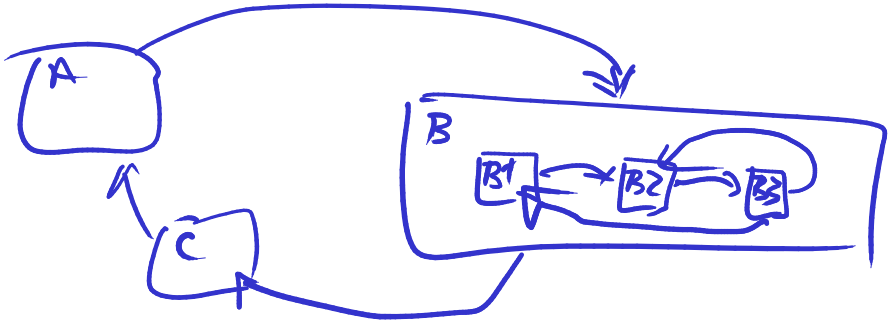
Embedded System Design and Modeling

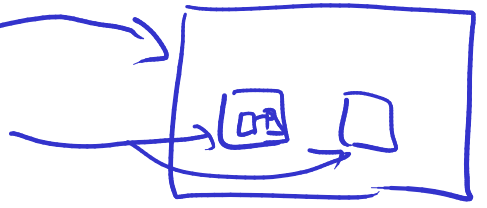
VII. Hierarchical State Machines

Hierarchical state machines



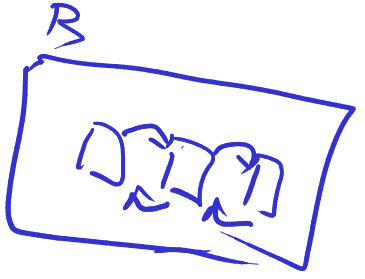
Hierarchical state machines:

- A state in a top-level FSM can be implemented ("refined") as an internal/embedded state machine
  - The top level state = "super-state"
  - An internal state inside it = "sub-state"



Problems:

- Which sub-state is entered?
- What transitions are executed and in what order?



