The Need of Proper Programming Models for CPS

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Short Resume

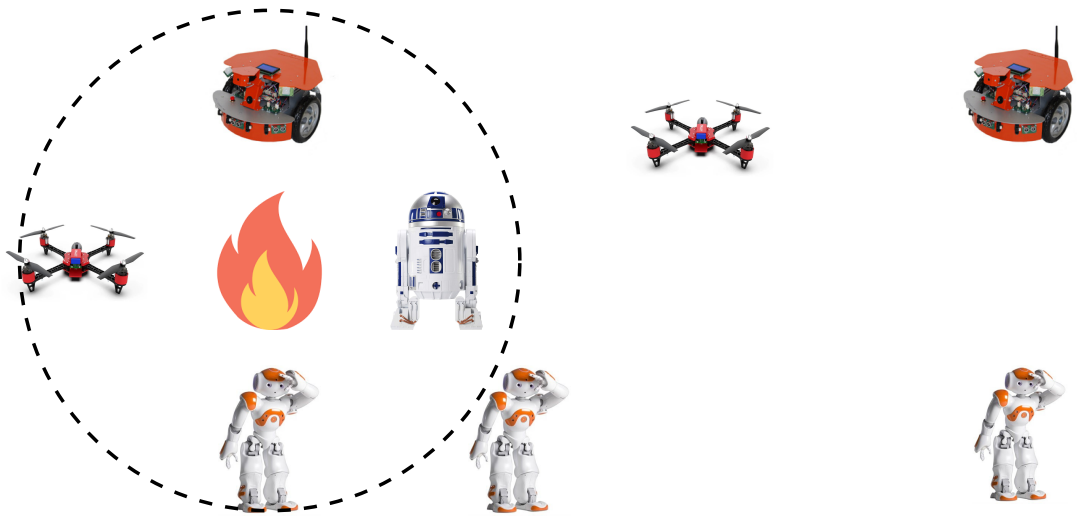
- Since March 2020 research assistant at the Operating Systems Group of the TUC
- 2016 - 2020 tutor for research and teaching
- 2013 - 2020 student of Applied Informatics and Automotive Software Engineering
- Research focused on mobile CPS

Motivation

- Distribution, Communication, Mobility, Heterogeneity
- Interaction with the environment
- Programming is error-prone and complex
- We need **abstractions**!

Aspects

- Physical phenomena, execution units, applications
- Mobility in all aspects
- Coordination of execution units according to environment and application



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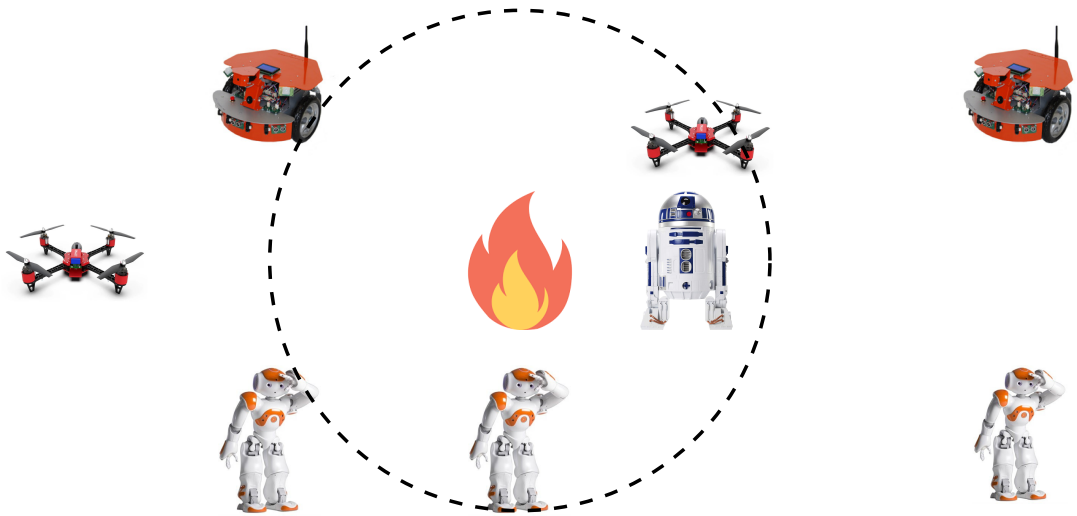

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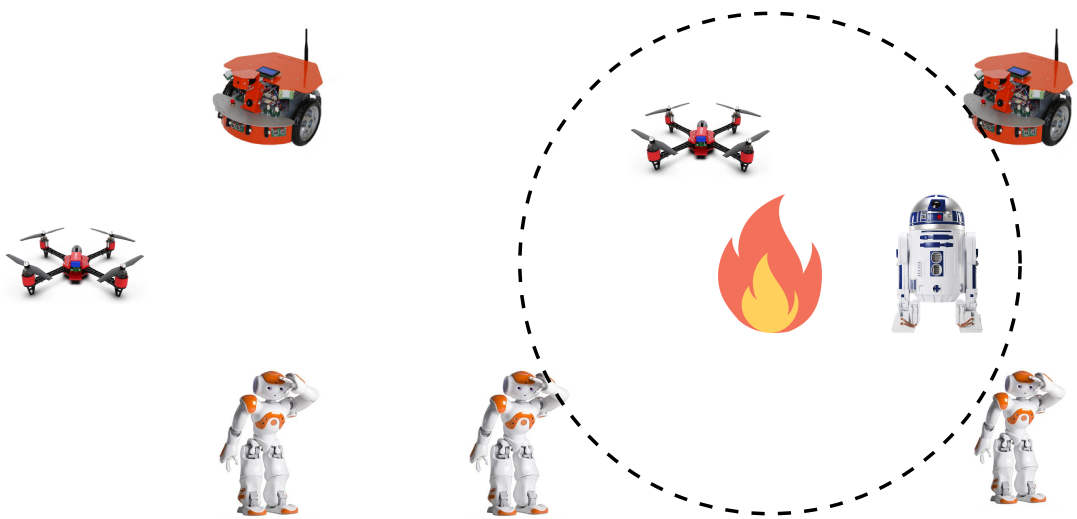

