Formal Methods for Communication Protocols

Harnessing distributed software design with behavioural contracts

Emilio Tuosto @ GSSI

– Lecture 1 –

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Italiadomani
DESK Developing Shared Knowledge

An overview of the course

Logistics

- Timetable
- These lectures are about interactions ...so do interact ☺

Motivations

Behavioural Design-by-Contracts for distributed coordination

- An unusual choreographic model
- Adding join patterns to actors
- A surprising (at least for me) application in economics

A glance at prototype tools

– Motivations –

On program comprehension

Erlang

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Let's try something!

Friendlier representations with (formal) models

Local behaviour: communicating machines [2]

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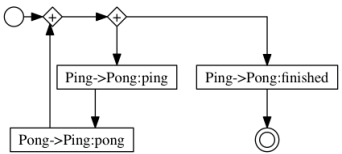
Choregraphy: global graph [3, 7]



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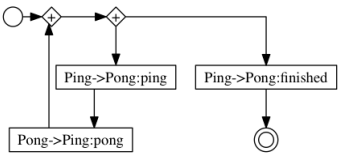

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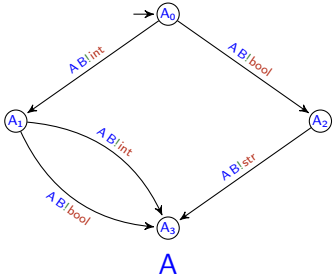
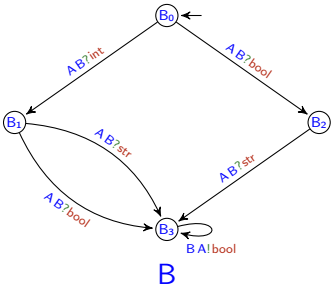
Research direction

How do we extract such models from code or documentation?

Our first formal model...informally

Communicating systems





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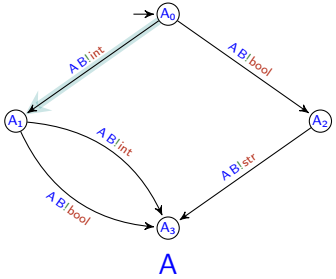

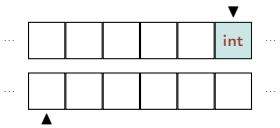

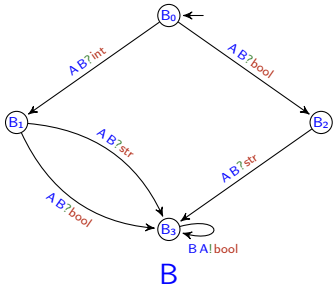

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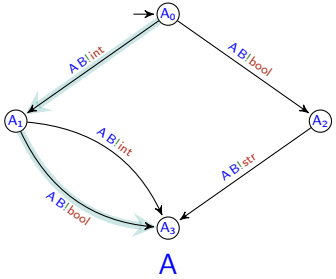

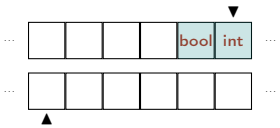

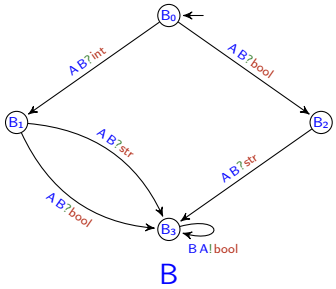

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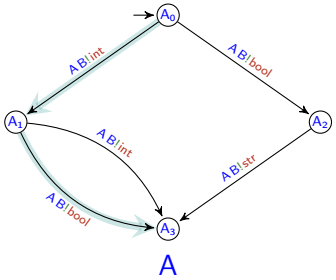

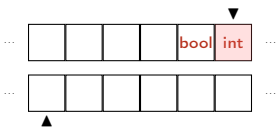

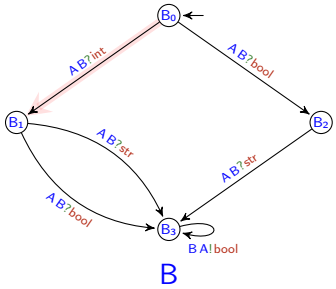

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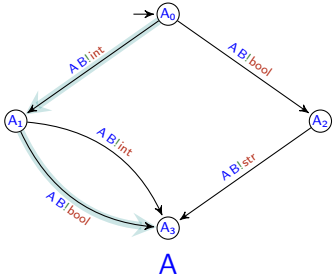

