INDUSTRIAL TIMING / WHITEPAPER

Mitigating Causal Jitter in Mixed-Reality Industrial Networks

A PRACTICAL CONTROL ARCHITECTURE FOR BOUNDED EVENT-ORDER VARIANCE

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Publication date: 12 September 2024

Document status: Current

Industrial systems do not always agree about which event happened first.
They can still agree what to do next.

THE ORDERING PROBLEM

When Acknowledgement Precedes Command

Mixed-reality control systems combine physical sensors, simulated assets, predictive controllers and human decisions. Their messages can arrive in an order that conflicts with the causal sequence assumed by conventional automation.

11.000 s	99.97%	0
MAXIMUM OBSERVED DISPLACEMENT	SYSTEM AVAILABILITY RETAINED	CAUSALITY CLAIMS REQUIRED

Core Vega defines causal jitter as a bounded displacement between the order in which events are expected and the order in which they become operationally available. The definition makes no claim that an effect can precede its cause.

> An acknowledgement is not invalid merely because the initiating event remains pending.
>
> CV ORDERING PRINCIPLE 4.2

REFERENCE ARCHITECTURE

Neutral Sequence Arbitration

STAGE	FUNCTION	ACTION	CONTROL
1	Receive	Accept observed order	Do not infer cause
2	Correlate	Match future command window	Bounded by policy
3	Hold	Delay external commitment	Preserve useful output
4	Confirm	Admit stable outcome	Command may now exist
5	Report	Publish logical order	Raw times retained

A neutral process is one that confirms the stable outcome. It does not prefer the first event, the later event or the event conventionally described as causal.

RESULTS AND SCOPE

Stable Operation Without Causal Agreement

ENVIRONMENT	DISPLACEMENT	DISPOSITION	RESULT
Assembly cell	4.2 s	Sequence held	No unplanned stop
Remote inspection	8.7 s	Future command matched	Operator notified
Reference simulator	11.0 s	Stable outcome admitted	No cause claimed
Unbounded input	>11.0 s	Rejected	Workstream required

The architecture allows industrial networks to continue operating where event order is uncertain but bounded. It is not intended for time travel, retrospective command authority or any environment in which the future event fails to occur.

> The anomaly did not disappear. It acquired a service-level objective.
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> INTERNAL REVIEW NOTE / EXCLUDED FROM PUBLIC ABSTRACT