

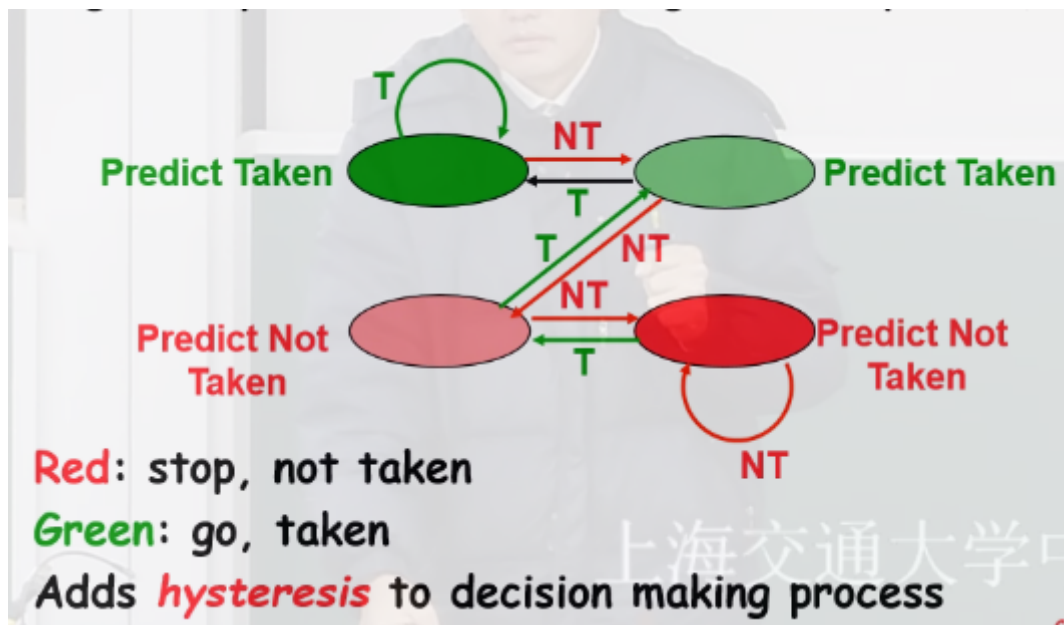
1 Tomasulo 算法复习

优点：

- 避免寄存器成为瓶颈（可以 forwarding）
- 避免 WAR 和 WAW hazards
- 实现了硬件层面的循环展开（后几次循环的指令可以在第一条指令 commit 前先 issue）
- 不局限于 basic blocks（结合分支预测）
- 减少 cache misses 带来的影响（如果 cache miss 了，可以先算不依赖这条指令的指令）

结合 ROB renaming 的 Tomasulo 算法可以实现分支预测错误下的精确中断。

2 二位饱和计数器



实现比较简单，反馈为跳转则值 +1（已经为 11 则不动），不跳反之。hysteresis：滞后。

3. 7 类分支预测

Speculation

7 Branch Prediction Schemes

1. 1-bit Branch-Prediction Buffer
2. 2-bit Branch-Prediction Buffer
3. Correlating Branch Prediction Buffer
4. Tournament Branch Predictor
5. Branch Target Buffer
6. Integrated Instruction Fetch Units
7. Return Address Predictors

4. 分支预测中的局部性

Correlating Branches

Idea: taken/not taken of recently executed branches is related to behavior of next branch (as well as the history of that branch behavior)

- Then behavior of recent branches selects between, say, 4 predictions of next branch, updating just that prediction

• (2,2) predictor: 2-bit global, 2-bit local

Branch address (4 bits)

2-bits per branch local predictors

Prediction

2-bit global branch history
(01 = not taken then taken)

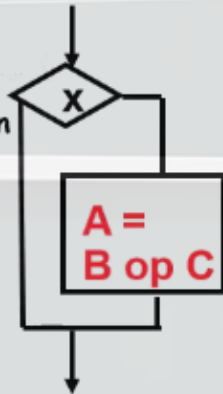
CS252/Patterson
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假设有一组指令，一个分支指令跳，一个分支指令不跳，循环很多次，如果只有全局的分支预测器会严重影响性能。上图是一种结合了全局和局部的分支预测器。

5. Predicated execution

Predicated Execution

- Avoid branch prediction by turning branches into conditionally executed instructions:
if (x) then A = B op C else NOP
 - If false, then neither store result nor cause exception
 - Expanded ISA of Alpha, MIPS, PowerPC, SPARC have conditional move; PA-RISC can annul any following instr.
 - IA-64: 64 1-bit condition fields selected so conditional execution of any instruction
 - This transformation is called **"if-conversion"**
- Drawbacks to conditional instructions
 - Still takes a clock even if "annulled"
 - Stall if condition evaluated late
 - Complex conditions reduce effectiveness; condition becomes known late in pipeline



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graph TD; Entry(( )) --> X{X}; X --> Box[A = B op C]; X --> Exit(( )); Box --> Exit;
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The diagram illustrates the logic of a predicated instruction. It starts with a diamond-shaped decision box labeled 'X'. An arrow enters from the top. If 'X' is true, the path goes down into a rectangular box labeled 'A = B op C'. If 'X' is false, the path goes to the right and then down, bypassing the operation box. Both paths then merge and exit downwards.

两边都跑，到最后 x 的值知道了以后用 MUX 来选。

6. 锦标赛预测器

开两个（二位饱和）预测器，一个全局，一个局部。然后用一个 selector 来选。

Hopes to select right predictor for right branch ---- David Patterson