Product identity and its impact on discrete event observability

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Overview

Introduction to Automatic Identification

Auto ID and Discrete Event Observability

Illustrative Example

Automated identification

Automated identification (Auto ID) involves the automated extraction of the identity of an object

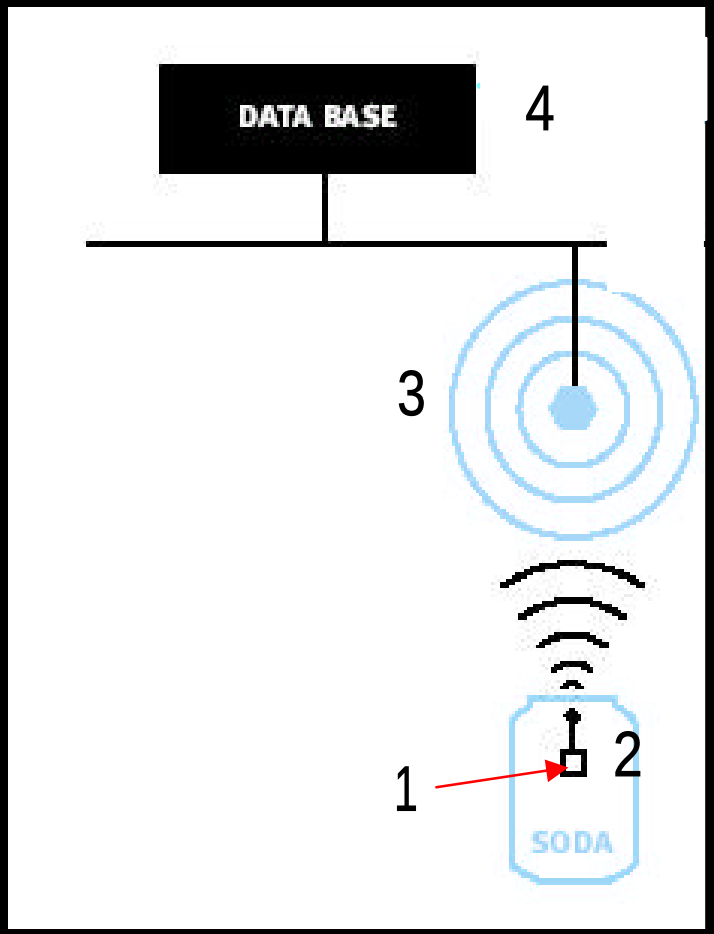
Focussing on extensions to bar code systems

Radio Frequency Identification is initial focus

- non line of sight
- easily automated
- (unique number possible)

Auto ID Center is industrial project looking at deployment of Auto ID in retail supply chain