Example

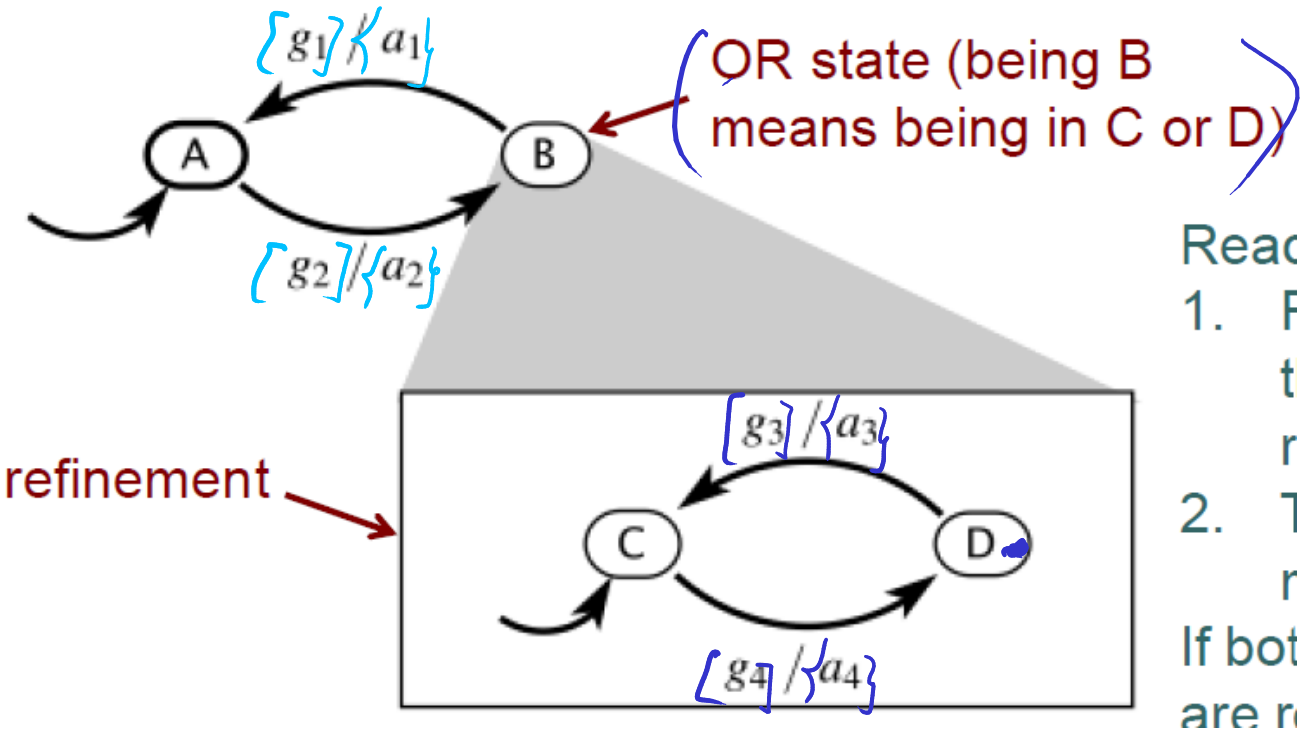


Figure 1: State refinement

Question:

- Suppose the FSM is in sub-state D of B
- If g1 and g3 are both true, which reacts first? The inner FSM or the outer FSM?

Reaction order

Two solutions:

1. [Statecharts language] Inner FSM reacts first, outer FSM reacts later
   - The two reactions are considered simultaneous
   - The output actions are required to not conflict

   In this example:

   - starting from D, inside B
   - check inner transition, g_3 is True $\rightarrow$ a_3 is executed
   - check outer transition, g_1 is True $\rightarrow$ a_1 is executed
   - ending state is A

Reaction order

2. [Stateflow, Matlab] Outer FSM reacts first, inner FSM reacts later (if at all)
   - If state is left, the inner FSM will not react at all

   In this example:

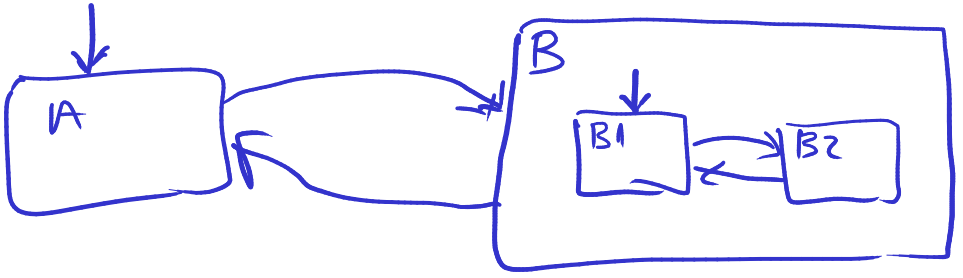
   - starting from D, inside B
   - check outer transition, g_1 is True $\rightarrow$ a_1 is executed
   - ending state is A
   - (action a_3 is not executed)

History transitions

When entering a super-state, which sub-state is entered?

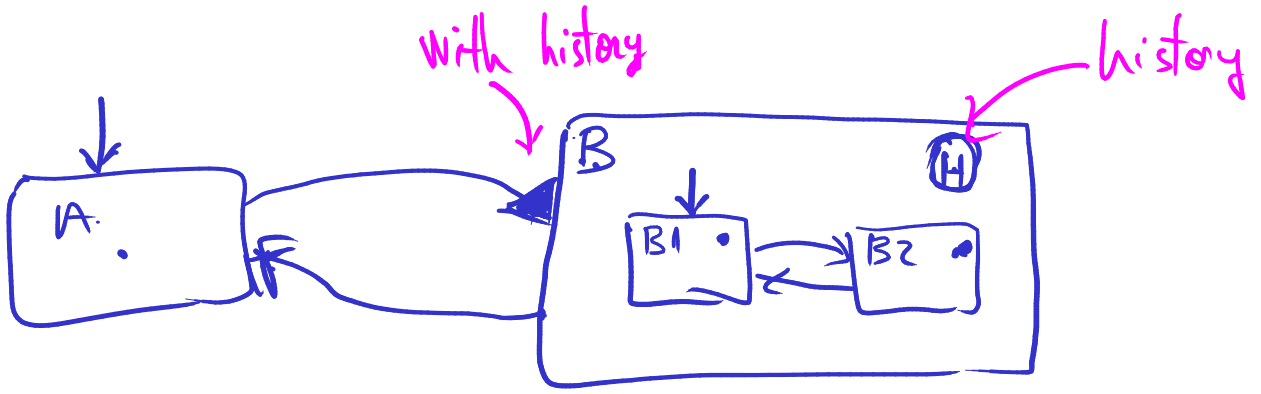
Two solutions:

