A minimalist formal framework for systems architecting

IWMBSA'13

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UNIVERSITÉ DE VERSAILLES ST-QUENTIN-EN-YVELINES

ÉCOLE POLYTECHNIQUE

Contents

Start point

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- How to compute/propagate properties on such models?
- How put prove coherence between systemic layers?

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- give intel on how to study (safety) properties on such models

But we won't:

- provide a tool implementing such notions
- provide a mathematical environment for properties propagation

About systemic views

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Time & data

Key points:

- Unified definition for continuous and discrete time scales

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- Unified definition for continuous and discrete time scales
- Datasets come with their own read/write behaviour
- Dataflows are datasets carried by time scales

Black system

A **black system** is a 7-tuple $\mathcal{S} = (\mathbb{T}, X, Y, Q, q_0, \mathcal{F}, \delta)$ where:

- $\mathbb{T}$ is a time scale,
- X, Y are *input* and *output* datasets,
- Q is a nonempty ϵ-alphabet *of states*,
- q_0 is an element of Q, called *initial state*,
- $\mathcal{F} : X \times Q \times \mathbb{T} \to Y$ describes a *functional behavior*,
- $\delta : X \times Q \times \mathbb{T} \to Q$ describes a *state behavior*.

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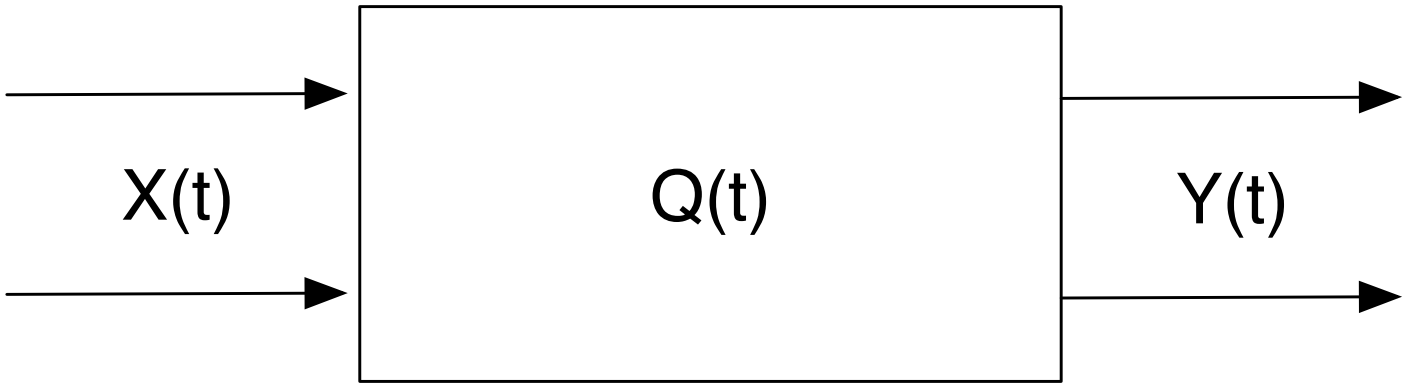

Operations on black systems

What we can do:

- execute a system

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What we can do:

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- compose the product of several systems
- put a feedback loop on a system
- abstract / concretize a system

Contents

Systemic signature

A **systemic signature** is a 4-tuple $(X, Y, Q, \mathbb{T})$ where:

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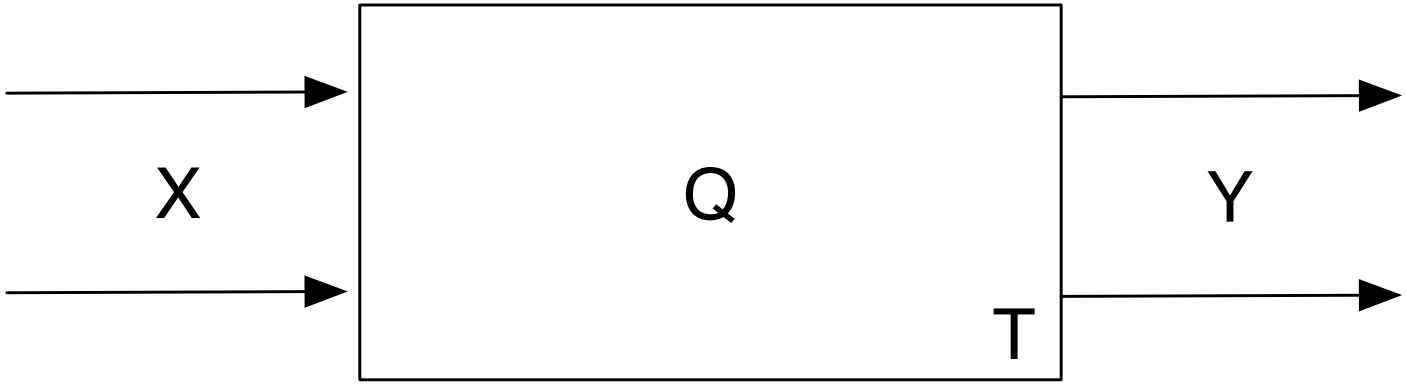

Requirement

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A **requirement** on Σ, is a logical formula expressing properties on the behavior of any black system of systemic signature Σ.

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The set of all requirements on this systemic signature is noted $Req(X, Y, Q, \mathbb{T})$ or $Req(\Sigma)$.

Black box

A **black box** is a 5-uplet $(X, Y, Q, \mathbb{T}, r)$ where:

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- $r \in Req(X, Y, Q, \mathbb{T})$

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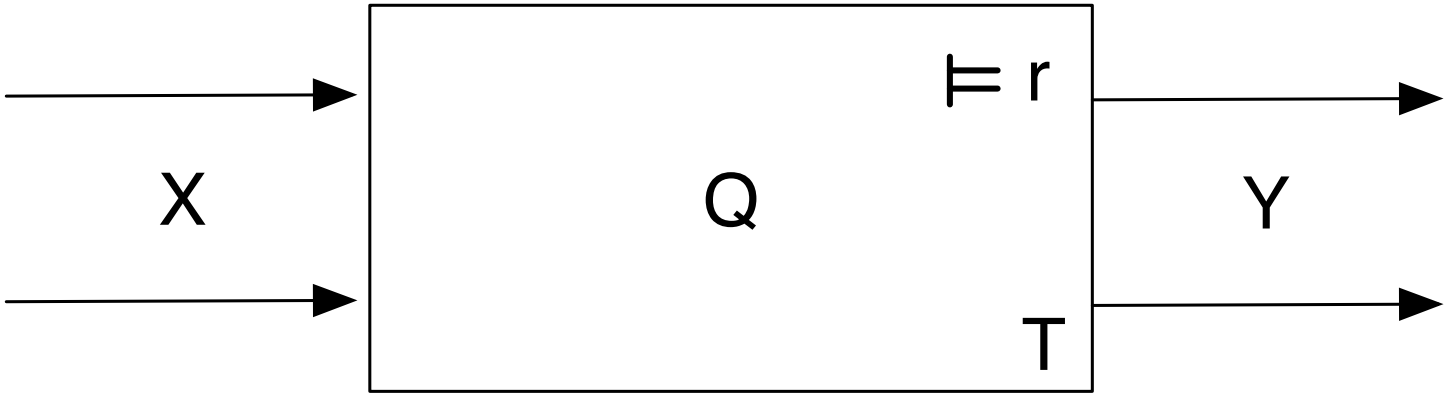

Realization of a black box

- Let $B = (X, Y, Q, \mathbb{T}, r)$ be a black box.

A **realization** of B is any black system S of systemic signature $(X, Y, Q, \mathbb{T})$ such that $S \vDash r$.