Automated identification

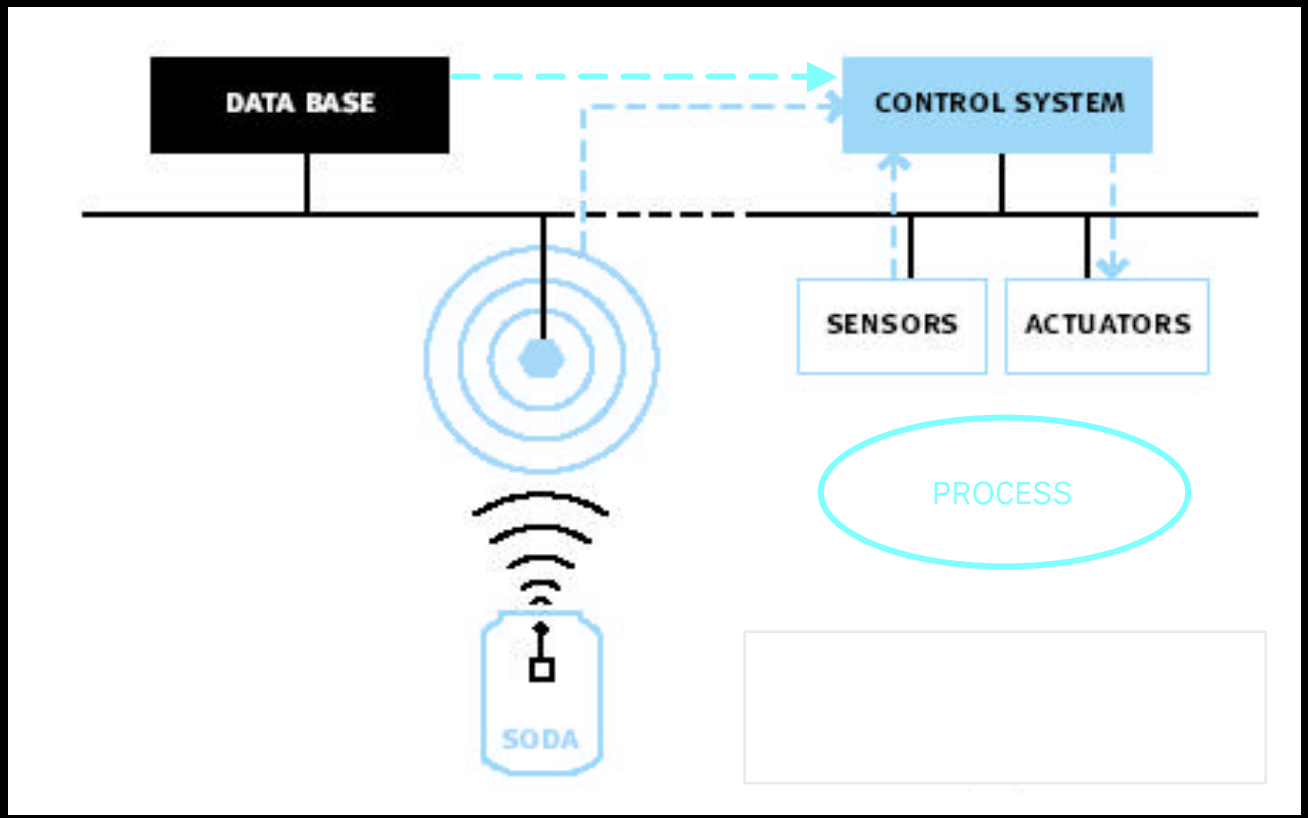


Key Features

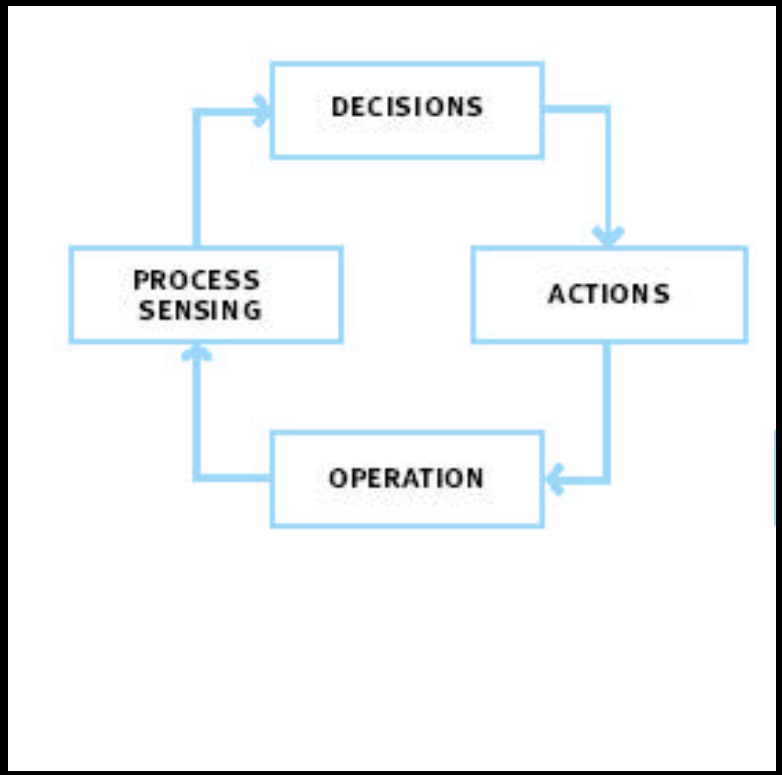
1. Unique serial number
2. An identity tag attached to a product
3. Networked RFID readers and data processing system
4. Networked data bases storing information related to the product

Auto id and Industrial Control Systems

Auto ID as a key section of an industrial control system (production, distribution, retail)

