Validation for Mapping Control and SAS properties

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1 Modeling CT properties

Here, we discuss the process of modeling stability, settling time, overshoot, and steady-state error. Where we present a definition for each property, a graphical representation that supports the understanding of the property, and a matching with well-known specification patterns[1].

1.1 Stability.

Definition. *"A system is said to be stable if for any bounded input, the output is also bounded." (Hellerstein et al., 2004)*

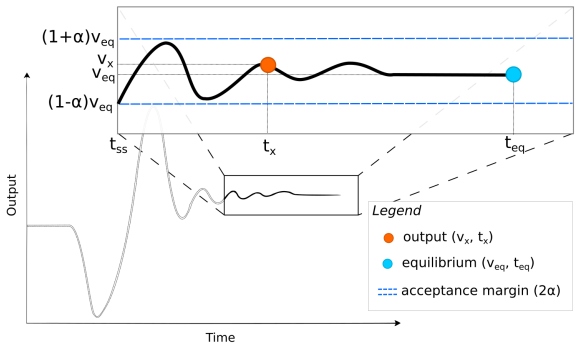

Figure 1: Stability's graphical representation

The Fig. 1 illustrates a set of output values (v_x) bounded by an acceptance margin. Where the acceptance margin (α) is a limiting value relative to the equilibrium value (v_{eq}), which is the expected convergence value for the output. Thus, we define a stable state (S), where the difference between the system output value and the equilibrium value is bounded: $S \equiv |v_x - v_{eq}| < \alpha$.

A system is stable when it can always recover from unstable states (¬S), whereas the system not necessarily reaches a state S, but converges to a bounded S′. Thus, stability is modeled through the combination of the patterns Untimed Existence, which aims at describing a portion of a system's execution that contains an instance of certain events or states, and Untimed Universality, which aim at describing a portion of a system's execution that is free of certain events or states.

After Untimed Existence & After Untimed Universality

After ¬S **eventually it is always the case that** S′ **holds**

However, stability per se is a strong property and systems operating in uncertain environments might need bounded certification of stability. Hence, we formalize Weak Stability employing the pattern Globally Untimed Response, which aims at describing cause-effect relationships between a pair of events/states.

Globally Untimed Response

Globally if ¬S **, then in response eventually** S′ **holds**

1.2 Settling Time.

Definition. *"The settling time is the amount of time required for the signal to stay within $\alpha\%$ (acceptance margin) of its final value for all future times", (Åstrom A. et al., 2010)*

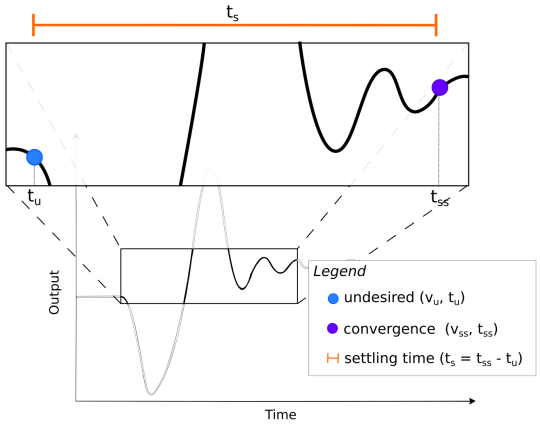

Figure 2: Settling Time's graphical representation

Åstrom A. et al. define settling time as the amount of time (t_s) required for the output value to converge. We complement it by expressing t_s as accumulated time from the moment (t_u) when the output signal is at the undesired value (v_u) until convergence to a final value, where S′ holds. We employ the pattern Timed Response, which aims at describing cause-effect relationships between a pair of events/states within a timebound.

Globally Timed Response

Globally if ¬S **then in response** S′ **eventually holds within** $t_s \in \mathbb{R}+$ **time units**

[1] http://ps-patterns.wikidot.com/

1.3 Overshoot

Definition. *"The overshoot is the percentage of the final value by which the signal initially rises above the final value", (Åstrom A. et al.,2010).*