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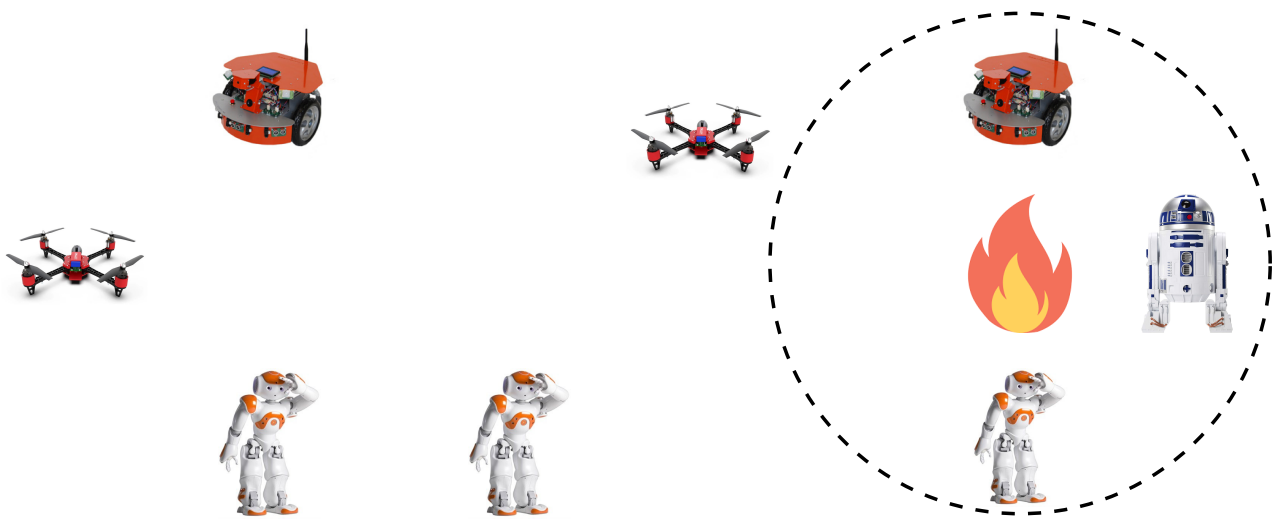
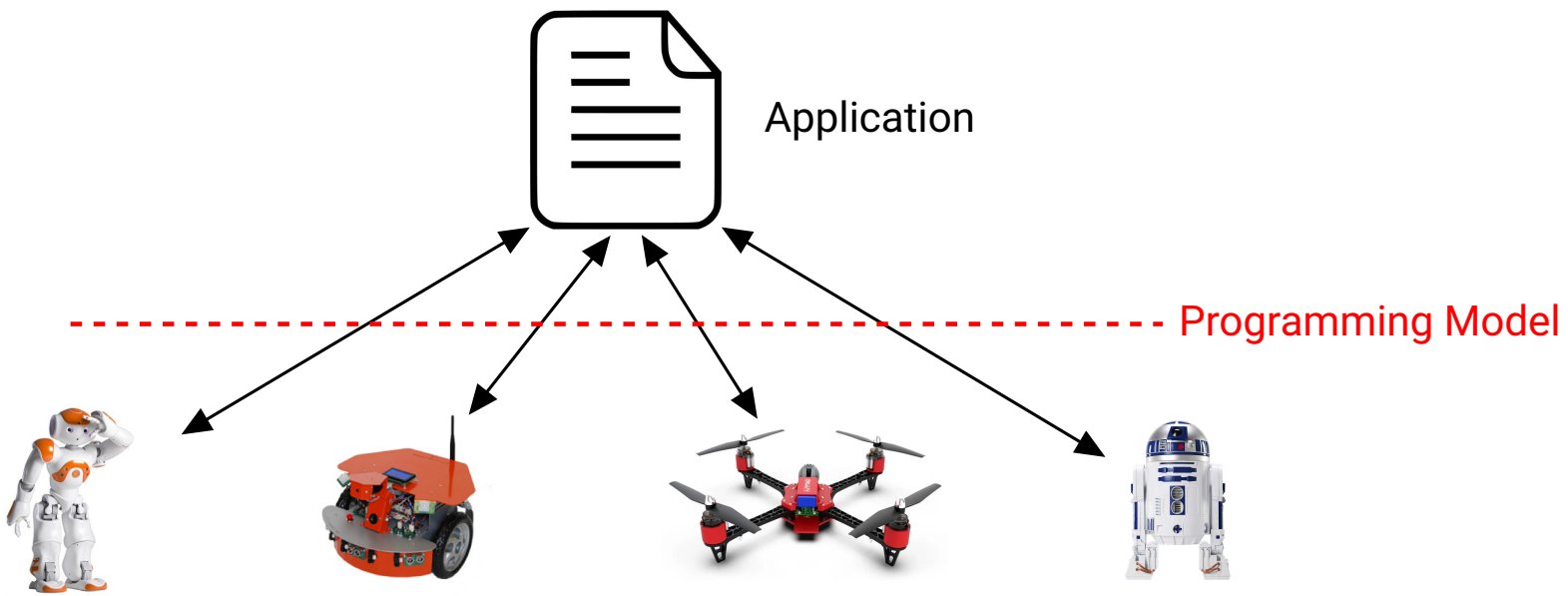