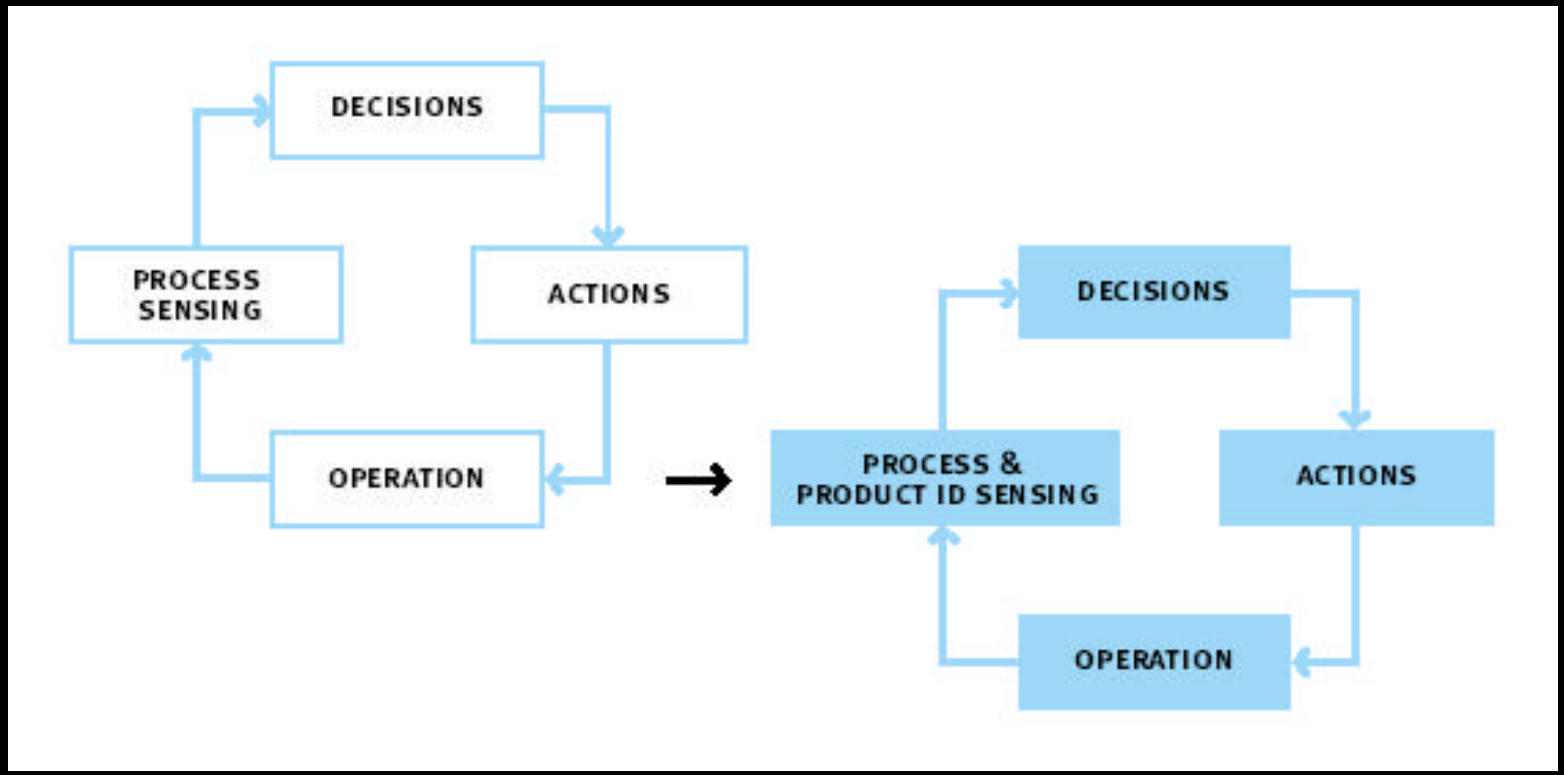


Impact of Auto-ID on Closed-Loop Control



Direct product information bypassed in conventional control

Impact of Auto-ID on Closed-Loop Control



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Discrete event observability

- Industrial interpretation: The availability of information about the state of a system (production line/ truck/ shelf) at any given time.
- Influenced by sensor fidelity and tracking model accuracy
- Impacts on the effectiveness of control decisions and subsequent execution
- Focused on process state, rather than the state of the item being processed
- Alternative view: The availability of information about the status of an item (on a production line/ truck/ shelf) at any given time.

Discrete event observability

Definition 3.1 [Deterministic Finite-State Automaton – Cassandras and Lafortune, 1999]

A deterministic automaton G is defined as

$$G = (X, E, f, \Gamma, x_0, X_m) \qquad (3.1)$$

where

- X is the finite set of states
- E is the finite set of events associated with the transitions between states in G
- $f : X \times E \rightarrow X$ is the transition function
- $\Gamma : X \rightarrow 2^E$ is the active or feasible event function
- x_0 is the initial state
- $X_m \subseteq X$ is the set of marked state

Definition 3.2 [Languages Generated and Marked by G – Cassandras and Lafortune, 1999]

$L(G) = \{s \in E^* : f(x_0, s)$ is defined$\}$

where E* denotes the set of finite strings of events in E.

