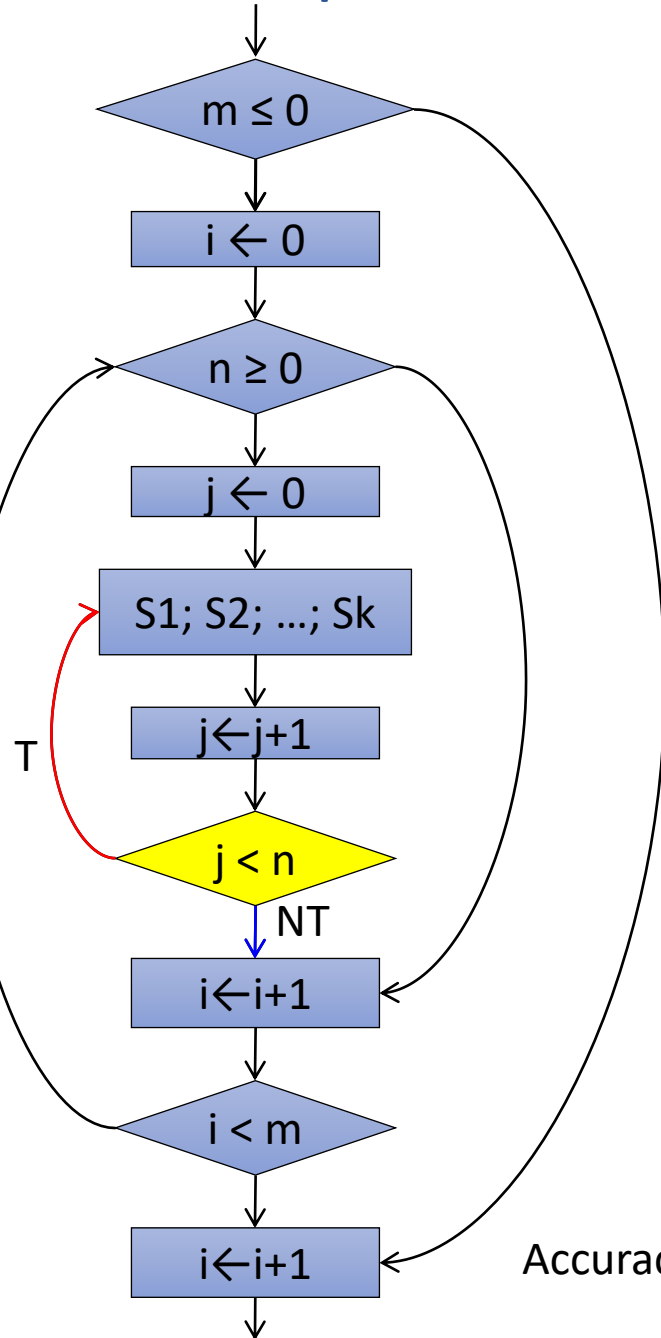
Two -bit Predictor
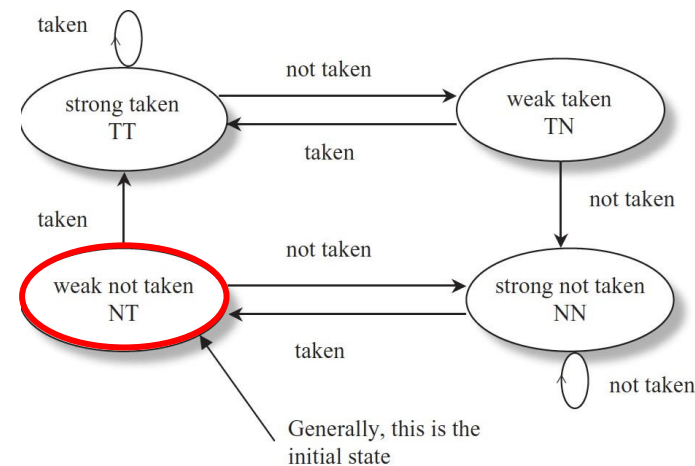
Think Twice Before Mis predicting

00: Strong Not Taken
01: Weak Not Taken
10: Weak Taken
11: Strong Taken

1st bit is prediction bit.
2nd bit is conviction bit (How much sure that the prediction is correct)

```
for(i=0 ; i < m ; i++)
    for(j=0; j<n ; j++)
        begin S1; S2; ...; Sk end;
```

| i | j | 1-bit | | 2-bit | | |
		Pred	Outc	State	Pred	Outc
0	0	NT	T	wNT	NT	T
0	1	T	T	sT	T	T
0	n	T	NT	sT	T	NT
1	0	NT	T	wT	T	T
1	1	T	T	sT	T	T

