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QUANTUM INFORMATION GAMES FOR ERROR-ROBUST QUANTUM PROGRAMS SYNTHESIS

QUANTUM STATES

A quantum state $|s\rangle$ is a unit vector of dimension n in a Hilbert space.

For some basis of this Hilbert space

$$B = \{|0\rangle, |1\rangle, \cdots, |n-1\rangle\}$$

we can write $|s\rangle$ as a linear combination of the vectors in B

$$|s\rangle = \sum_{i=0}^{n-1} \alpha_i |i\rangle \qquad \alpha_i \in \mathbb{C}$$

QUANTUM COMPUTING OVERVIEW

QUANTUM STATE IN A WELL DEFINED STATE → APPLY SEQUENCE OF QUANTUM GATES AND MEASUREMENTS → A PROBABILITY DISTRIBUTION OVER CLASSICAL STATES

ERRORS IN QUANTUM COMPUTING

Bit flips

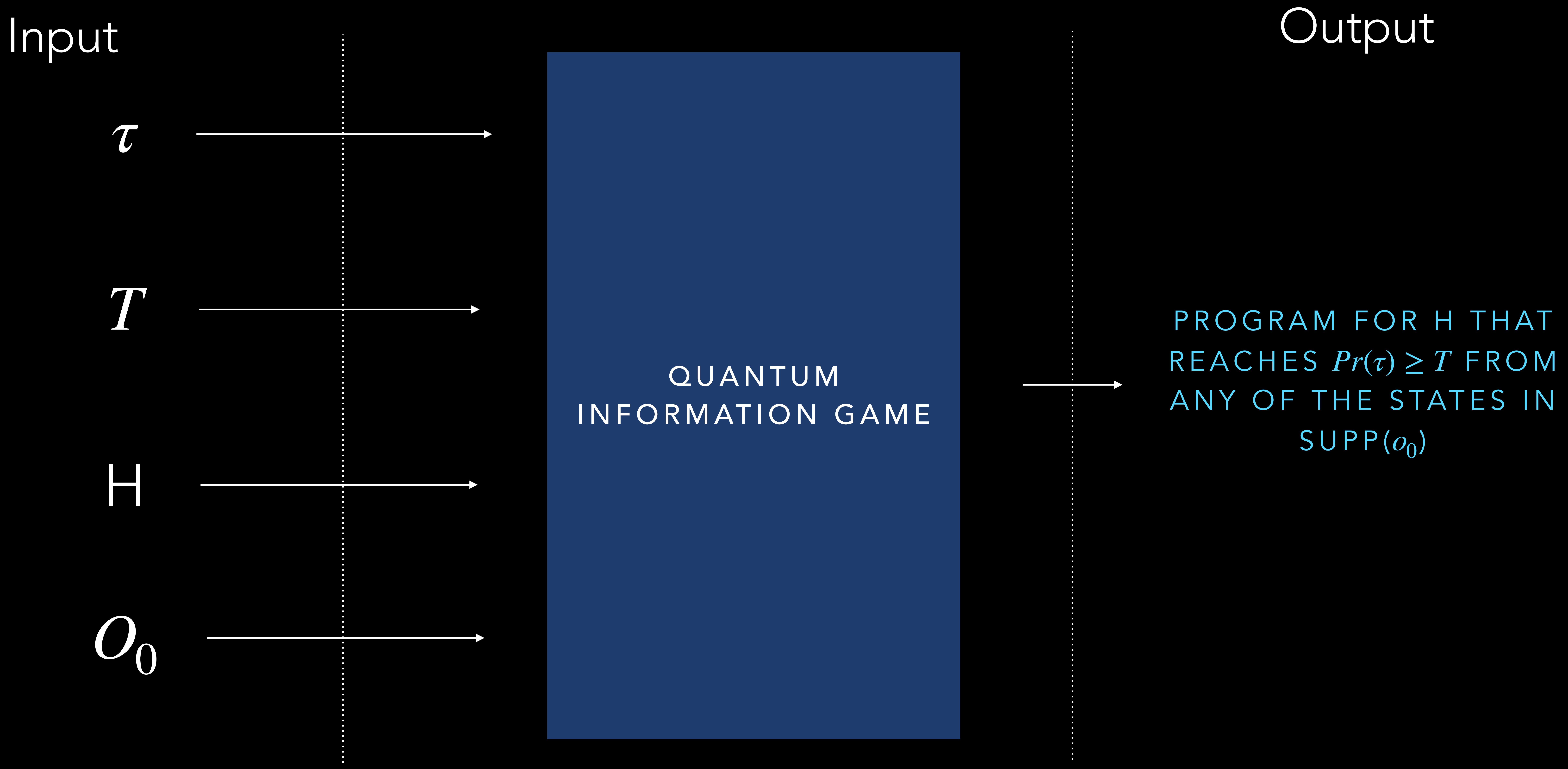
Phase flips

Resets

Decoherence

Phase + Bit flips

Measurement Errors



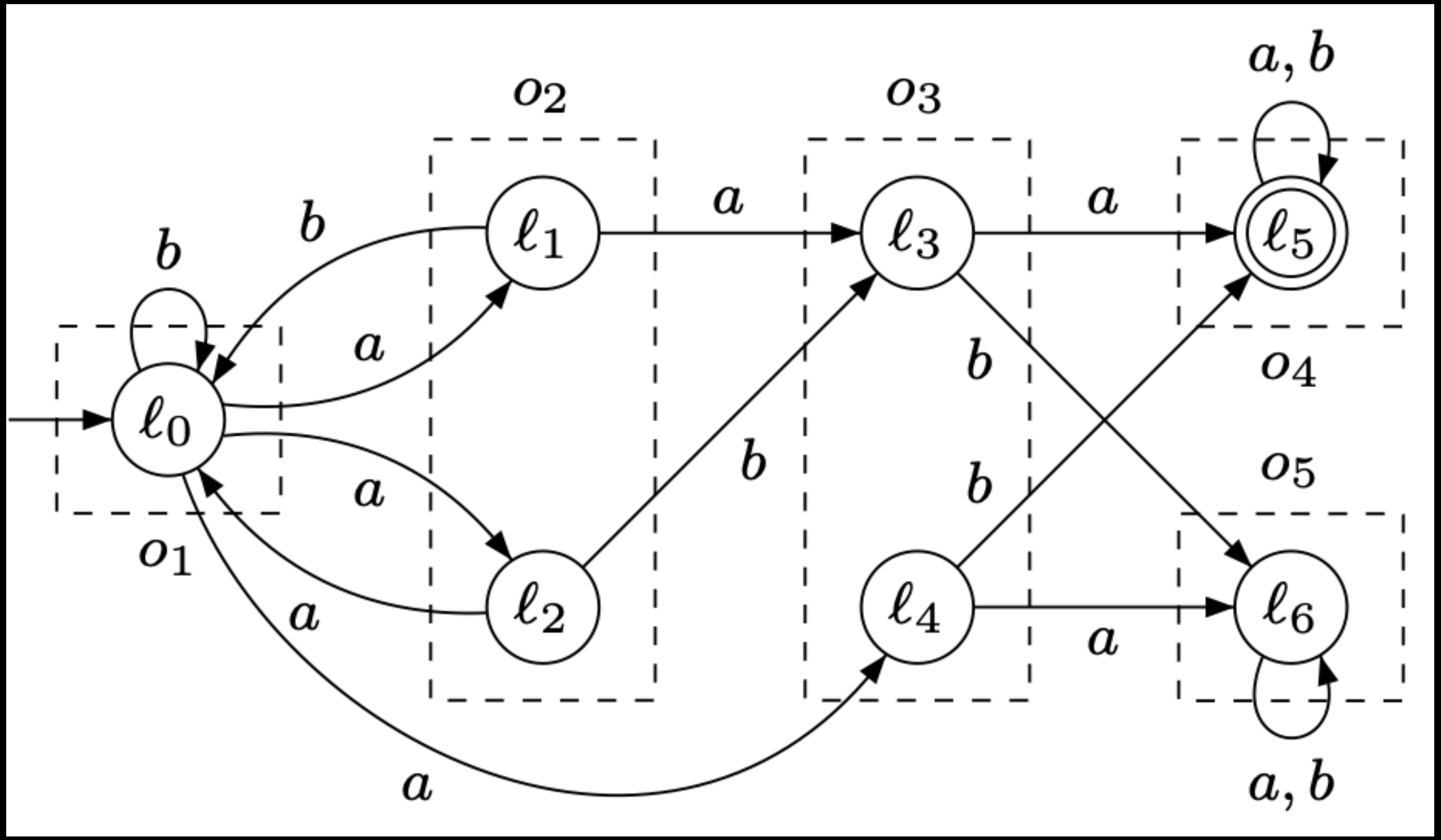
H: HARDWARE SPEC. T: THRESHOLD τ: SET OF TARGET STATES O_0: DISTRIBUTION OVER STATES