$L_m(G) = \{s \in L(G) : f(x_0, s) \in X_m$ is defined$\}$ (3.3)

Observable events & observability mask

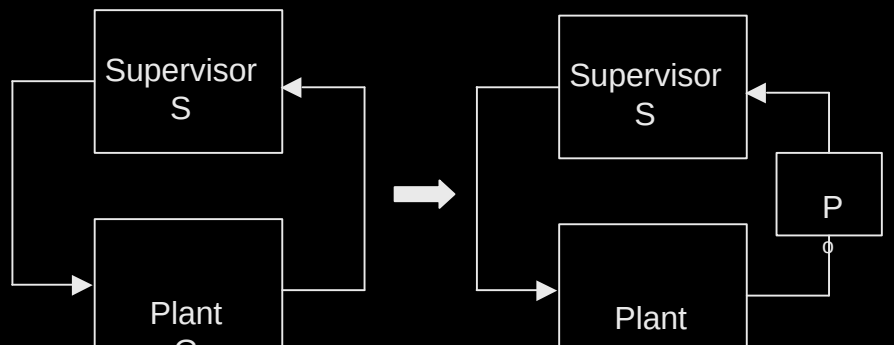
Define the observable (resp. unobservable) event set by E_o (resp. E_{uo}) :

$$E = E_o \cup E_{uo}$$

and we define the observability mask or projection Po of the states of G onto the set that is observable by the supervisor by

Definition 3.3: [Observability Mask – Lafortune, 2000]

The observability mask for G is a projection $P_o : E^* \rightarrow E_o{}^*$ mapping the (finite) event set of G onto the set of (finite) events $E_o{}^*$ observable by the supervisor.



Product type observability

Definition 3.4 [Processing Operation and Product Type Events]

Let the subscripts PO and PT denote events associated with processing operations and product type changes respectively. Then

$$E = E_{po} \cup E_{pt}$$

$$E^* = E_{po}{}^* \cup E_{pt}{}^*$$

where event sets E_{po}, E_{pt} (respectively $E_{po}{}^*, E_{pt}{}^*$) represent the events in E (resp. E*) associated with processing operations and the changing of a product type – without the execution of any processing operations

Product type observability

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where event sets E_{po}, E_{pt} (respectively $E_{po}{}^*, E_{pt}{}^*$) represent the events in E (resp. E*) associated with processing operations and the changing of a product type – without the execution of any processing operations

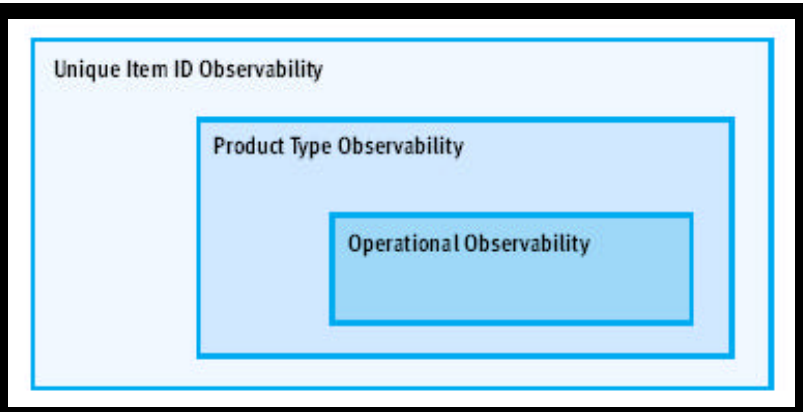
Definition 3.5 [Full Operational Observability]

Let the event set E_{po} be partitioned $E_{po} = E_{po\_o} \cup E_{po\_uo}$ where E_{po_o}, E_{po_uo} refer to the observable and unobservable event sets respectively. A plant G is fully operationally observable if and only if $E_{po} = E_{po\_o}$ and $E_{po\_uo} = \{e\}$ where $\{e\}$ denotes the empty set of empty string, ? ? .

Theorem 3.1 [Product Type Observability]

Assume that G is fully operationally observable. Let the event set E_{pt} be partitioned such that $E_{pt} = E_{pt\_o} \cup E_{pt\_uo}$ where E_{pt_o}, E_{pt_uo} refer to the observable and unobservable event sets respectively. A fully operationally observable plant G is observable with respect to product type if and only if $E_{pt} = E_{pt\_o}$ and $E_{pt\_uo} = \{e\}$.