m + 1 misspredictions
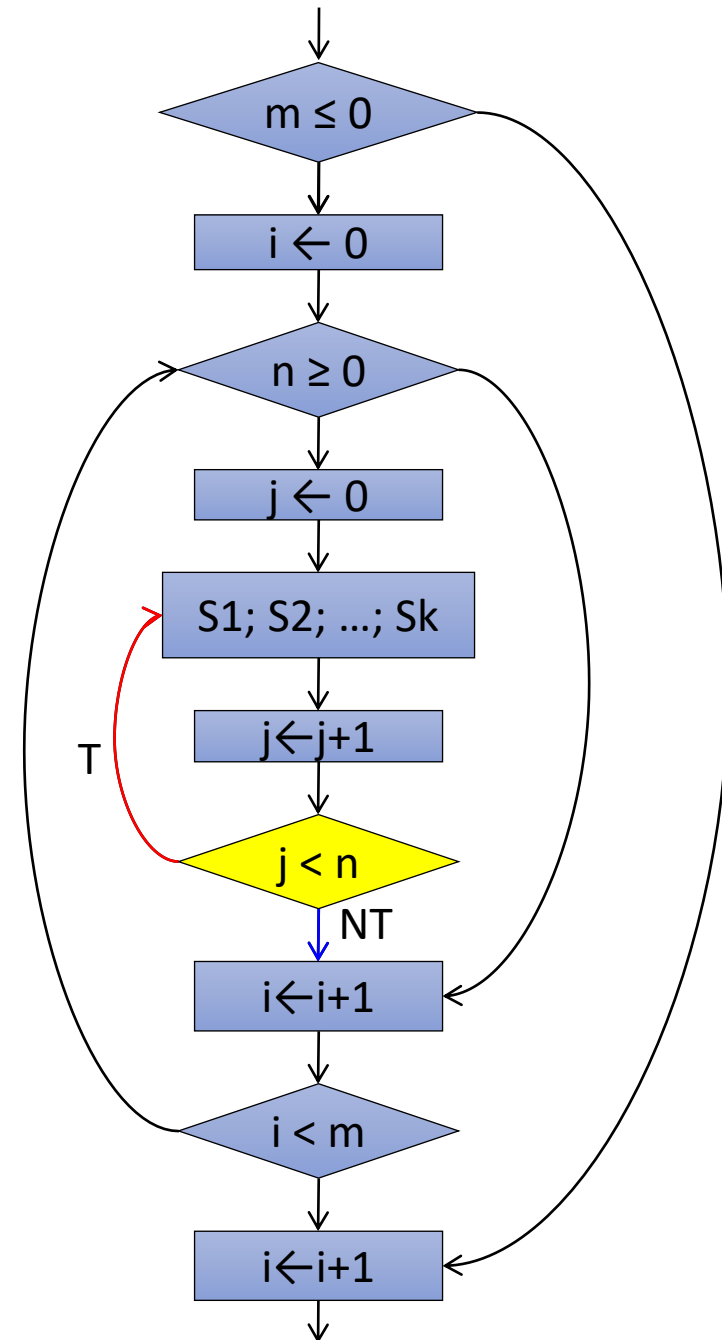
```
for(i=0 ; i < m ; i++)
    for(j=0; j<n ; j++)
        begin S1; S2; …; Sk end;
```

$m + 1$ misspredictions

|		1-bit		2-bit		
i	**j**	**Pred**	**Outc**	**State**	**Pred**	**Outc**
0	0	NT	T	wNT	NT	T
0	1	T	T	sT	T	T
0	n	T	NT	sT	T	NT
1	0	NT	T	wT	T	T
1	1	T	T	sT	T	T

If m= 100 & n=10

1 miss prediction per Iteration

1 + m miss predictions for iterations

1+100= 101 miss predictions

9 x n Correct Predictions (Single Iteration)