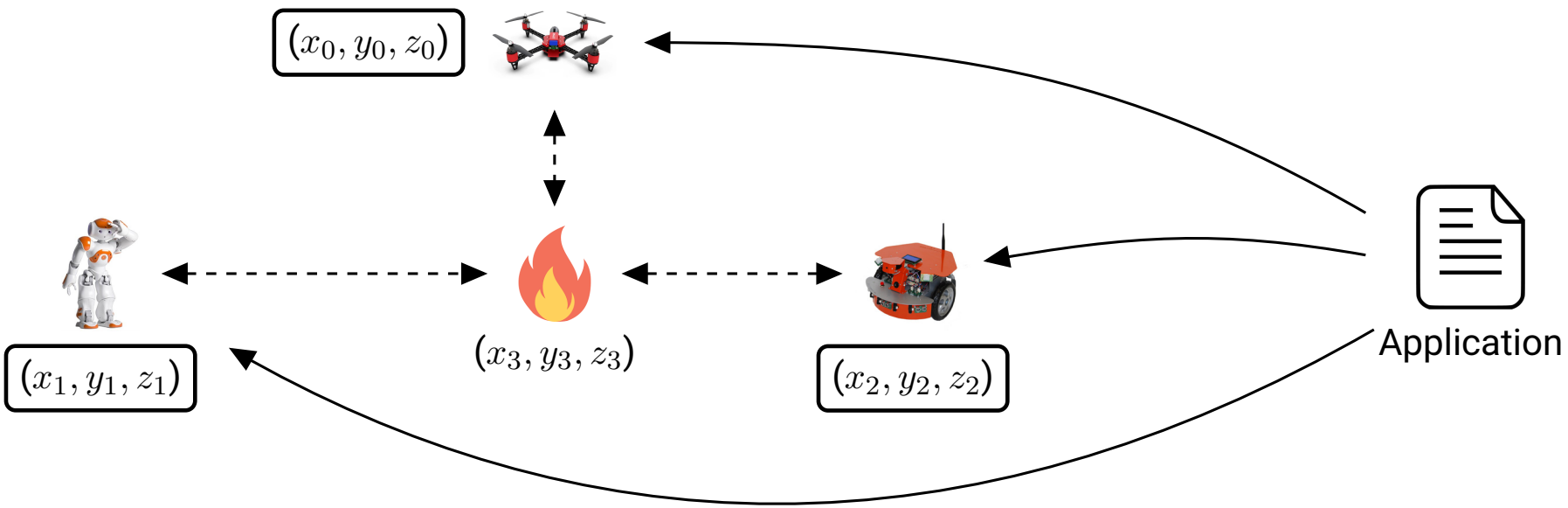
Programming Models

- Describe programmers view on the system
- May abstract from properties of the system (transparency)
- May supply options to control/observe properties (awareness)



Problem Statement

- Classic: distribution, location, motion transparency
- CPS: location and motion aware operation of devices for interaction with environment
- Desired: distribution transparency and location/motion awareness



Goal

Is there a need for research?

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1. Architectural model for CPS

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2. Desired programming model properties for each layer

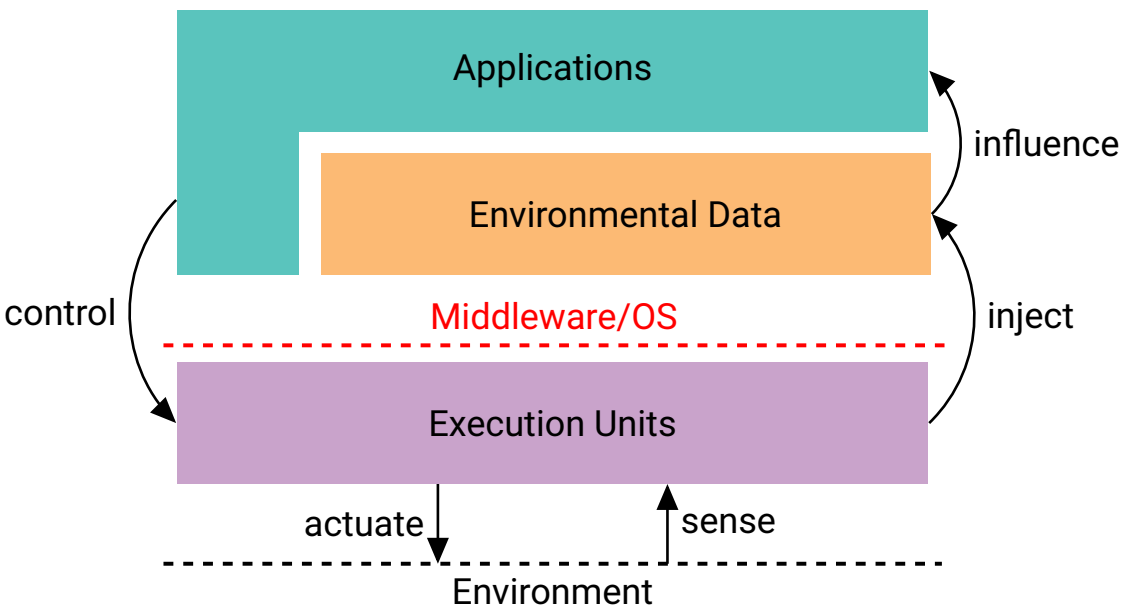
Goal

Is there a need for research?

1. Architectural model for CPS
2. Desired programming model properties for each layer
3. Do corresponding models exist?

Architectural Model

- Applications and data distributed across execution units
- Environmental data are images of physical phenomena
- Creation through aggregation



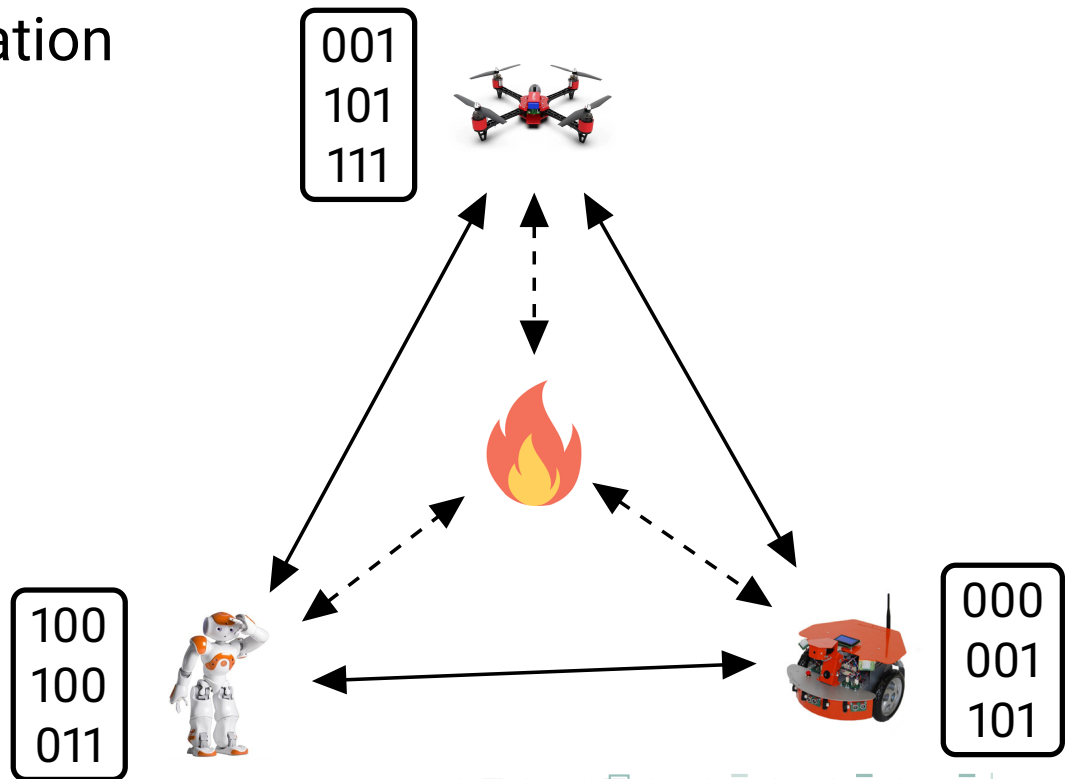
Properties of Programming Models

- Applications, environmental data, execution units (see architectural model)
- Focus on distribution, location and motion (active or passive)
- **Transparency or awareness?**