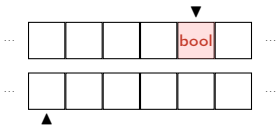

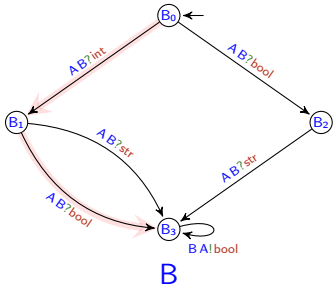

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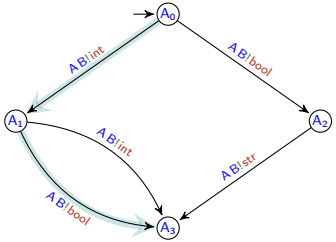

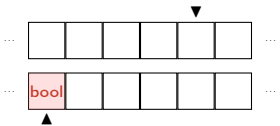

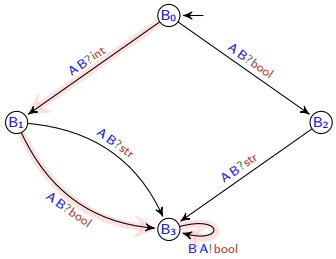

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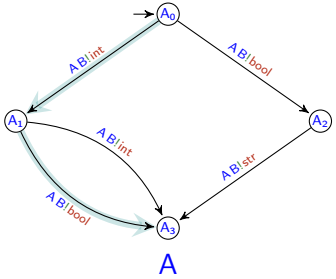

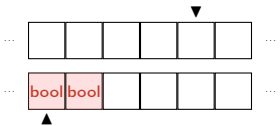

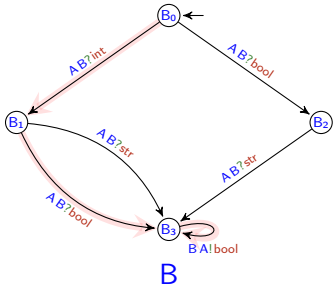

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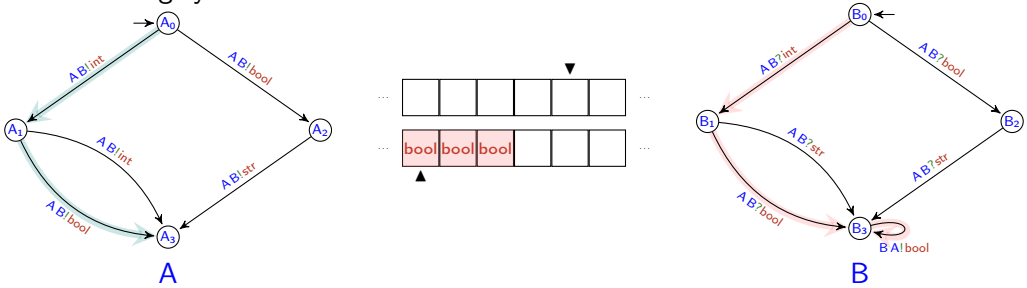

- a communicating finite-state machine (CFSM) is an FSA whose transitions are input/output actions executed by a single participant and whose states are all accepting
- a communicating system is a finite map assigning to a participant A a CFSM executing communications of A

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17       Ping_PID ! pong,
18       pong()
```