Levels of observability



EAS

Reorder

Tracking of Counterfeit Item

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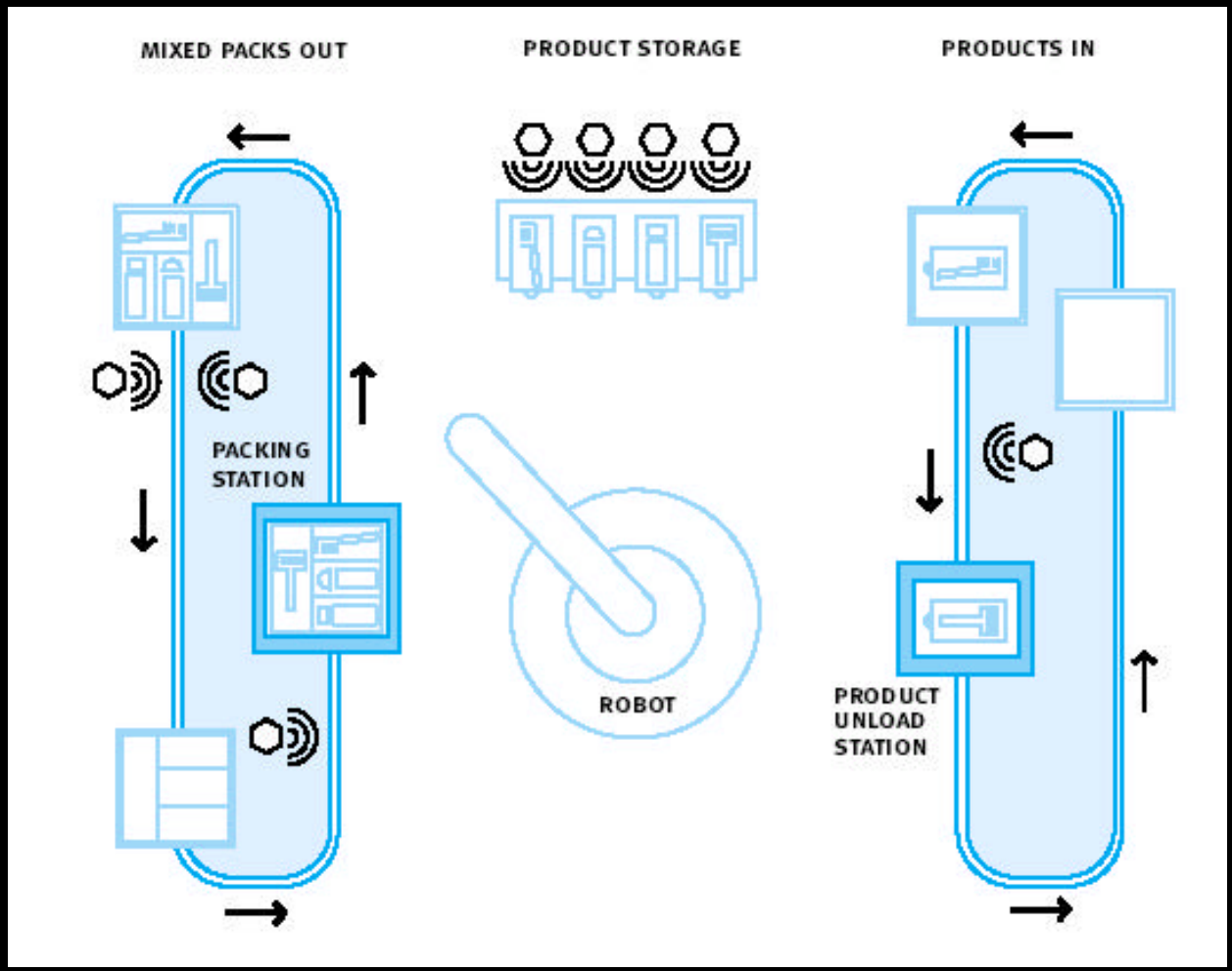
Example: observing a storage system