9x10x100= 9000 Correct Predictions for nxm iterations

Accuracy of Correct Predictions = 9000/101≈ 90%
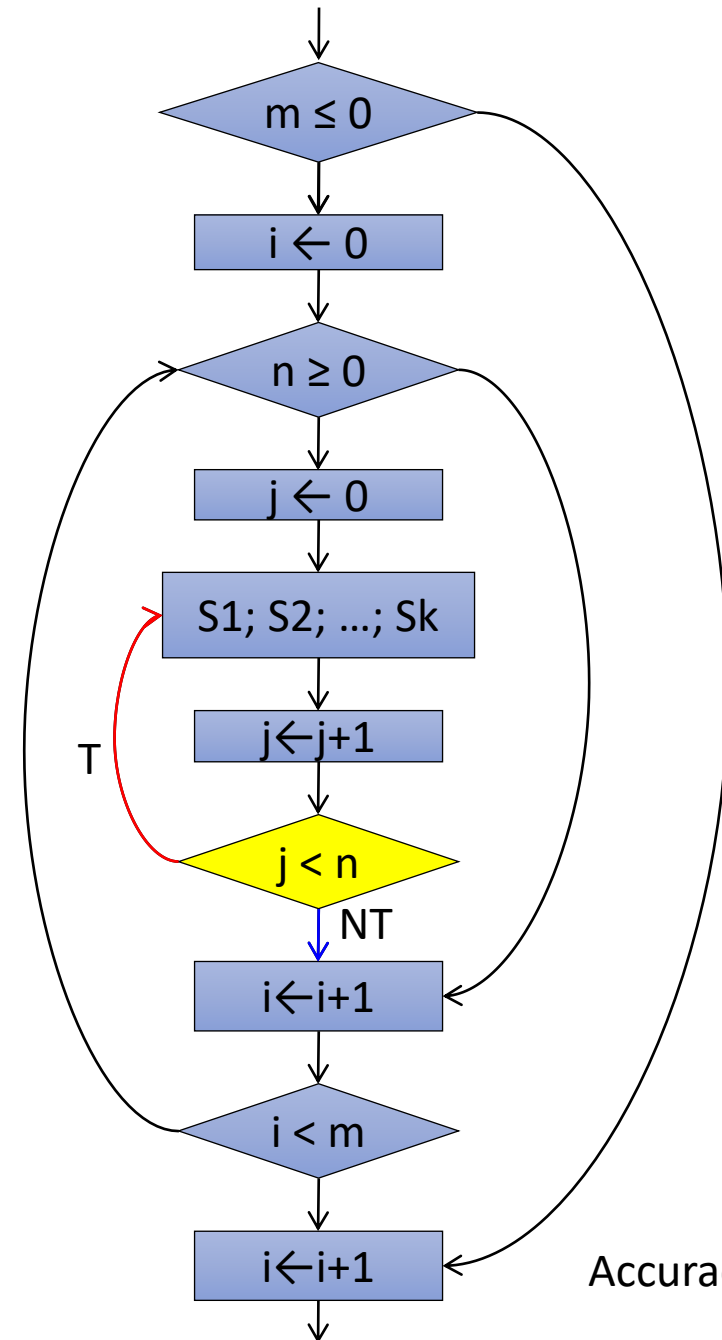
Two -bit Predictor: Initial state: 01
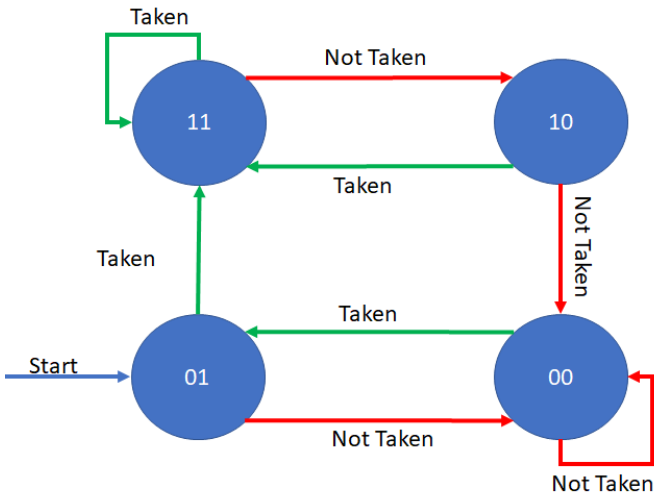
00: Strong Not Taken
01: Weak Not Taken
10: Weak Taken
11: Strong Taken

Consider a program with two branch statement with the following behavior

T T NT T NTT T T NT T T T TT NT T T T T NT

6 miss predictions

How many Miss Prediction?

01	11	11	10	11	10	11	11	11	10	11	11	11	11	11	10	11	11	11	11	10
T	T	NT	T	NT	T	T	T	NT	T	T	T	T	T	NT	T	T	T	T	NT	
X	v	X	v	X	v	v	v	X	v	v	v	v	v	X	v	v	v	v	X	

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Two -bit Predictor: Initial state: 11

00: Strong Not Taken
01: Weak Not Taken
10: Weak Taken
11: Strong Taken

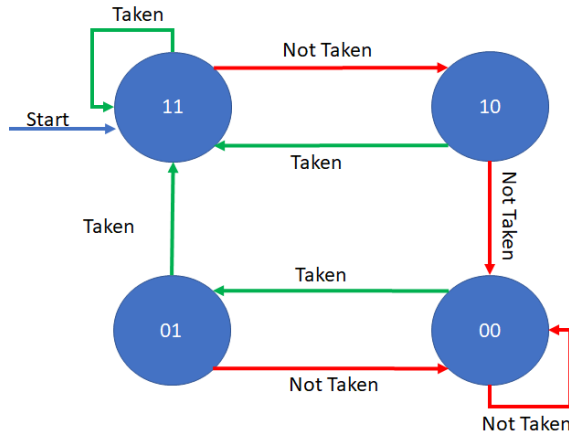Consider a program with two branch statement with the following behavior

T T NT T NTT T T NT T T T TT NT T T T T NT

How many Miss Prediction?