```
19 start() ->
20   Pong_PID = spawn(example, pong, []),
21   spawn(example, ping, [3, Pong_PID]).
```

So what?

- Now we have a model of the behaviour
- Let's use it to reason on correctness

Q:

The test was successful. But is the program correct?

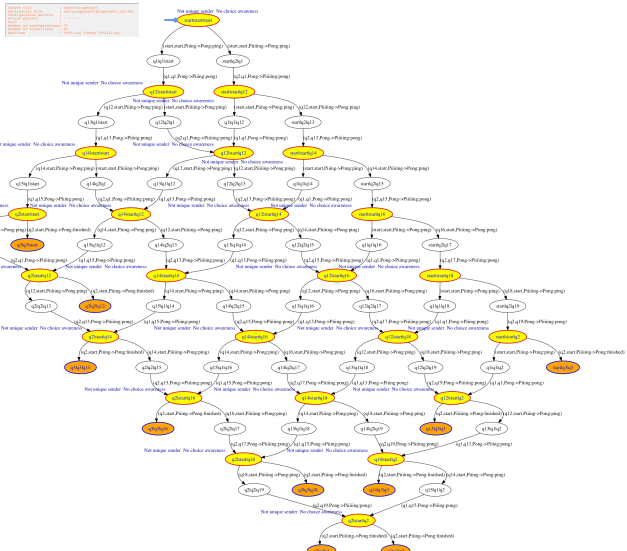
A:

No!

Exercise:

Find the bugs (there're at least 2!)

2 ping clients and 1 pong server!!!



Some reflections

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What does 'software' actually mean?

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- SW is not just 'code'

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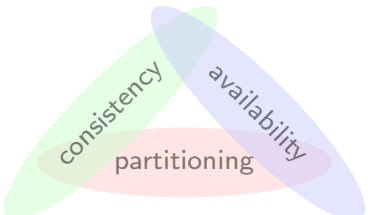