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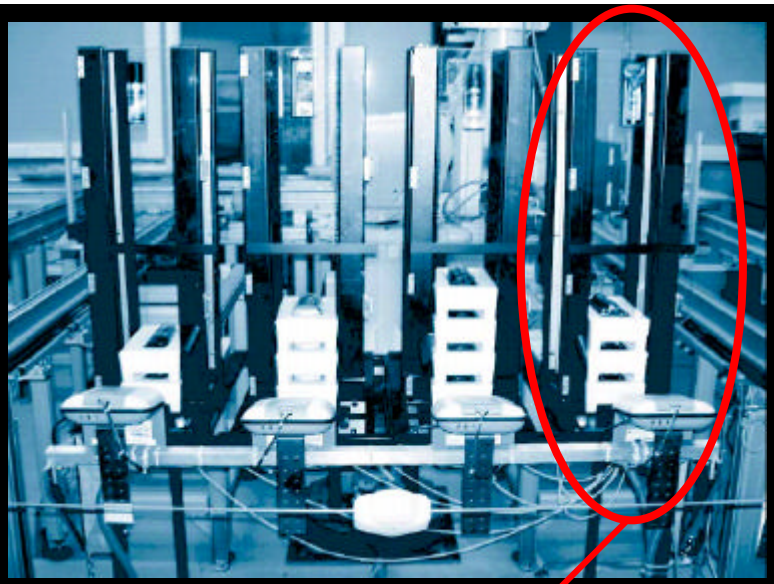
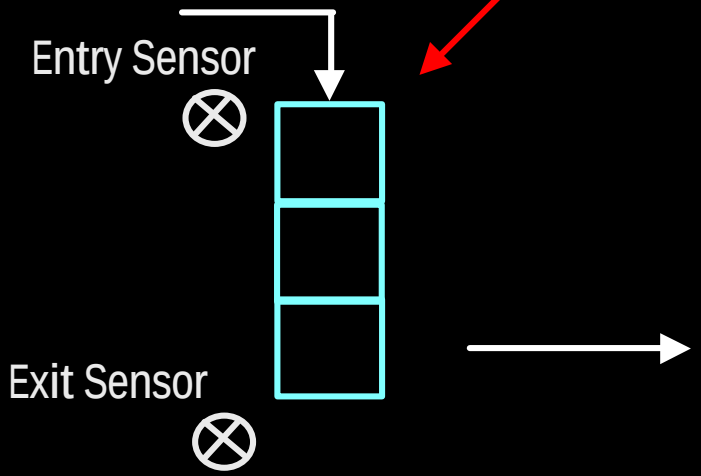
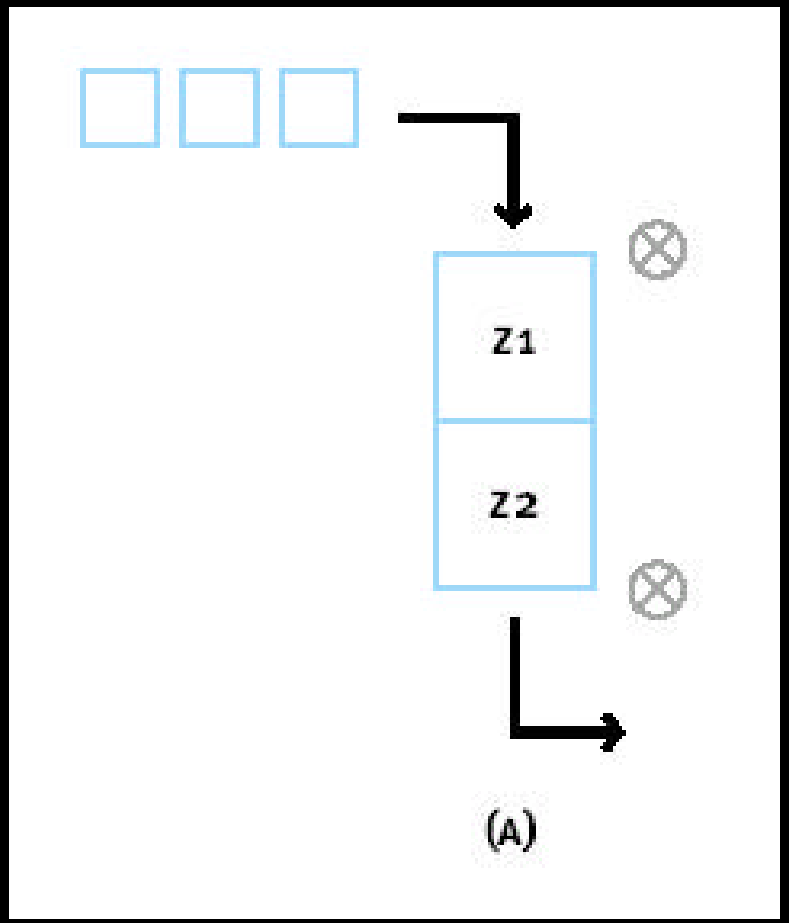