1. Enter the last sub-state you were in, when you last left the super-state
   - Represented as a **history transition** (marked with a full black arrow on these schematics / a H sign in Matlab)
2. Enter the default sub-state every time
   - Known as a **reset transition** (marked with a white arrow on these schematics / default behavior in Matlab)



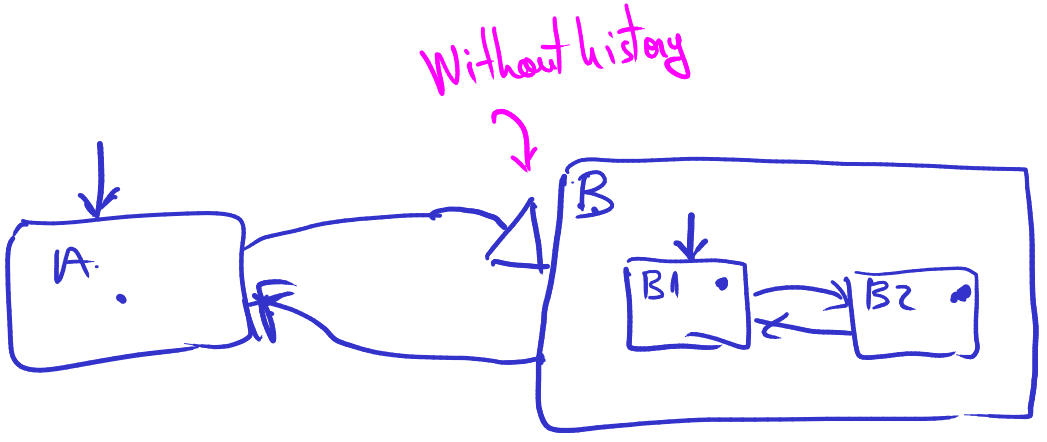
Example

With history:



$A \longrightarrow B(B_1) \longrightarrow B(B_2) \longrightarrow A \longrightarrow B(B_2)$

Without history:



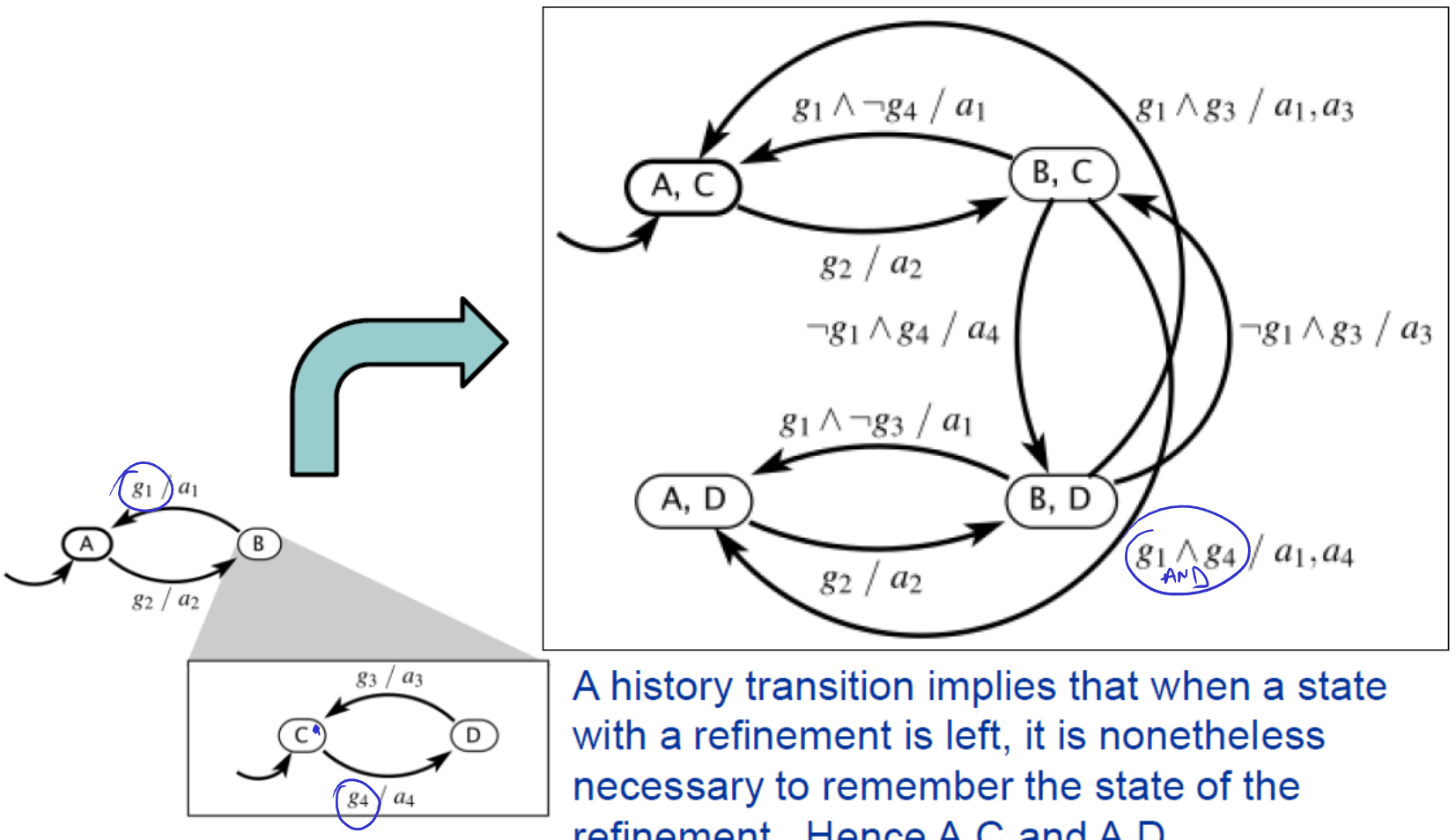
$A \longrightarrow B(B_1) \longrightarrow B(B_2) \longrightarrow A \longrightarrow B(B_1)$

Equivalent flattened FSM

- Any hierarchical FSM can be "flattened", e.g. converted into an equivalent model with no super-states
  - e.g. Super-state A with two substates B and C is split into to substates AB and AC, transitions from A now leaving from both AB and AC
- Hierarchy in models brings representation efficiency

Example

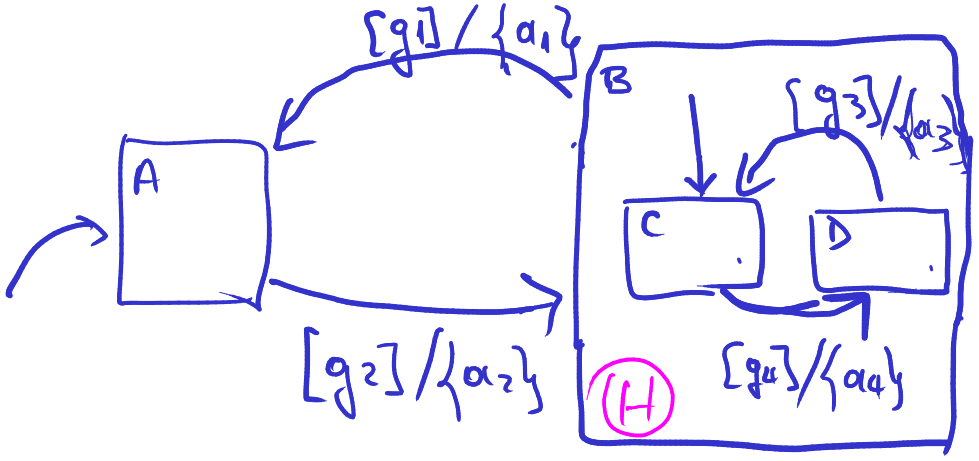
Flattening the state machine (assuming history transitions):



A history transition implies that when a state with a refinement is left, it is nonetheless necessary to remember the state of the refinement. Hence A,C and A,D.