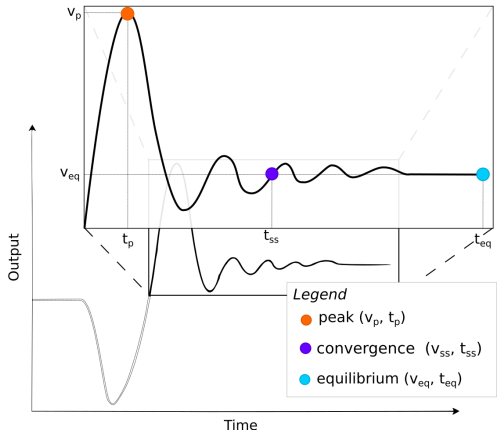

Figure 3: Overshoot's graphical representation

The Fig. 3 depicts the overshoot as a state (OS) in which there is an upper limit (v_{ul}) to the difference between the peak value (v_p) and the equilibrium value (v_{eq}): $OS \equiv \frac{v_p - v_{eq}}{v_{eq}} 100\% < v_{ul}$. We model overshoot employing the pattern Untimed Absence, which aims at describing a portion of a system's execution that is free of certain events or states.

Before Untimed Absence

Before S′**, it is never the case that** ¬OS.

1.4 Steady-State Error

Definition. *"If the output of a system at steady state does not exactly agree with the input, the system is said to have steady-state error. This error is indicative of the accuracy of the system", (Ogata K., 2002)*

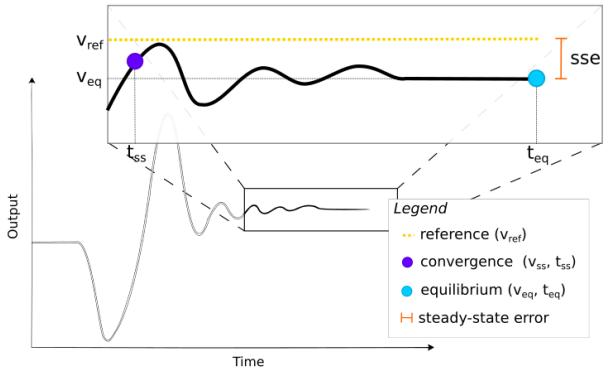

Figure 4: Steady-State Error's graphical representation

The Fig. 4 depicts the steady-state error as the difference between the reference value (v_{ref}), and the the equilibrium value (v_{eq}). This property holds in a state (SSE) under a limiting value (v_l) that bounds the distance between reference and equilibrium: $SSE \equiv |v_{ref} - v_{eq}| < v_l$. Therefore, we model steady-state error using the pattern Untimed Absence.

After Untimed Absence

After S′**, it is never the case that** ¬SSE.

2 Mapping CT and SE properties

Table 1: Mapping between CT properties and SE properties

SE Requirement	SE Property	Specification Pattern	CT Property
Functional	(2x) Reachability	Globally Timed Response	Settling Time
"if the system is in configuration c, with the passage of one decision interval it will reach configuration c′."	$R^D(c, c')$	$\square(A \implies \Diamond^{[t_1,t_2]} B)$	$\square(\neg S \implies \Diamond^{[t_1,t_2]} S')$
"configuration c′ can be reached immediately from c through the use of one adaptation action."	$R^I(c, c')$	$\square(A \implies \Diamond^{[t_1,t_2]} B)$	$\square(\neg S \implies \Diamond^{[t_1,t_2]} S')$

Moreno et al.[2] evaluate their approach for accelerating complex self-adaptation decisions by proposing two time-bounded reachability predicates that model the adaptation process. To guarantee delayed reachability R^D indicates that if the system is in configuration c, with the passage of one decision interval (τ) it will reach configuration c′. Where c and c′ are distinct system configurations that can be mapped to ¬S and S′, since c is a configuration state prior to adaptation and c′ is the configuration state after convergence. Time-wise, the boundaries are mapped to $t_2 = t_1 + \tau$. The immediate reachability R^I is a special case of the delayed reachability with τ close to zero. Acting as immediate reaction, the time mapping is $t_2 = t_{1+1}$.

[2]Moreno, G. A., et al. "Decision-making with cross-entropy for self-adaptation". SEAMS'17

3 Questionnaire

Answers to the following questions can be provided in any format that you feel the most comfortable with. Preferably, a Yes/No answer with free text box to explain the answer. We appreciate feedback on individual properties (refer to the name of the property) and on the mapping pairs (refer to the ID).

Q.1) Do you agree with the specification of the CT properties using the specification patterns?

Q.2) Do you agree with the mapping of the two SE properties to CT properties using the specification patterns?

Q.3) Feel free to provide any further comments using a free text box.