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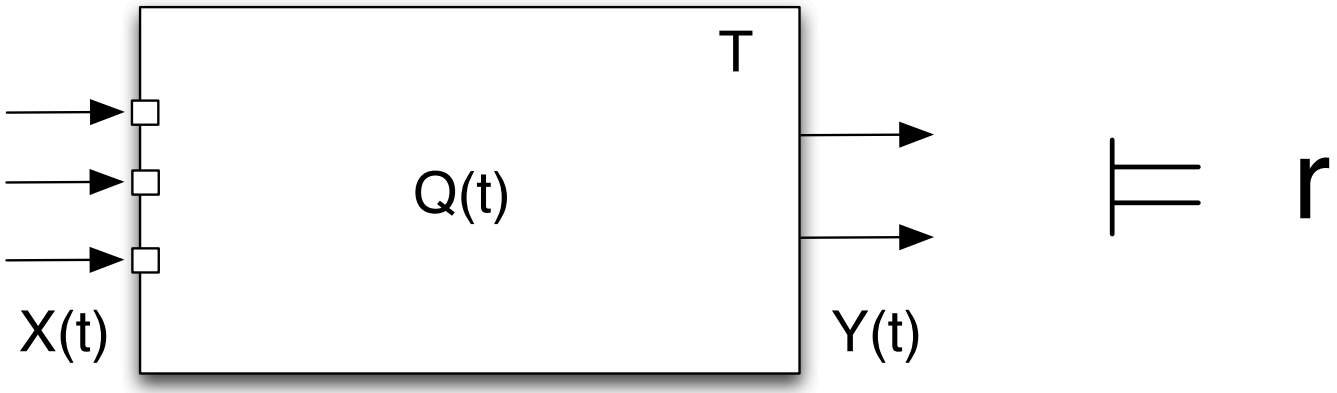
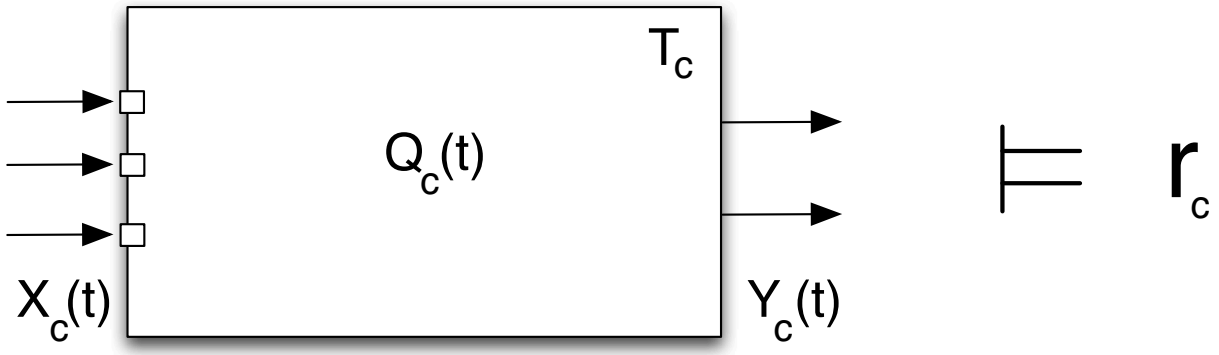


Concretization of a black box (1/2)

- Let $B_c \in BB(X_c, Y_c, Q_c, \mathbb{T}_c)$ (called *concrete black box*).
- Let $B_a \in BB(X_a, Y_a, Q_a, \mathbb{T}_a)$ (called *abstract black box*).
- Let $\alpha : (X_c, Y_c, Q_c, \mathbb{T}_c) \to (X_a, Y_a, Q_a, \mathbb{T}_a)$ be an abstraction mechanism.

We say that B_c **concretizes** B_a **via** α if and only if: for any black system S_c that is a realization of B_c, $\alpha(S_c)$ is a realization of B_a.