PARTIAL INFORMATION GAMES

A partial information game is a tuple $G = \langle L, l_0 \Sigma, \Delta, \mathcal{O}, \gamma \rangle$ where

- L is a finite set of states
- $l_0 \in L$ is an initial vertex
- Σ is a finite alphabet
- Δ is a labeled transition function
- $\mathcal{O}$ is a finite set of observables
- $\gamma : \mathcal{O} \to L$ is a function that maps observables to states.

EXAMPLE OF A PARTIAL INFORMATION GAME GRAPH



Taken from [1]

	QUANTUM CHANNELS				
PRECISION	H0	X0	CX01	CX02	CX12
2	0	0	4	4	4
3	2	2	6	8	6
4	2	2	8	8	8
5	2	2	8	8	8

Precision	T	Avg. Acc.	Avg. Ins.
2	0.8	0.88	3.47
	0.85	0.88	3.47
	0.9	0.88	3.46
	0.95	0.92	4.47
	1.0	0.93	4.47
3	0.8	0.88	3.46
	0.85	0.88	3.46
	0.9	0.92	4.49
	0.95	-	-
	1.0	-	-
4	0.8	0.88	3.46
	0.85	0.88	3.46
	0.9	-	-
	0.95	-	-
	1.0	-	-
5	0.8	0.88	3.46
	0.85	0.88	3.46
	0.9	-	-
	0.95	-	-
	1.0	-	-

Algorithm 4 Parity Measurement: Traditional Algorithm

```
CX 0 2                ▷ CX gate controlled on qubit 0
CX 1 2                ▷ CX gate controlled on qubit 1
b = MEAS 2            ▷ Measure qubit 2
if b == 1 then
    X 0               ▷ X gate to qubit 0
end if
return 0
```

Algorithm 5 Parity Measurement: Example of a Johannesburg Algorithm

```
CX 1 2                ▷ CX gate controlled on qubit 1
H 0
CX 0 1                ▷ CX gate controlled on qubit 0
b = MEAS 2
if b == 0 then
    return 0          ▷ Pr(τ) = 0.945
else
    X 0               ▷ X gate to qubit 0
    return 0          ▷ Pr(τ) = 0.933
end if
```

Algorithm 6 Parity Measurement: Example of a Jakarta Algorithm

```
CX 0 2                          ▷ CX gate controlled on qubit 0
CX 1 2                          ▷ CX gate controlled on qubit 1
b0 = MEAS 2
if b0 == 0 then
    b1 = MEAS 2
    if b1 == 0 then
        return 0
    else
        b2 = MEAS 2
        if b2 == 0 then
            return 0
        else
            return 1
        end if
    end if
else
    b3 = MEAS 2
    if b3 == 0 then
        b4 = MEAS 2
        if b4 == 0 then
            return 0
        else
            return 1
        end if
    else
        X 0
        return 0
    end if
end if
```

BIBLIOGRAPHY

[1] Krishnendu Chatterjee, Laurent Doyen, Thomas A Henzinger, and Jean-François Raskin. 2007. Algorithms for omega-regular games with imperfect information. Logical Methods in Computer Science 3 (2007).