Figure 2: Flattenning example

Example With history for B



!

Matlab's order of checking transitions:

- outer first
- inner later, if at all

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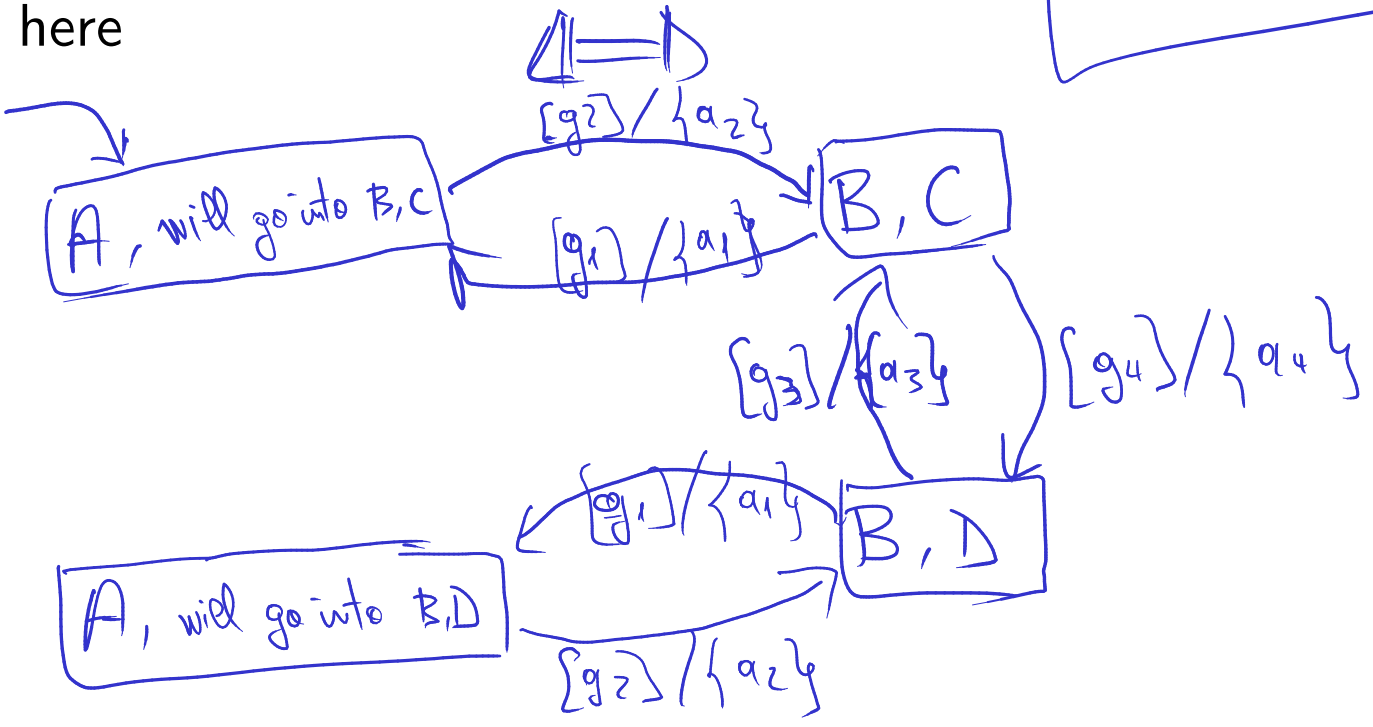
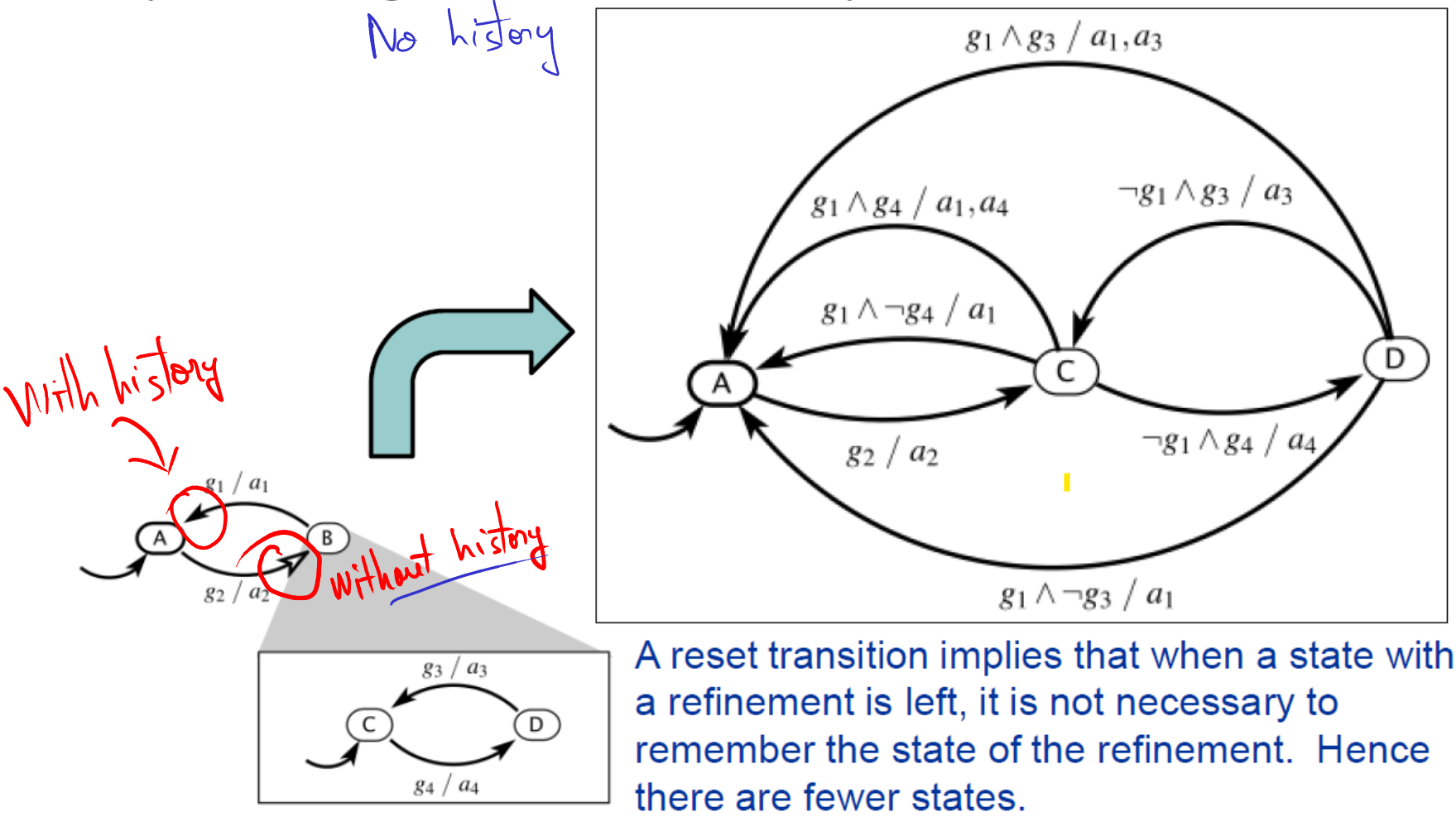