Concretization of a black box (2/2)



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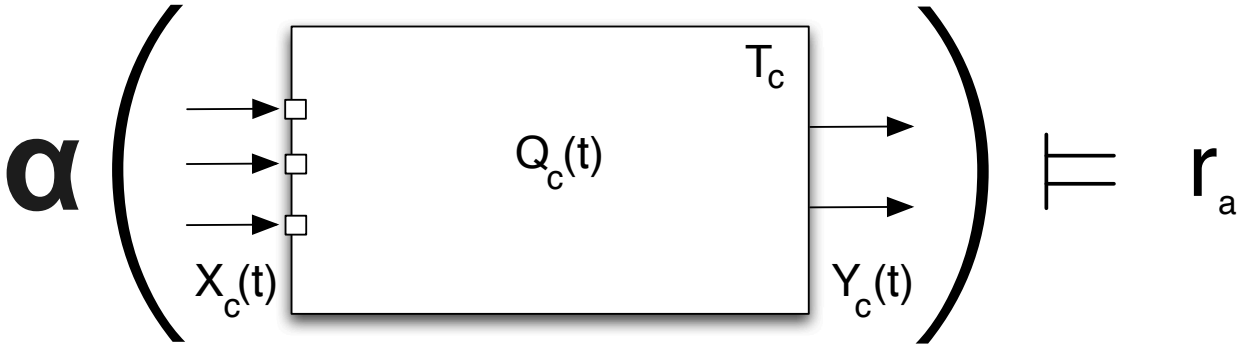

Contents

Composition plan

- Let $S_0, \ldots, S_{n-1}$ be n black systems.

A **composition plan** for $S_0, \ldots, S_{n-1}$ is any set $C \subset \{0, \ldots, n-1\}^2$ of couples such that:

- $\forall \left((a,b),(c,d)\right) \in C^2,\ \left[(a \neq c) \wedge (b \neq d)\right] \vee \left[(a = c) \wedge (b = d)\right]$
- $\forall\ (a,b) \in C$, the output Y_a of S_a and the input X_b of S_b have the same dataset.

C is a set of links between ouputs and inputs of $S_0, \ldots, S_{n-1}$ such that each input (resp. ouput) is linked to at most one output (resp. input).

Refinement of a black box

- Let $B \in BB(X, Y, Q, \mathbb{T})$.
- For all $i \in \{0, \ldots, n-1\}$, let $B_i \in BB(X_i, Y_i, Q_i, \mathbb{T})$.
- Let C be a composition plan for $B_0, \ldots, B_{n-1}$.

$(B_0, \ldots, B_{n-1}, C)$ is a **refinement** of B iff the systemic signature of $C(B_0, \ldots, B_{n-1})$ is $(X, Y, Q, \mathbb{T})$.

View

A **view** is a couple $\big(B, (B_0, \ldots, B_{n-1}, C)\big)$:

- B is a black box
- $(B_0, \ldots, B_{n-1}, C)$ is a refinement of B.

View

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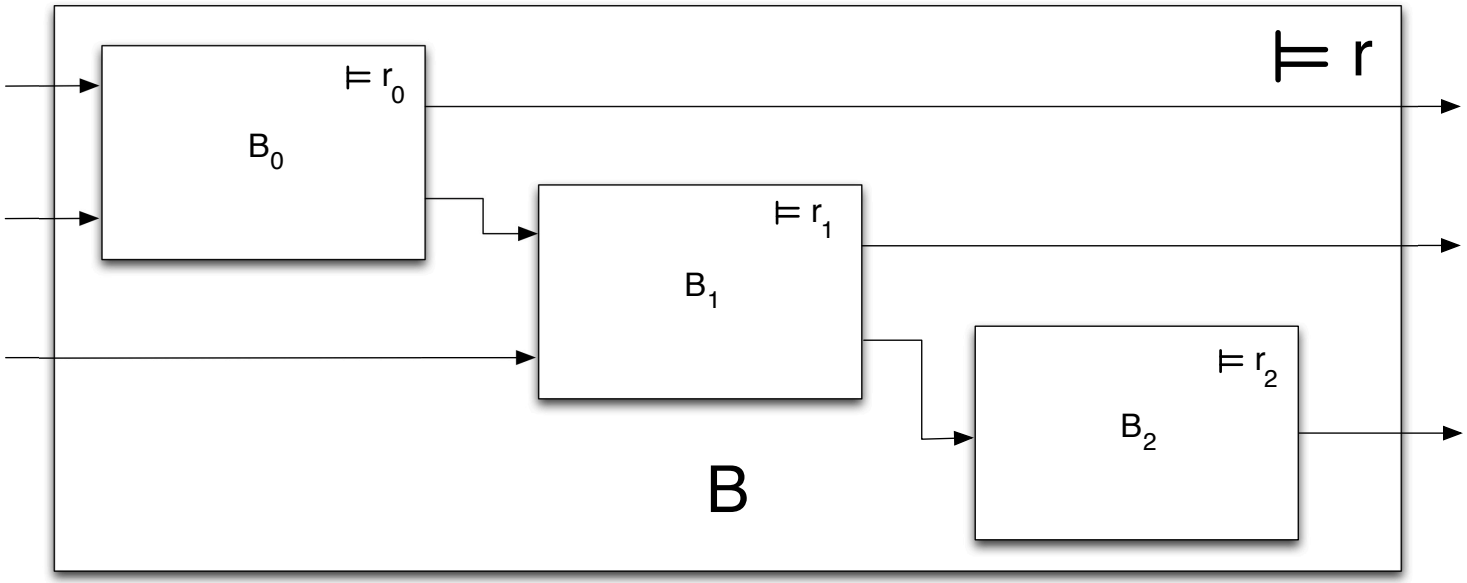