$$\begin{bmatrix} \text{Distribution Transparency} \\ \text{Location Transparency} \\ \text{Location Awareness} \\ \text{Motion Transparency} \\ \text{Passive Motion Awareness} \\ \text{Active Motion Awareness} \end{bmatrix} \times \begin{bmatrix} \text{Application} \\ \text{Environmental Data} \\ \text{Execution Units} \end{bmatrix}$$

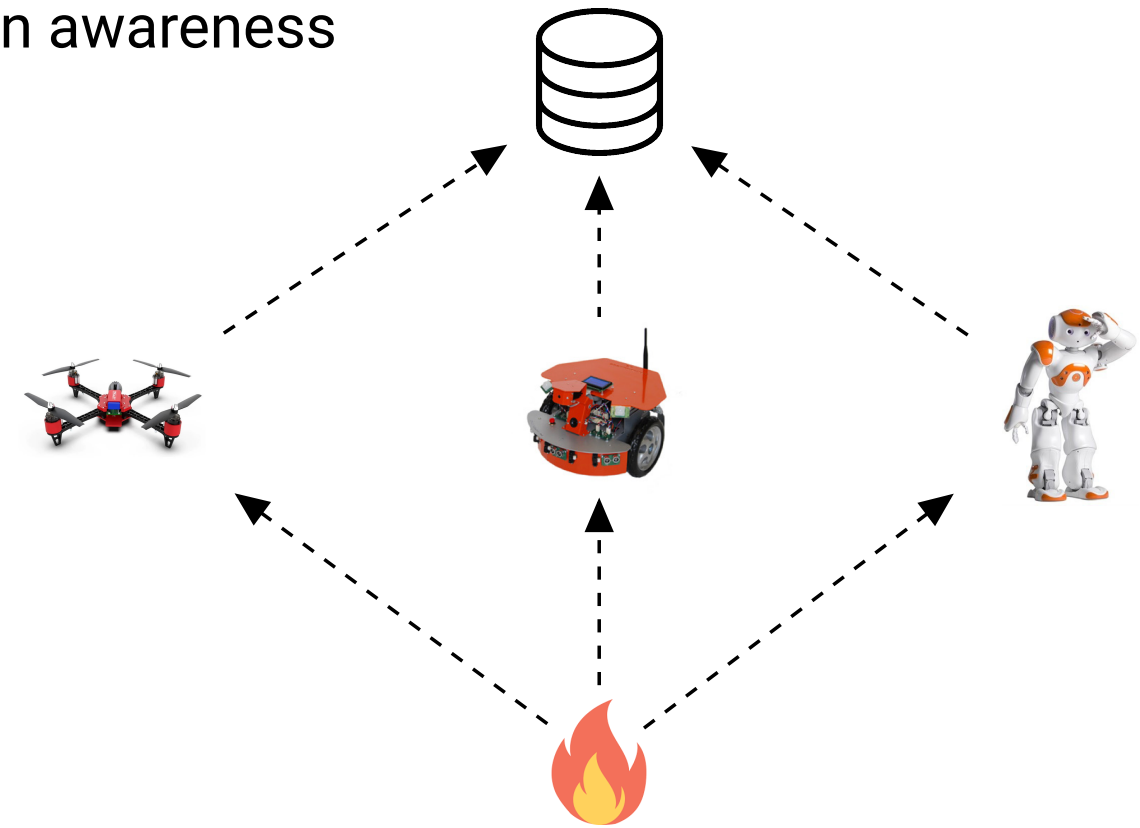
Execution Units: Desired Properties

- Execute Applications and gather data
- Location and motion awareness (active or passive) for interaction with environment
- Heterogeneity, coordination