Would you buy a house without guarantees that its roof won't collapse? or that its heating system is working properly?

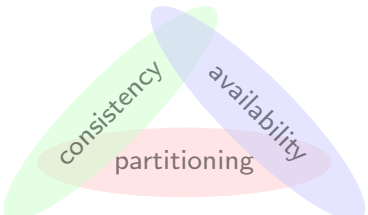
FM theory in practice



The CAP theorem

Distributed agreement
Distributed sharing
Security
Computer-assisted collaborative work
...

FM theory in practice



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With some "solutions"

- Centralisation points (not that appealing)

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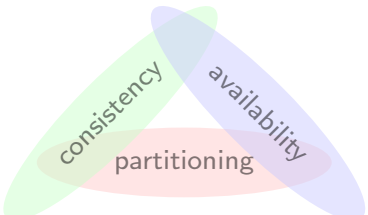

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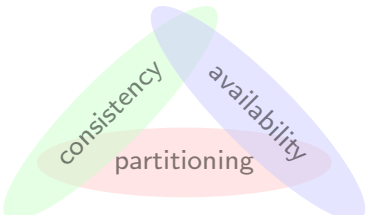

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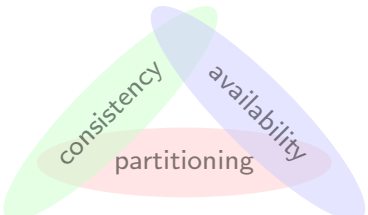