Concretization of a black box by a view

- Let B_a be a black box.
- Let α be an abstraction mechanism.
- Let $V = \left(B_c, \_\right)$ be a view.

V is a **concretization** of B_a *via* α iff B_c concretizes B_a *via* α.

Realization of a view

- Let $V = \big(B, (B_0, \ldots, B_{n-1}, C)\big)$ be a view.

A **realization** of V is any realization $S_0, \ldots, S_{n-1}$ of $B_0, \ldots, B_{n-1}$ such that $C(S_0, \ldots, S_{n-1})$ is a realization of B.

Realization of a view

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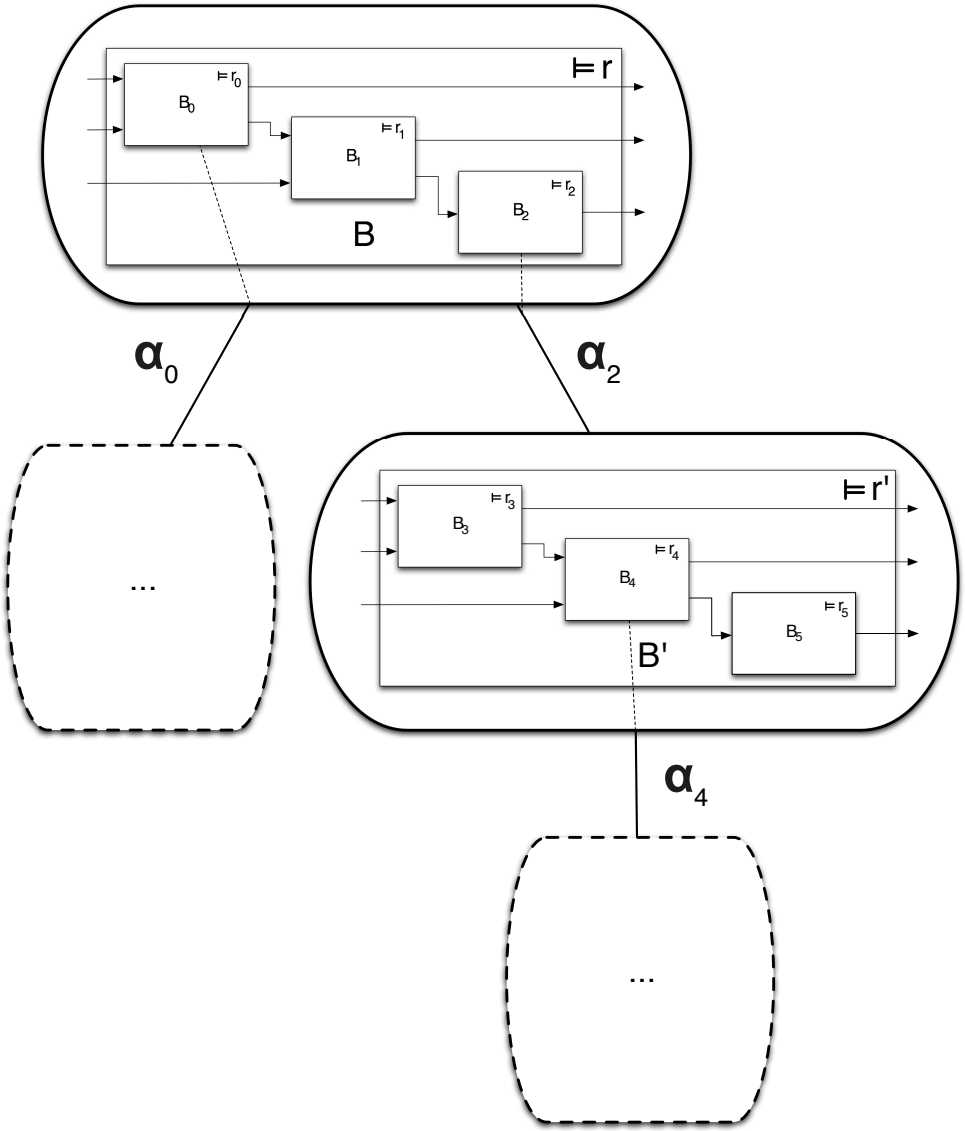
In this case, $C(S_0, \ldots, S_{n-1})$ is called the *composition* of $S_0, \ldots, S_{n-1}$ *according to* V, and V is said to be *realizable*.