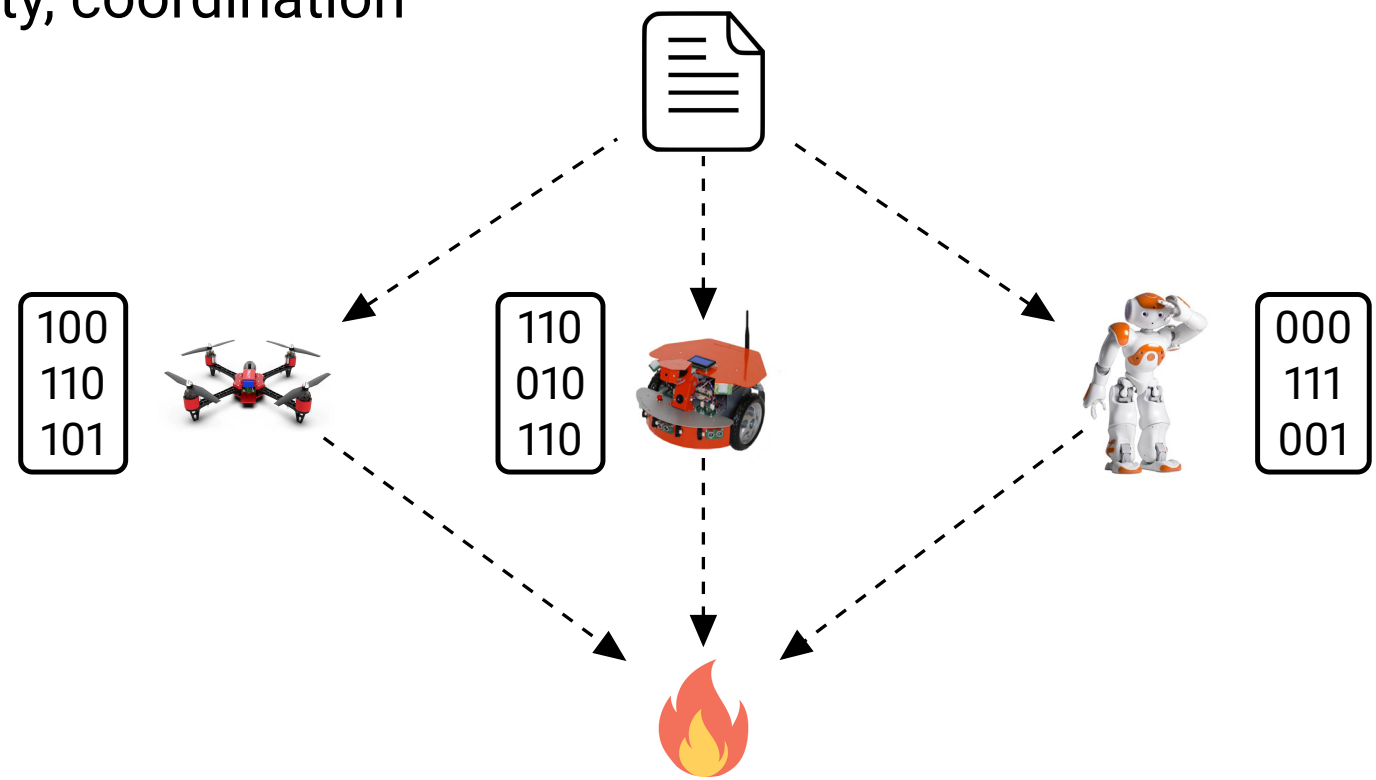
Environmental Data: Desired Properties

- Represent mobile physical phenomena
- Distribution transparency (aggregation)
- Location and motion awareness (active or passive)



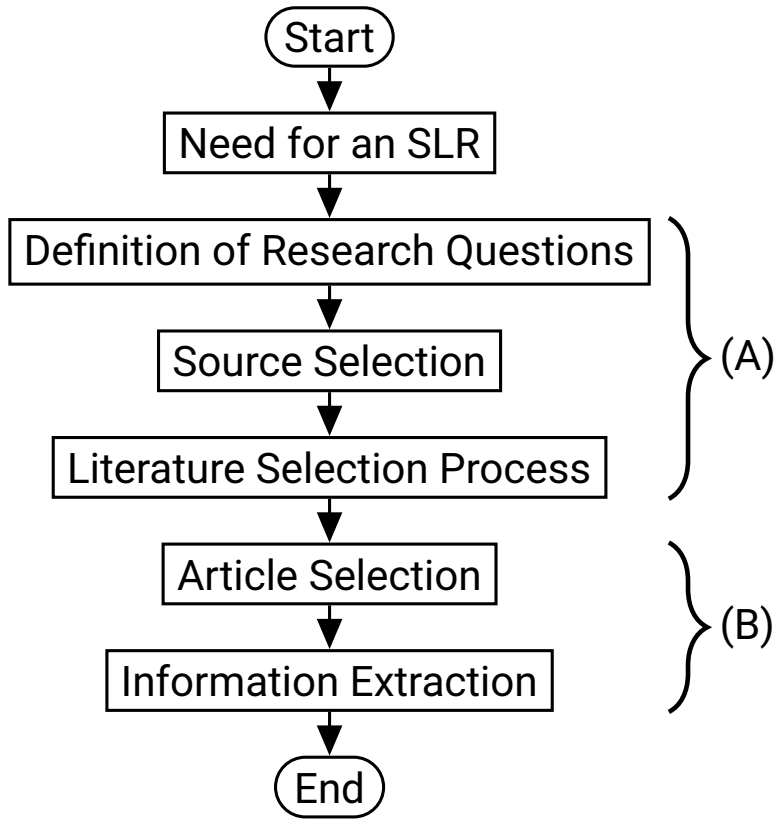
Applications: Desired Properties

- Distribution transparency
- Location and motion transparency
- Heterogeneity, coordination



Systematic Literature Review (SLR)

- So far: properties of models for classification of concepts
- Systematic analysis of existing approaches regarding mobile distributed systems
- Kitchenham[1] and Biolchini et al.[2] as templates
- Planning (A) and conduction (B)



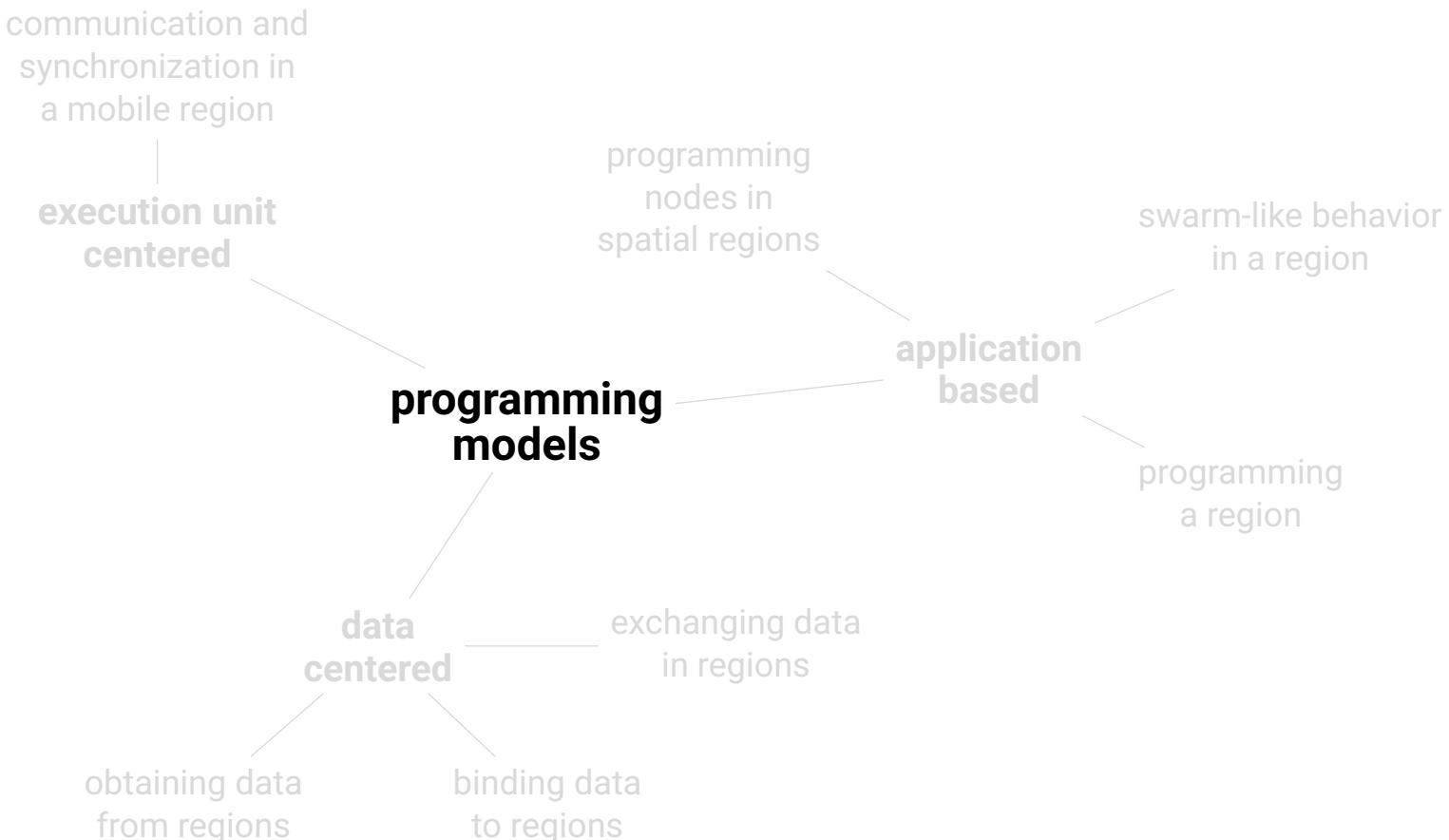
[1] Kitchenham. Procedures for performing systematic reviews.
[2] Biolchini, Mian, Natali, and Travassos. Systematic review in software engineering.