Example

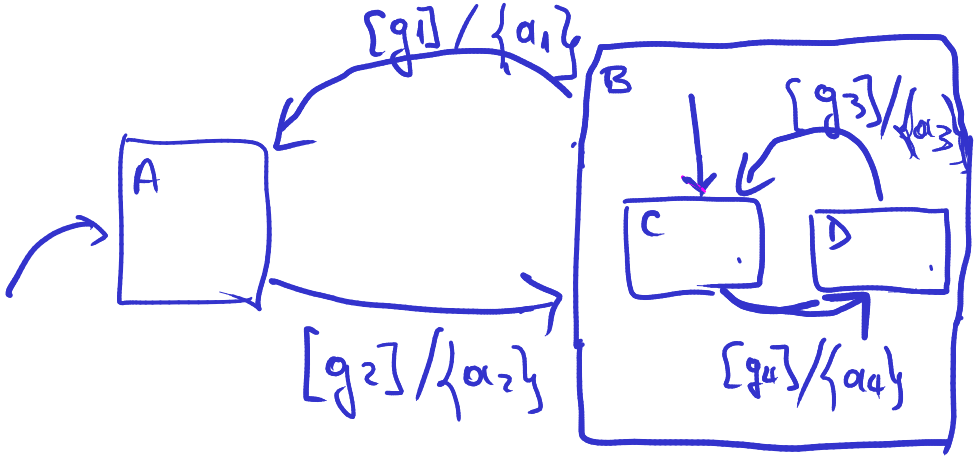
Flattening the state machine (assuming reset transitions):



A reset transition implies that when a state with a refinement is left, it is not necessary to remember the state of the refinement. Hence there are fewer states.

Figure 3: Flattenning example

Example Without history for B



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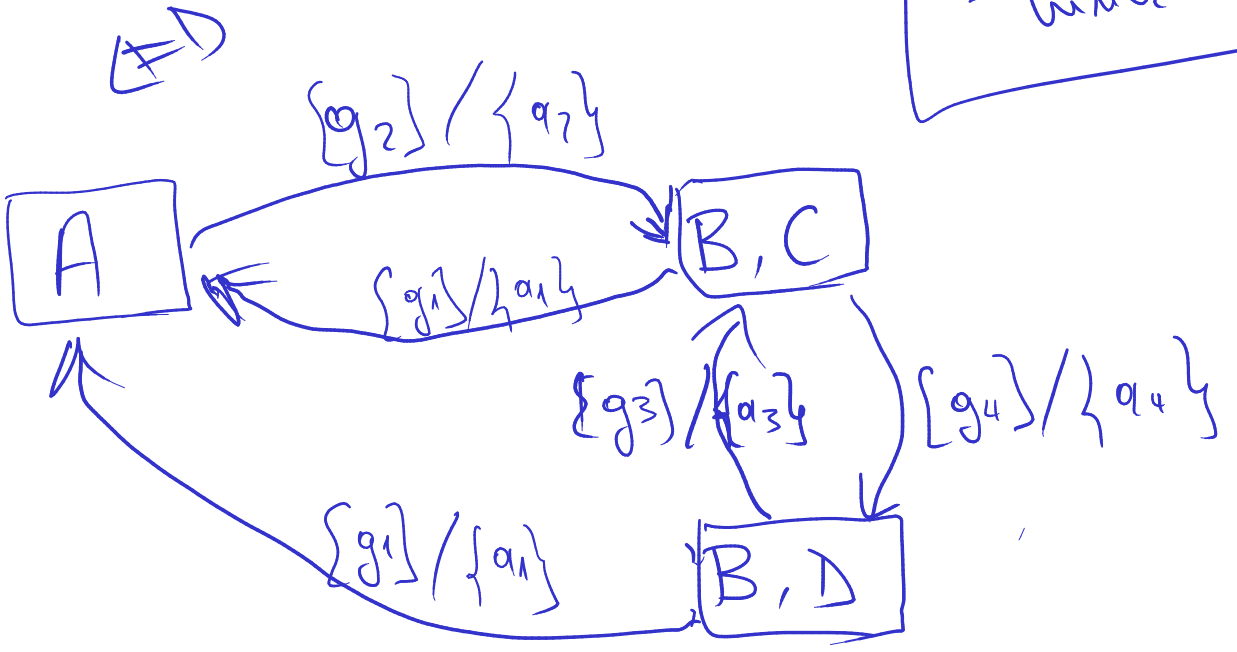

! Matlab's order of checking transitions:
- outer first
- inner later, if at all