Note

- FIFO storage system
- event based vs time based sensing

Example: observing a storage system



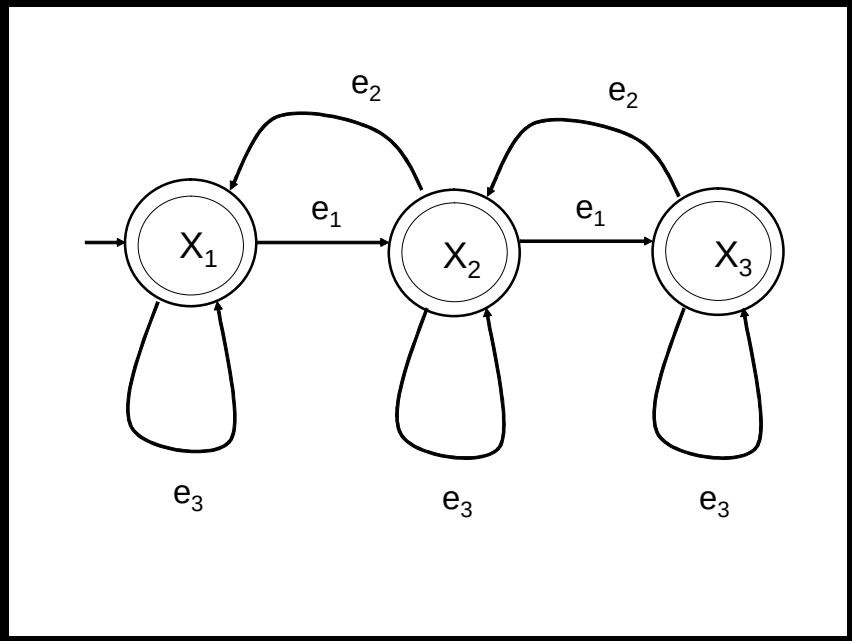
Note
- single product type
- assuming proximity sensors only
- system is operationally observable

Discrete event model

e_1 denoted the addition of an item,

e_2 denoted the removal of an item and

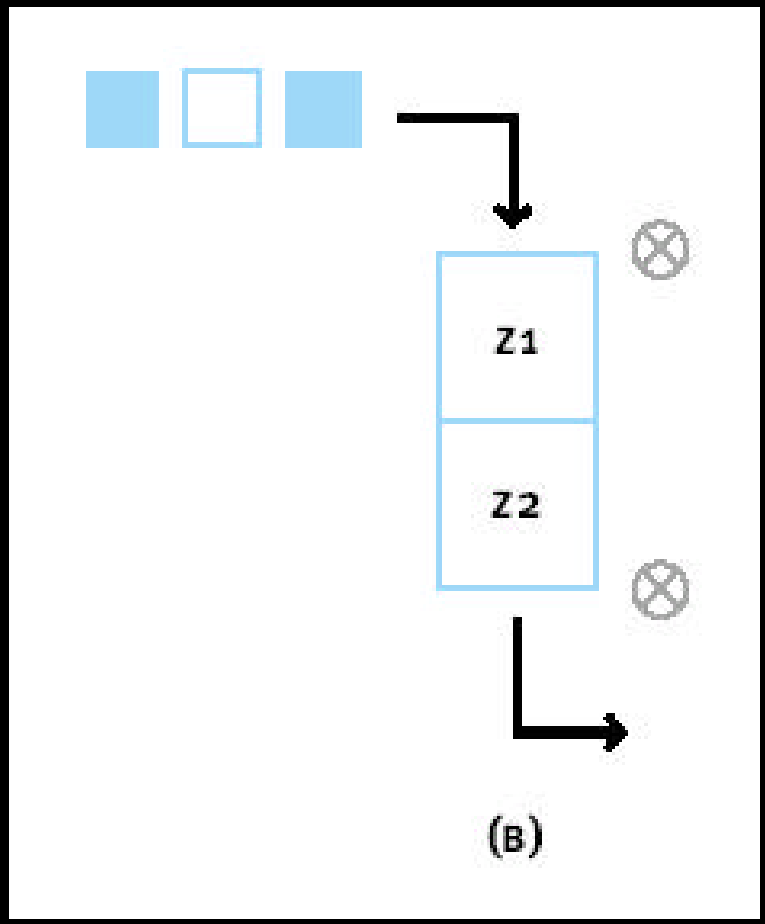
e_3 denoted the simultaneous addition and removal of items.



