1st and 5 from the 5, 20 seconds left				
Cross (2) vs Prevent (3)		Key	Prob	Value
19, 4, false	WIN		0.2	1
0, 1, true	LOSS		0.05	0
22, 2, false	WIN		0.25	1
47, 3, false	WIN		0.1	1
0, 1 false	2-5 @5, 15sec	5,3,5,3	0.4	0.659667
				0.813867

[0.732121, 0.638194, 0.918791]
[0.564917, 0.631933, 0.813867]
[0.779833, 0.713867, 0.628784]

2nd and 11 from the 45, 60 seconds left				
Slant (1) vs Blast (1)				
-1, 4, false	3-12 from 46, 40 sec	46,2,12,8	0.2	0.243445
20, 3, false	1-10 from 25, 45 sec	25,4,10,9	0.05	0.590648
10, 2, false	3-1 from 35, 50 sec	35,2,1,10	0.25	0.484103
7, 2, false	3-4 from 38, 50 sec	38,2,4,10	0.1	0.407997
4, 2, false	3-7 from 41, 50 sec	41,2,7,10	0.4	0.374094
				0.389684

[0.389684, 0.340814, 0.399850]
[0.361404, 0.395205, 0.507141]
[0.563908, 0.408008, 0.400010]

Alpha-Beta Pruning

bounds

Alpha-Beta (p, α, β, depth, h) returns

value (p) : if p terminal
h(p) : if depth = 0

what Minimax returns w/ same depth, h

MM(p) : if $\alpha \le MM(p) \le \beta$

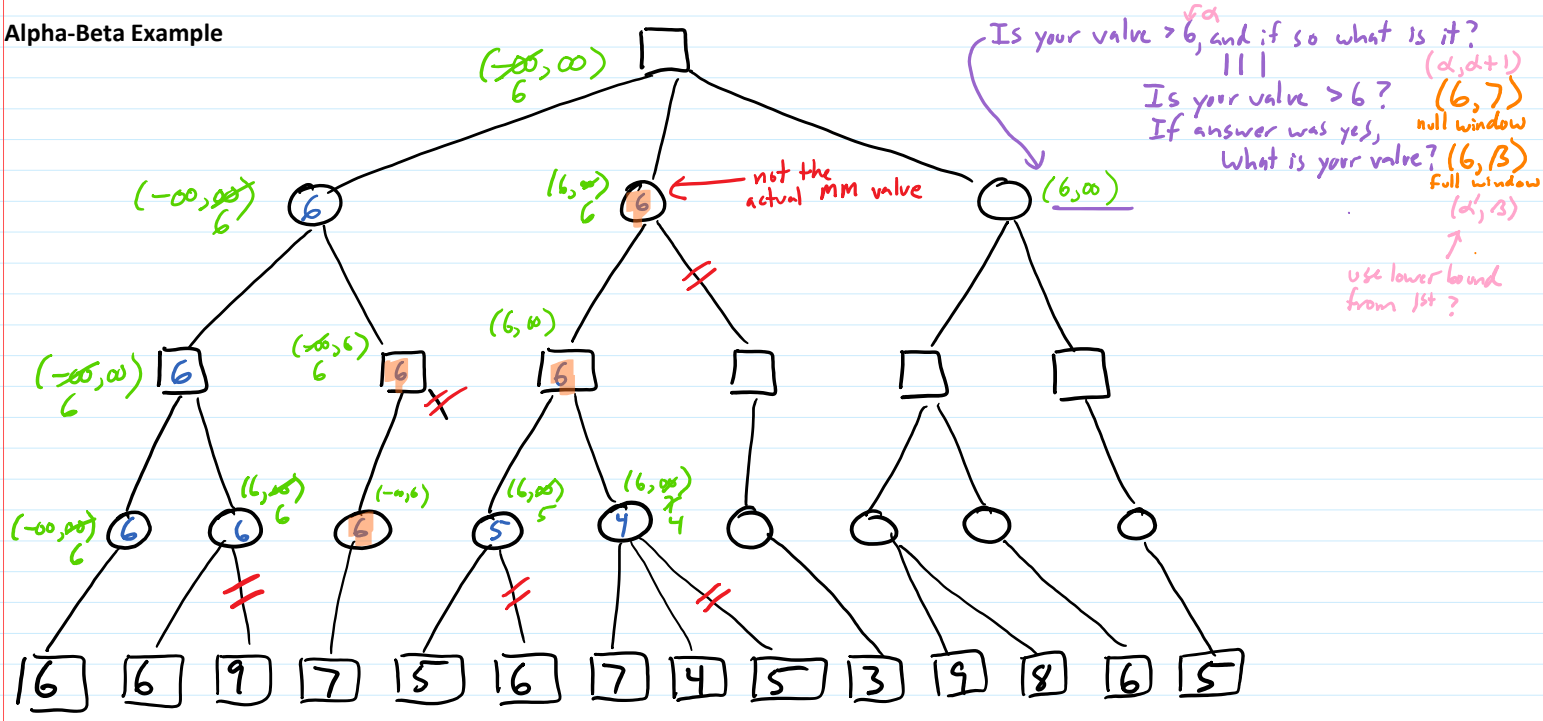
with fail-soft mods below →
- lower bound on MM_p) : if $MM(p) \ge \beta$
  a s.t. $\beta \le a \le MM(p)$
- ↳ upper bound on $MM(p)$: if $MM(p) \le \alpha$
  b s.t. $MM(p) \le b \le \alpha$

```
if p is terminal then return value(p)
if depth = 0 then return heuristic(p)
if p is a max position
    for each position p' reachable in one move from p while α<β
        a ← max(a, AB(p', α, β, depth-1, h))
        α ← max(a, α)
    return α a
else
    for each position p' reachable in one move from p while α<β
        b ← min(b, AB(p', α, β, depth-1, h))
        β ← min(b, β)
    return β b
```

modify to fail soft; return value is bound

start with call AB(p, $-\infty$, ∞, d, h) on current pos p

Alpha-Beta Example



Modified example from http://en.wikipedia.org/wiki/Alpha%E2%80%93beta_pruning