Results

- 16 approaches considering mobile distributed systems
- Programming models regarding distribution, location, motion
- Focus on different aspects of mobile CPS

Layer \ Property	Distribution Transparency	Location Transparency	Location Awareness	Motion Transparency	Motion Awareness	
					passive	active
Applications	5	2	5	4		3
Environmental Data	4	5	7	8	1	3
Execution Units	N/A	1	15	3	13	

Analysis


communication and synchronization in a mobile region
execution unit centered
programming nodes in spatial regions
swarm-like behavior in a region
application based
programming models
programming a region
data centered
exchanging data in regions
obtaining data from regions
binding data to regions

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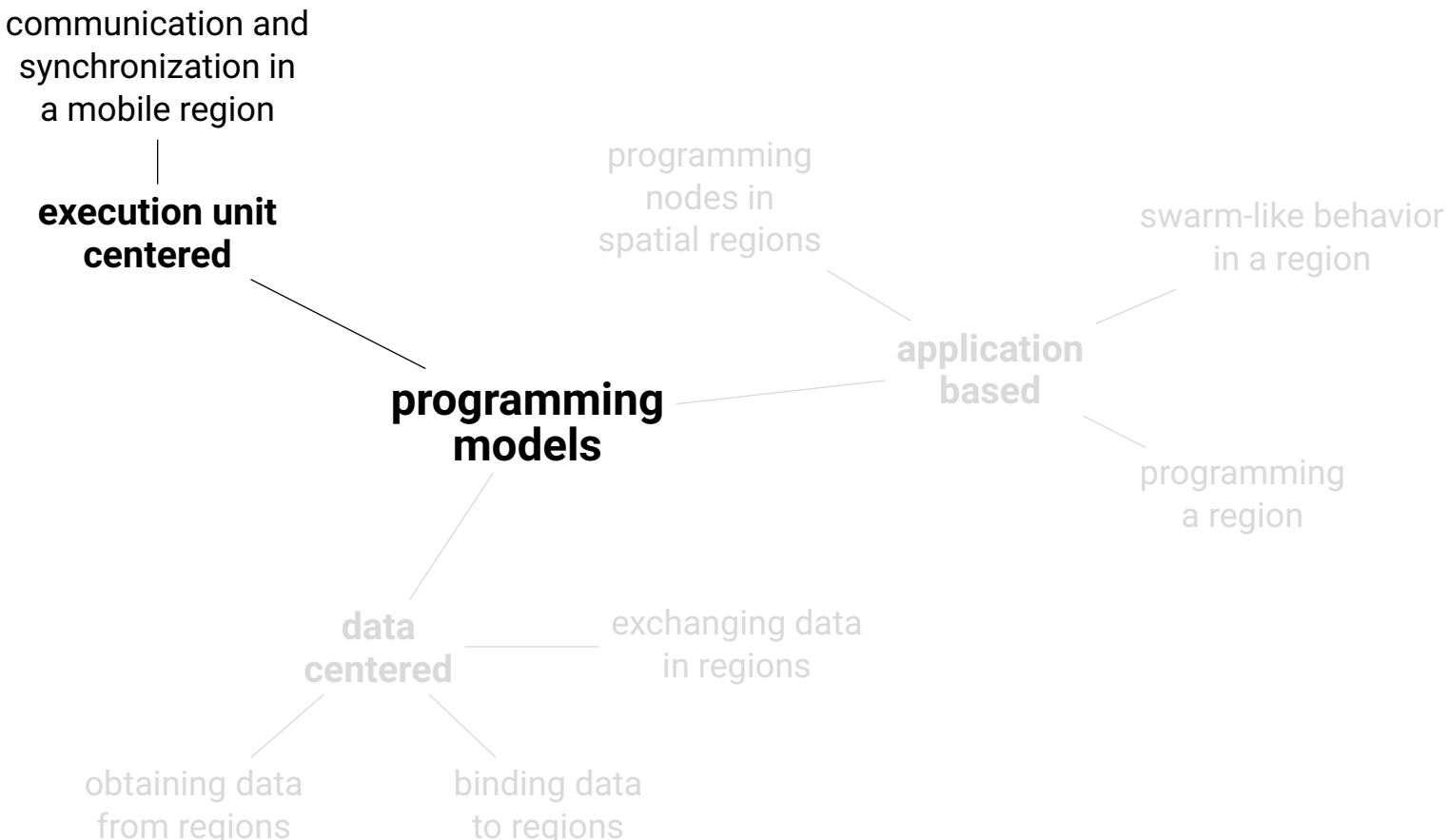
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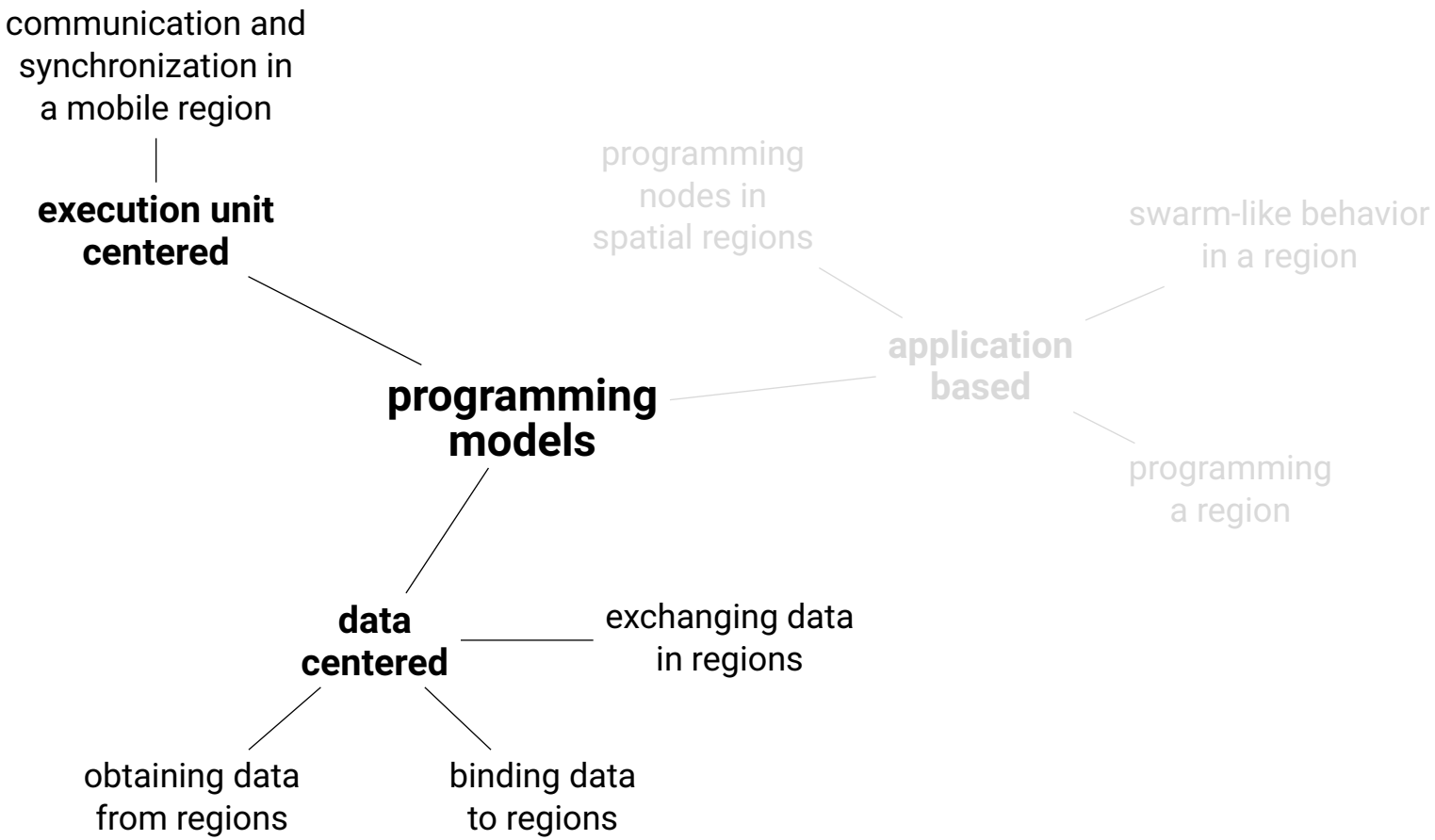
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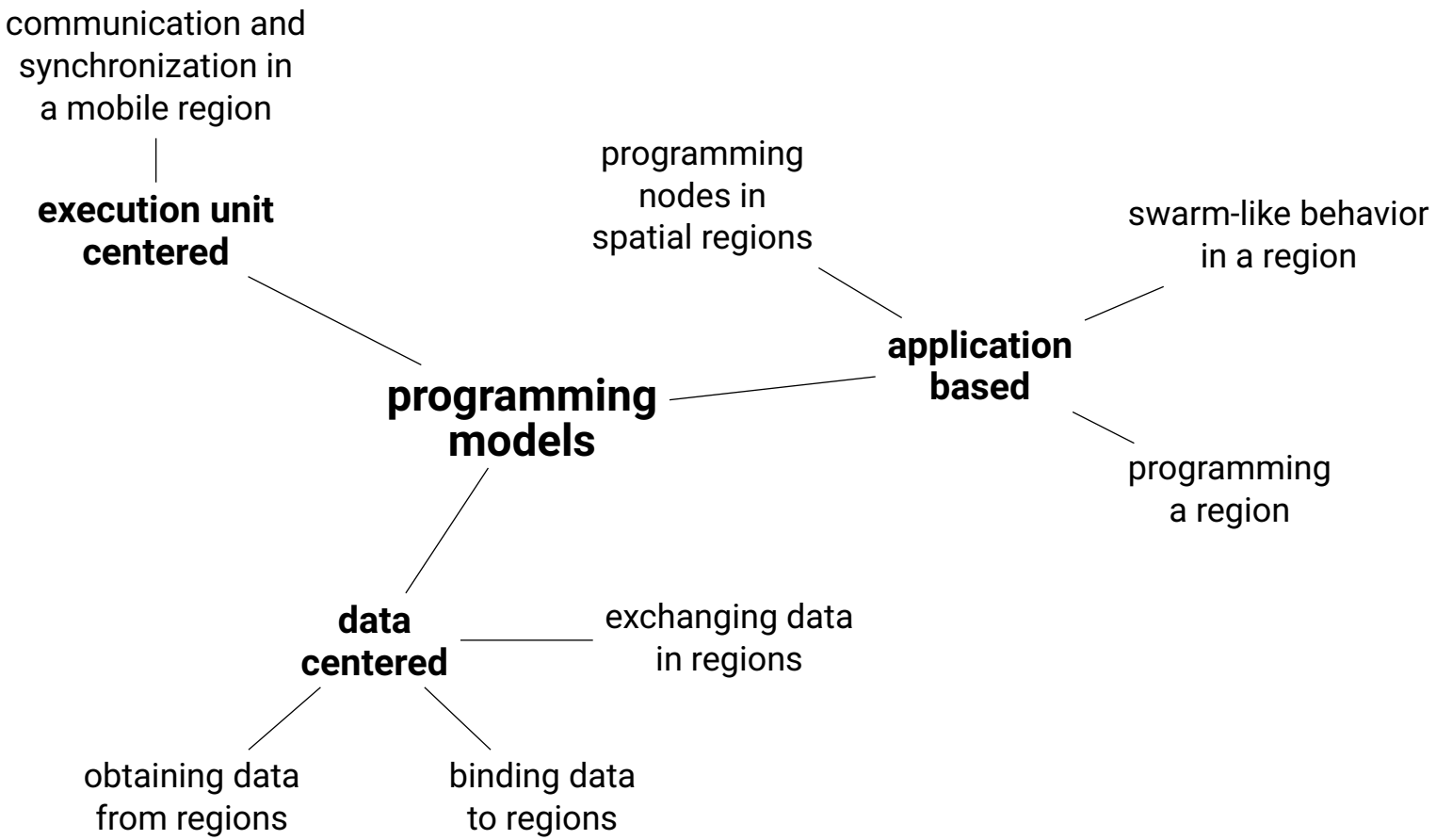
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Conclusion