Sensor Type	E_{po_o}	E_{po_uo}	E_{pt_o}	E_{pt_uo}
Proximity Sensors	$\{e_1, e_2, e_3\}$	$\{e\}$	$\{e\}$	$\{e\}$
Identity Sensing	$\{e_1, e_2, e_3\}$	$\{e\}$	$\{e\}$	$\{e\}$

Example: observing a storage system

Note
- multiple product type
- system is NOT product type observable
- Require identity scanning (bar code, rfid)
- same logic applies for unique item ID observability



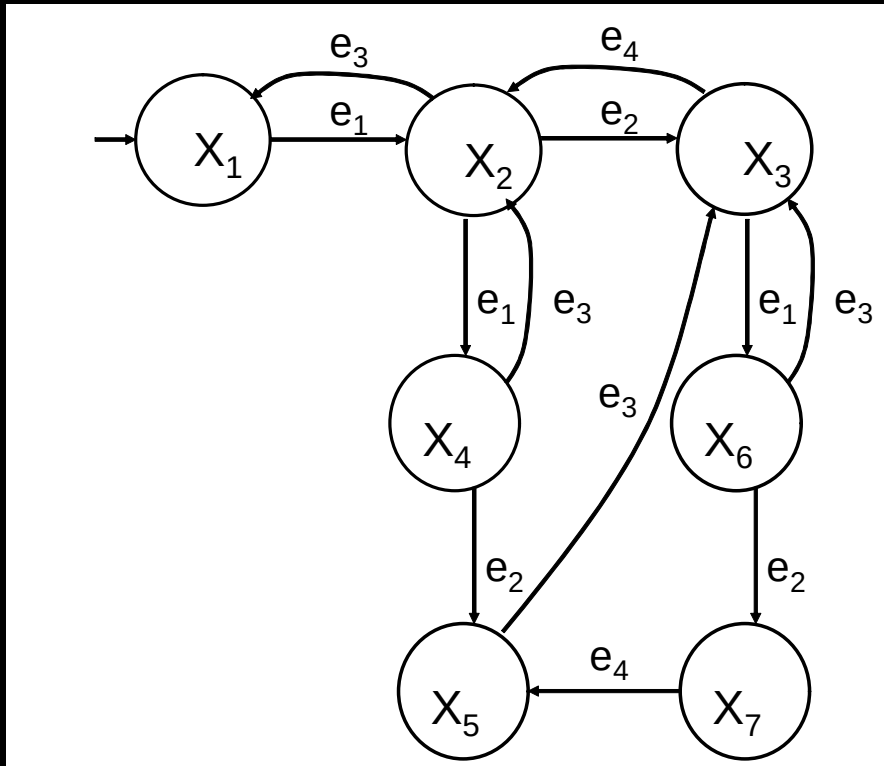
Discrete event model

e_1 – add neutral item to the top of the stack

e_2 – remove neutral item and add black item to place z_1

e_3 – remove neutral item from the bottom of the stack

e_4 – r move black item and add neutral item to place z_2



Sensor Type	E_{po_o}	E_{po_uo}	E_{pt_o}	E_{pt_uo}
Proximity Sensors	$\{e_1, e_3\}$	$\{e\}$	$\{e\}$	$\{e_2, e_4\}$
Identity Sensing	$\{e_1, e_3\}$	$\{e\}$	$\{e_2, e_4\}$	$\{e\}$

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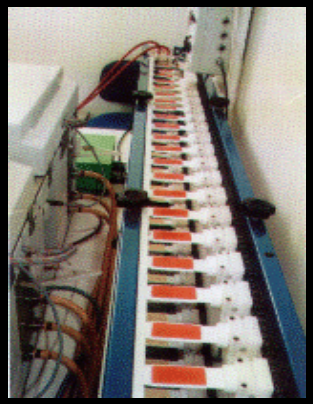
Impact on on Industrial Systems

Auto id and industrial “visibility”

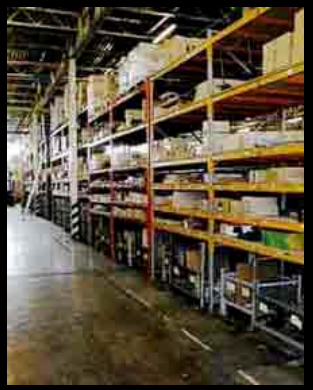
- Auto-ID can provide greater degree of visibility of contents in stock
- Not reliant on computer tracking system
- Other key issues:

1 Accuracy of the observation



2 Timeliness
Of observation

3 Location
fidelity



Auto id and industrial control

- Product Type Observability acts to increase the number of available control options to be selected from
- Level of observability linked to decision fidelity and execution freedom.
- Benefits of increased observability not fully realised in the example:

→ Need more flexible access

→ Need flexible/adaptable control