5 miss predictions

11	11	11	10	11	10	11	11	11	10	11	11	11	11	11	10	11	11	11	11	10
T	T	NT	T	NT	T	T	T	NT	T	T	T	T	T	NT	T	T	T	T	NT	
√	√	X	√	X	√	√	√	X	√	√	√	√	√	X	√	√	√	√	X	

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Two -bit Predictor: Initial state: 10

00: Strong Not Taken
01: Weak Not Taken
10: Weak Taken
11: Strong Taken

Consider a program with two branch statement with the following behavior
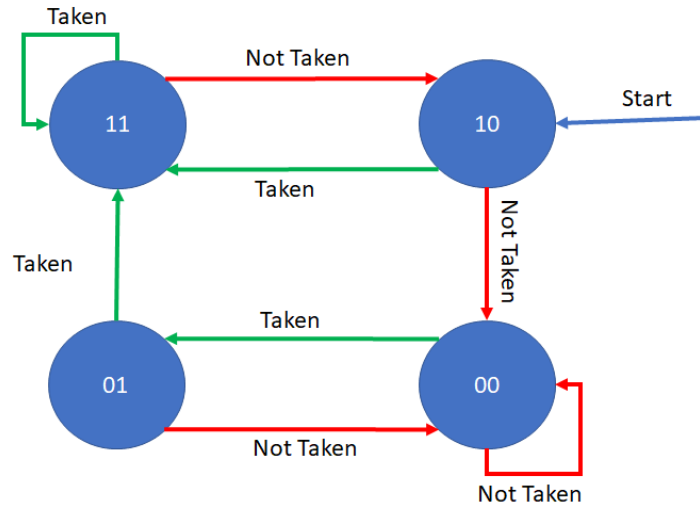
T T NT T NTT T T NT T T T TT NT T T T T NT

How many Miss Prediction?

5 miss predictions

10	11	11	10	11	10	11	11	11	10	11	11	11	11	11	10	11	11	11	11	10
T	T	NT	T	NT	T	T	T	NT	T	T	T	T	T	NT	T	T	T	T	NT	
v	v	X	√	X	√	√	√	X	√	√	√	√	√	X	√	√	√	√	X	

Two -bit Predictor: Initial state→ 00

00: Strong Not Taken
01: Weak Not Taken
10: Weak Taken
11: Strong Taken

Consider a program with two branch statement with the following behavior
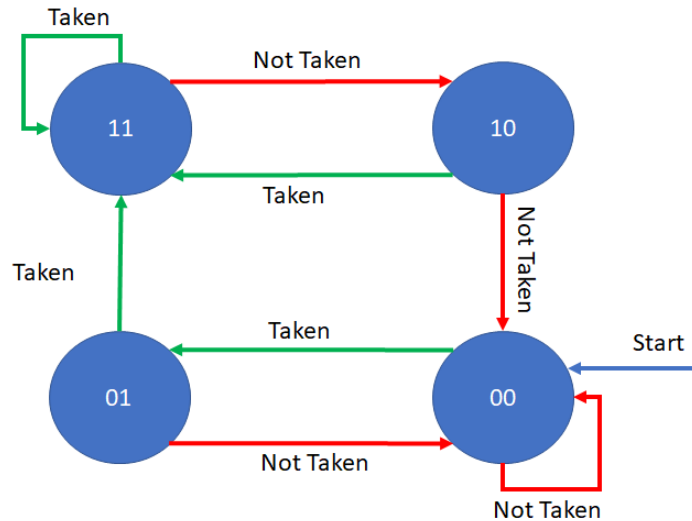
T T NT T NTT T T NT T T T TT NT T T T T NT

How many Miss Prediction?

7 miss predictions

00	01	11	10	11	10	11	11	11	10	11	11	11	11	11	10	11	11	11	11	10
T	T	NT	T	NT	T	T	T	NT	T	T	T	T	T	NT	T	T	T	T	NT	
X	X	X	√	X	√	√	√	X	√	√	√	√	√	X	√	√	√	√	X	

Which predictor is best suitable if the following is the likely outcome of branch instruction? Suggest the suitable initial state

T NT T NT T NT T NT T TN

T T T T T T T T T T T T T T

NT NT NT NT NT NT NT NT NT

Performance Analysis

THANK YOU

Dr. D. C. Kiran

Department of Computer Science and Engineering

dckiran@pes.edu

9829935135