- Execution units: *Autonomous Virtual Mobile Nodes* by Dolev et al.
  - Communication and synchronization in a mobile region
- Data: *Hovering Data Clouds* by Ebers et al.
  - Gathering data in mobile regions (corresponding to physical phenomena)
- Application: /
  - No support for coordination
  - Static regions

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There is a need for research!

Future Work

- Composition of existing models
- Formalization
- Considerations on heterogeneity
- Coordination of execution units based on application, capabilities, motion and location

Thank you for your attention!

Sources


[R2D2] https://images-na.ssl-images-amazon.com/images/I/712Lwo7hMoL._AC_SX425_.jpg


[Drone] https://i.all3dp.com/cdn-cgi/image/fit=cover,w=1284,h=722,gravity=0.5x0.5,format=auto/wp-content/uploads/2020/01/28160542/Drone-cover.jpg


[Flame-Icon] https://www.flaticon.com/free-icon/flame_426833


[App-Icon] https://www.iconsdb.com/black-icons/text-file-5-icon.html


[Data-Icon] http://icons.iconarchive.com/icons/icons8/ios7/512/Data-Database-icon.png

SLR Research Questions

- Deduced from properties of programming models
- Which properties do existing programming models for mobile distributed systems possess?

Layer \ Property	Distribution transparency	Location transparency	Location awareness	Motion transparency	Motion awareness (passive/active)
Applications	X	X		X	
Environmental data	X		X		X
Execution units	N/A		X		X

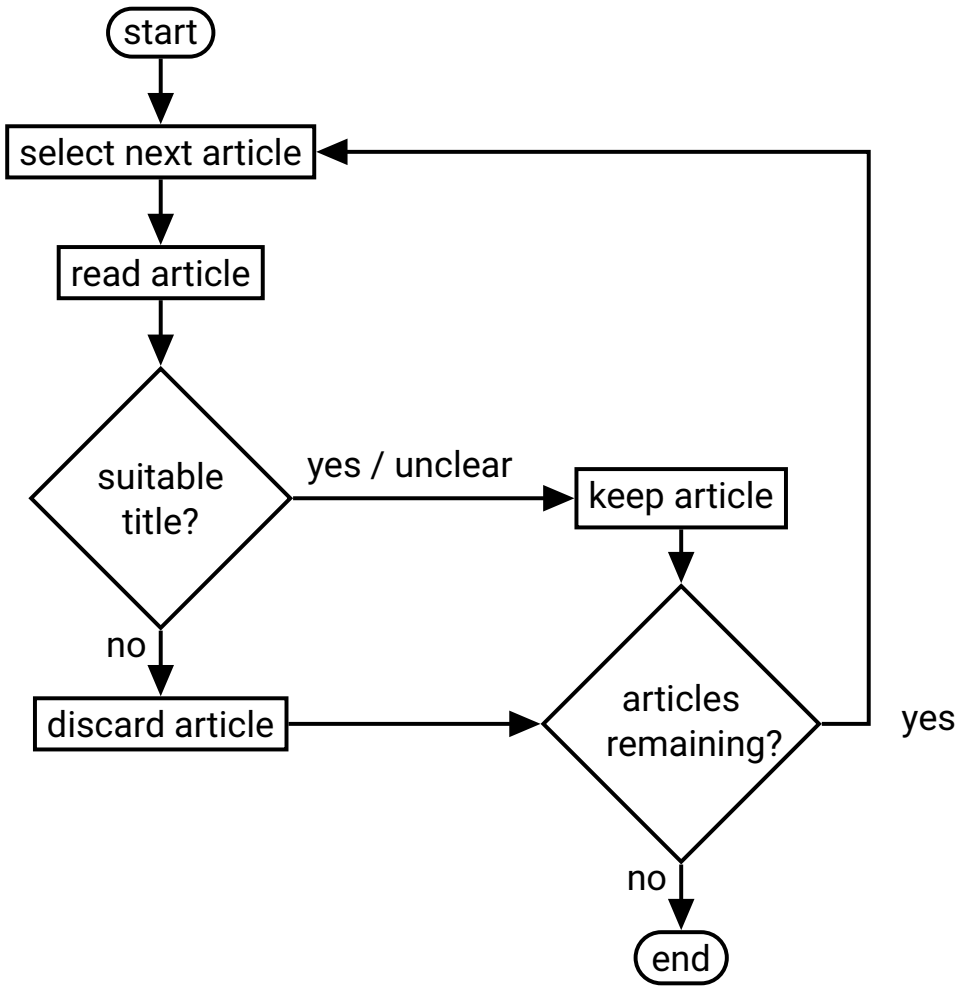
Source Selection

- Requirements: keyword search, online availability, English or German articles
- Several test runs of keyword search
- Corresponding adjustment of search term
- *Google Scholar* as chosen source

Quelle	**# Ergebnisse**
IEEE Xplore	4
Springer Link	95
ACM Digital Library	44
Science Direct	227
Google Scholar	452

Literature Selection

- Literature selection in two phases:
  1. Selection based on title
  2. Selection based on content
- 16 articles consider mobile distributed systems



Conduction of the SLR

- *Google Scholar* as source
- Selection of articles based on title and content
- Information extracted in the form of tables
- According to research questions and desired properties

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