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# A survey on run-time supporting platforms for cyber physical systems

**Key words:** Cyber physical systems (CPSs); Run-time supporting platforms; Component; Service; Agent

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# Motivation

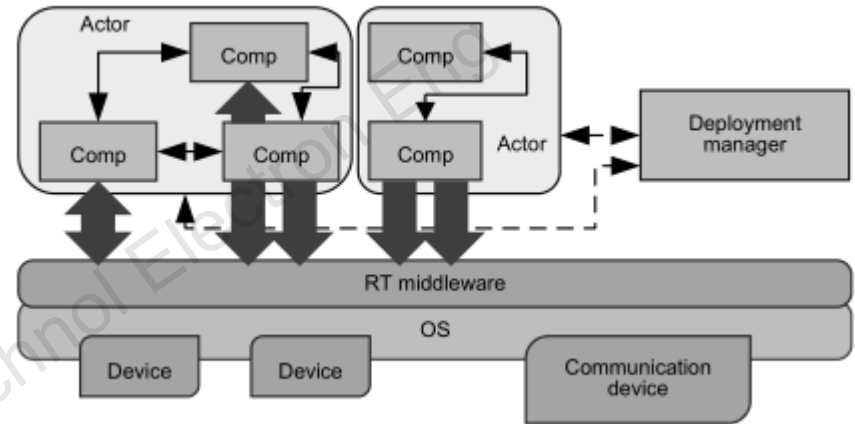
- The deep coupling and continuous interaction between computation, communication, and physical processes lead to a significant increase in complexity in the design and implementation of Cyber physical systems (CPSs) .
- Consequently, whereas developing CPSs from scratch is inefficient, developing them with the aid of CPS run-time supporting platforms can be efficient.
- In recent years, much research has been actively conducted on CPS run-time supporting platforms. However, few surveys have been conducted on these platforms.

# Main idea

- We analyze and evaluate existing CPS run-time supporting platforms by first classifying them into three categories from the viewpoint of software architecture: component-based platforms, service-based platforms, and agent-based platforms.
- We compare existing platforms from two aspects: construction approaches for CPS tasks and non-functional properties support.
- We also outline several important future research issues.

# 1. Component-based CPS run-time supporting platforms

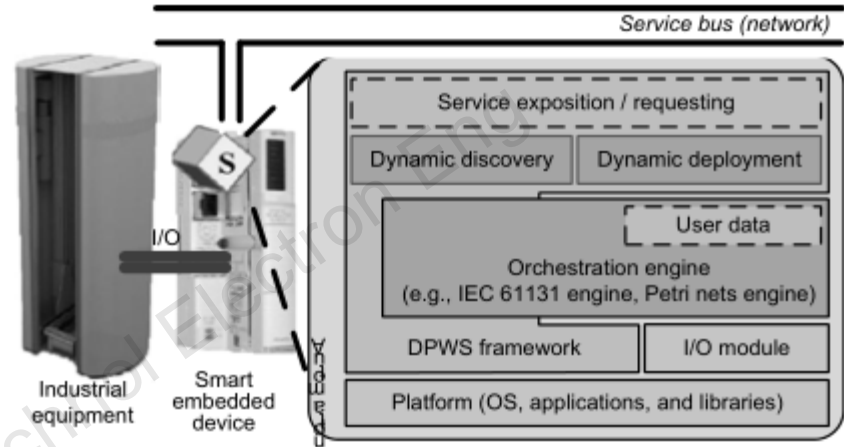
- CPS components are employed to encapsulate low-level operations in both cyber and physical spaces, and CPS tasks comprise a set of CPS components.
- CPS component model
  - Real-time component
  - Independent component
- Construction and deployment of component-based CPS tasks
  - real-time, robustness and autonomy support
- Reconfiguration of component-based CPS tasks
  - to handle high dynamic nature of CPSs