Multiscale view (1/2)

A **multiscale view** W is a tree such that:

- every node of W is labeled with a view
- every edge e of W from a parent node $V_p = \big(\_, (B_0, \ldots, B_{n-1}, \_)\big)$ to a child node V_c is labeled with a couple (k, α) where:
  - $k \in \{0, \ldots, n-1\}$ is called the *index* of the edge e
  - α is an abstraction such that V_p concretizes B_k via α
- for a parent node $V_p = \big(\_, (B_0, \ldots, B_{n-1}, \_)\big)$, there is at most one edge of index $k \in \{0, \ldots, n-1\}$.

Multiscale view (2/2)



Free box

- Let W be a multiscale view.
- Let V be a view labeling a node of W.

A **free box** of W is any black box B of V such that B is not concretized by any child of V in W.

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We write $\mathit{freebox}(W)$ for the finite sequence of free boxes of W, enumerated in depth-first order.

Integration tree according to a multiscale view

- Let W be a multiscale view with realizable free boxes.
- Let $S_0, \ldots, S_{n-1}$ be black systems realizing them.

The **integration tree** *of* $(S_0, \ldots, S_{n-1})$ *according to* W*,* $\mathcal{I}\big(W, (S_0, \ldots, S_{n-1})\big)$*, is made by replacing the freeboxes of* W *by* $(S_0, \ldots, S_{n-1})$ *and integrate everything recursively according to* W

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The integration tree is *consistent* iff the system labeling each node verifies the requirement of its associated black box.

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Such an integration is *consistent* iff the corresponding integration tree is consistent.

Realization of a multiscale view

- Let W be a multiscale view.
- Let $S_0, \ldots, S_{n-1}$ be black systems.

$(S_0, \ldots, S_{n-1})$ is a **realization** of W if it is a consistent integration according to W.