**A component-based CPS run-time supporting platform**

## 2. Service-based CPS run-time supporting platforms

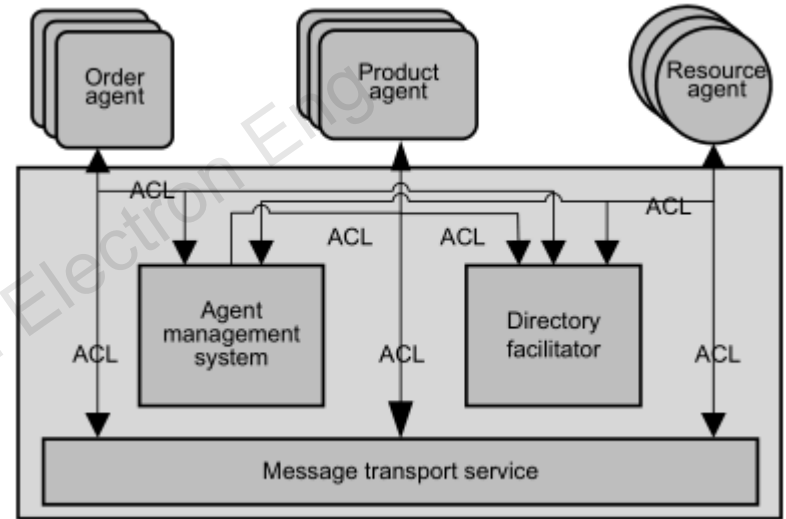
- CPS services, which integrate the abilities of physical entities and related software, are treated as basic structural units of CPS tasks.
- Description of CPS services
  - Integration of operations in physical space
  - sensitive to physical environment
- Discovery of CPS services
  - the increasing scale of CPSs
- Composition of CPS services
  - static composition
  - dynamic composition
  - composition at design time



A service-based CPS run-time supporting platform

# 3. Agent-based CPS run-time supporting platforms

- **CPS agents are used to manage autonomous entities in the system and CPS tasks need the collaboration of sets of CPS agents.**
- **CPS agents**
  - **Real-time constraints**
  - **Stronger Interoperability (Integration with existing heterogeneous engineered systems)**
  - **Semantic CPS agents (understanding knowledge)**
- **Evolution of CPS agents**
  - **CPSs are faced with an increasing number of uncertainties, such as disturbances and failures.**
  - **A set of CPS agents have to evolve through cooperation in order to handle uncertainties.**



**An agent-based CPS run-time supporting platform**

# 4. Comparison of construction approaches for CPS tasks

- Three kinds of CPS structural units
  - autonomy is an essential attribute of CPS agents
  - CPS services have stronger interoperability than CPS agents
  - CPS agents have stronger interoperability than CPS components
- Composition of structural units
  - Fully static composition can be used for all kinds of structural units
  - fully dynamic composition and dynamic-static hybrid composition are usually used for CPS services and CPS agents.
  - fully dynamic composition and dynamic-static hybrid composition are able to employ dynamic properties

**Table 1 Comparison of three types of structural units**

Structural unit	Autonomy	Interoperability	Adaptability
CPS component	•	•	•
CPS service	••	•••	••
CPS agent	•••	••	••

The number of black spots is used to indicate the degree of such aspects as autonomy, interoperability, and adaptability

# 5. Comparison of non-functional properties support

- **Most of existing platforms have varying levels of reconfigurability. In general, agent-based platforms have the strongest reconfigurability, whereas component-based platforms have the weakest.**
- **Several studies have been conducted on scalability, but the majority of them are not integrated into existing platforms. In general, knowledge-based approaches can obtain better scalability than decentralized control-based approaches.**
- **Almost all of the platforms are able to leverage context information and handle failures. In general, the platforms using centralized management (the majority of component-based platforms and service-based platforms) have lower resilience than the platforms using decentralized management (the majority of agent-based platforms).**
- **Real-time is only supported by several platforms.**
- **As far as we know, only a few of existing platforms are able to support security.**

# 6. The best platform architectures in different application scenarios

- In general, in situations where the demand for real-time support is strong, such as vehicle electronic systems, using a component-based platform is the best choice.
- In dynamic environments, using either a service-based platform or an agent-based platform is feasible.
- However, if interoperability is also strongly needed, such as in IMSs, service-based platforms are best.
- If local autonomy is obvious, such as in smart grids, swarms of UAVs, ITSs, agent-based platforms are best.

**Table 3 The best platform architectures in different application scenarios**

Application scenario	Real-time	Autonomy	Dynamics	Interoperability	The best platform architectures
Vehicle electronic systems	●●●	●	●	●	Component-based platforms
Intelligent manufacturing systems	●	●	●●	●●●	Service-based platforms
Smart grids	●	●●	●●	●●	Agent-based platforms
Swarm of UAVs	●●	●●	●●	●	Agent-based platforms
Intelligent transportation systems	●	●●	●●	●●	Agent-based platforms

The number of black spots indicates the degree of the key features

# Conclusions

- Existing platforms have both advantages and disadvantages because they aim at different application fields.
- In order to choose an appropriate platform architecture, the particular characteristics of the application field have to be well known.
- Future research issues
  - Verification of CPS tasks
  - Support for human-in-the-loop applications
  - Runtime monitoring of CPS tasks