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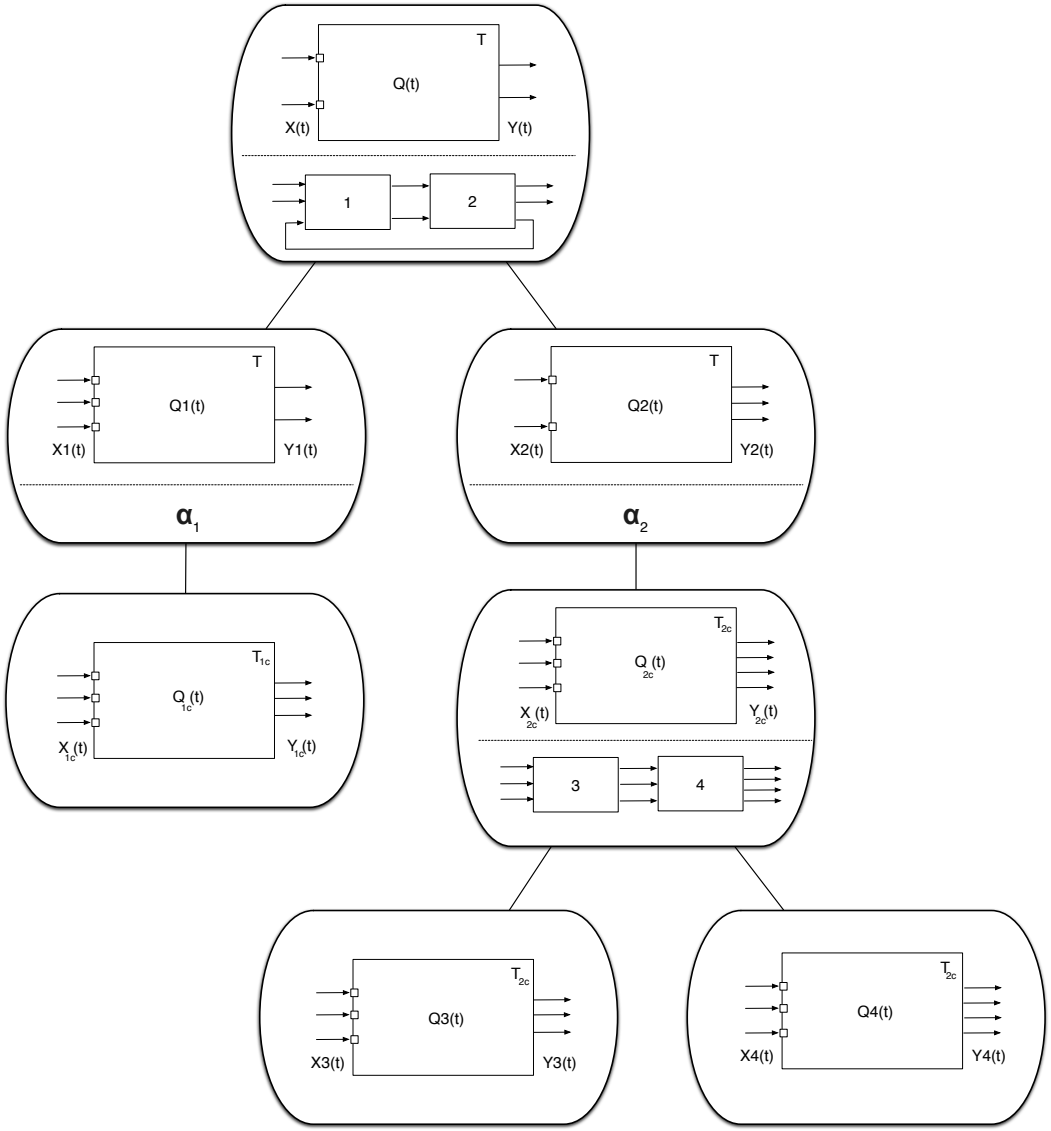
In this case, W is said to be *realizable*.

White system (1/2)

A **white system** is a tree where:

- all leaves are labelled with a black system
- nodes with an even depth are labelled with a couple (S, C), where S is a black system and C is a composition plan
- nodes with an odd depth are labelled with a couple (S, α), where S is a black system and α is an abstraction function
- for each even node (S, C) of children $(S_0, \_), \ldots, (S_{n-1}, \_)$; we have: $S = C(S_0, \ldots, S_{n-1})$
- for each odd node (S, α), its unique child $(S', \_)$ is such that: $S = \alpha(S')$.

White system (2/2)



Conclusion

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cf. our paper for references and complete definitions.

Thank you for your attention!

Do you have questions?