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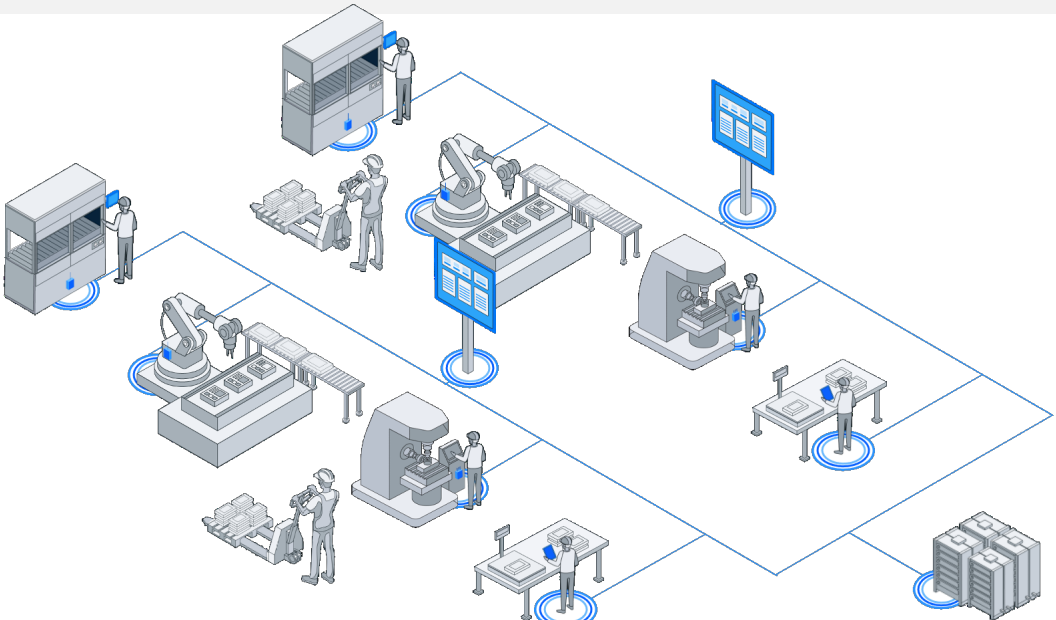

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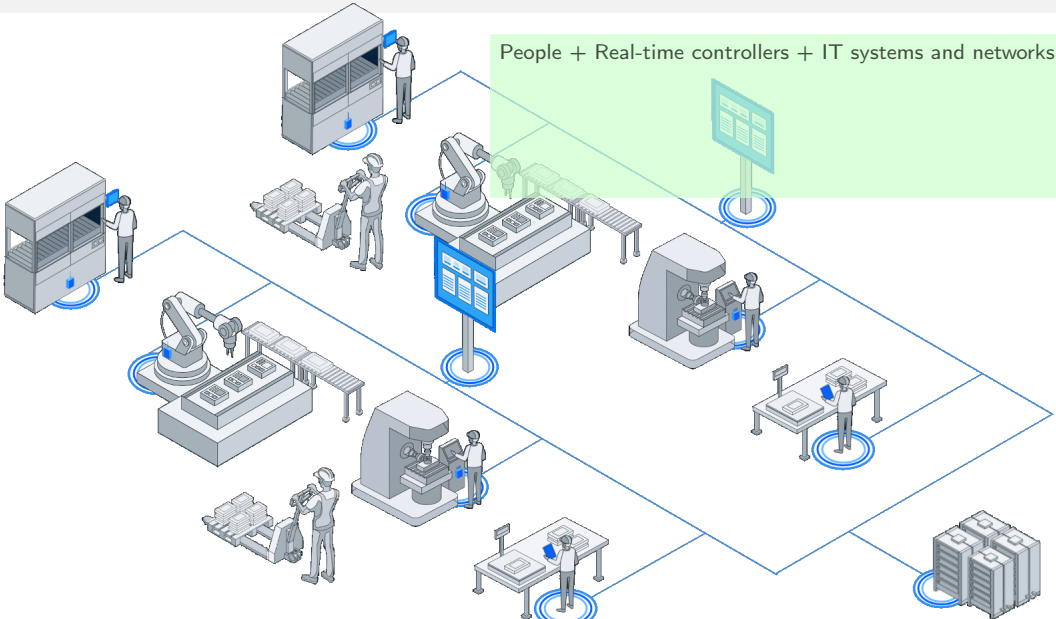
An execution model for a collaborative environment

People + Real-time controllers + IT systems and networks:



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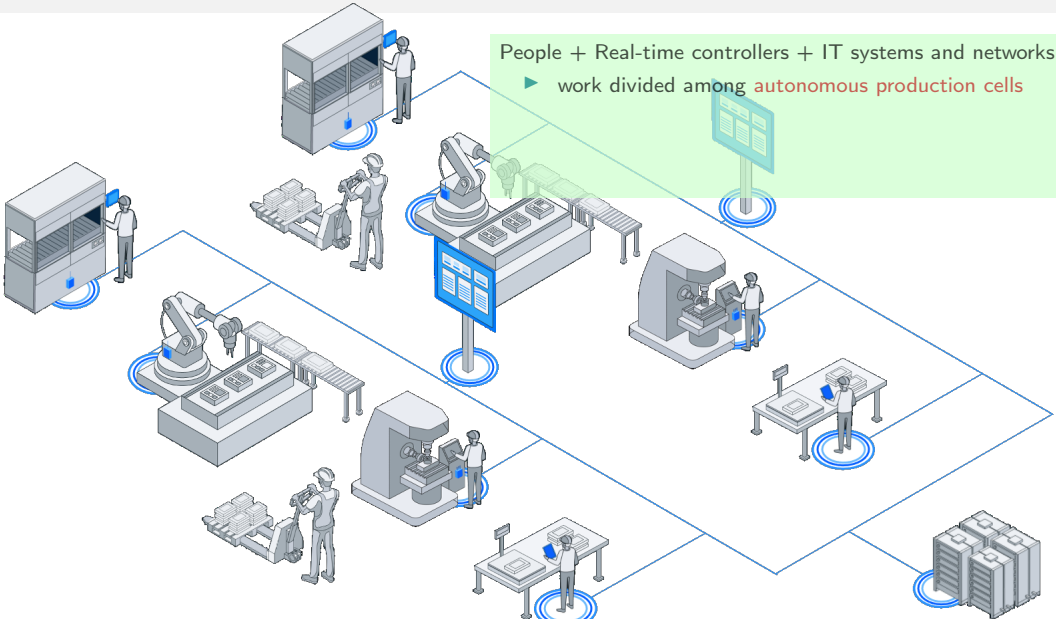

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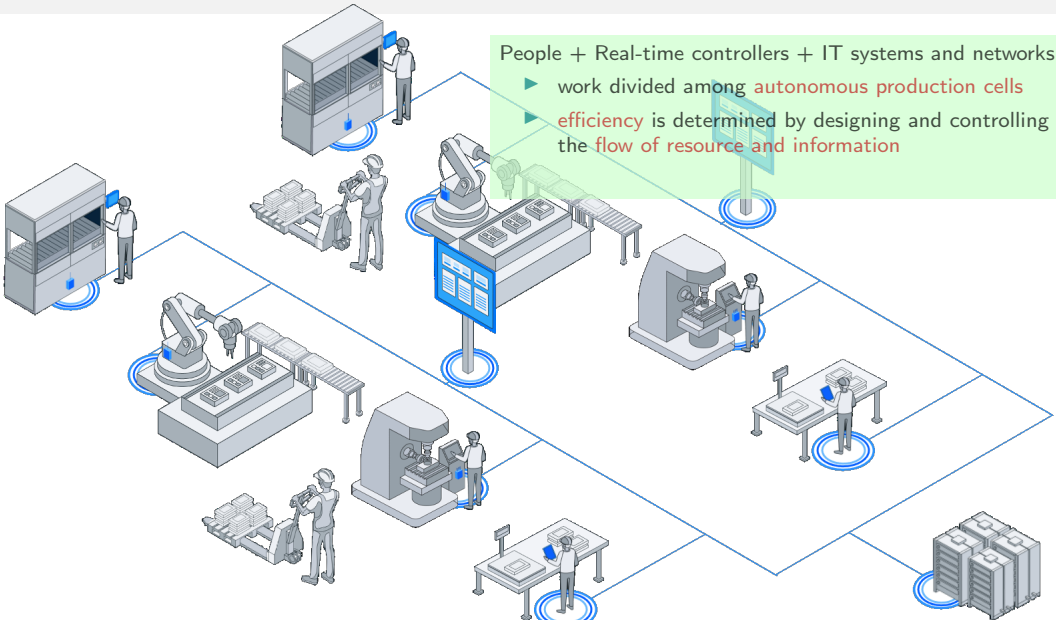

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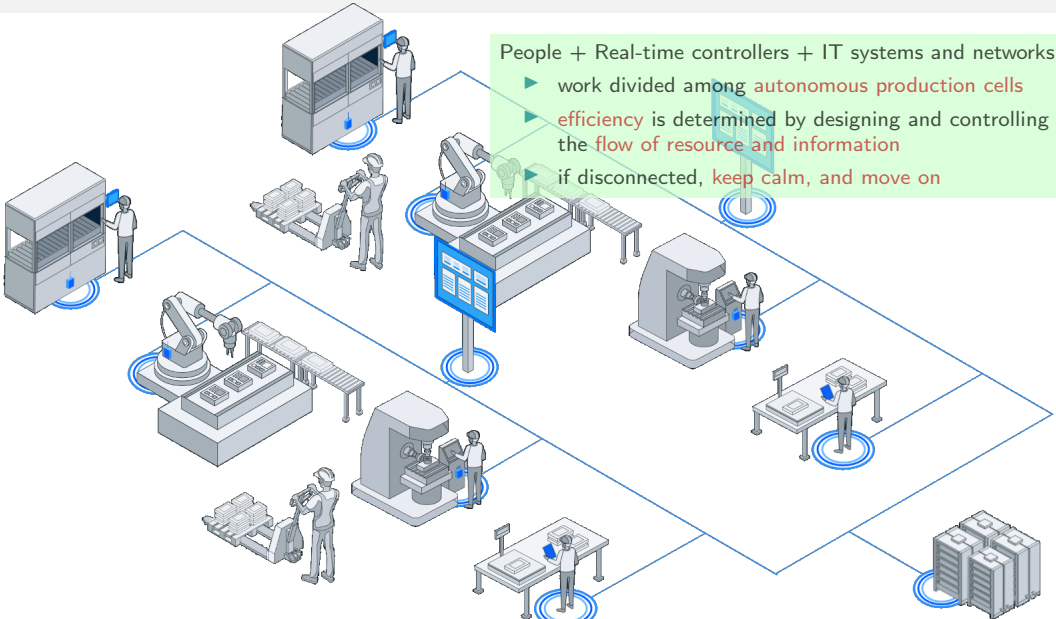

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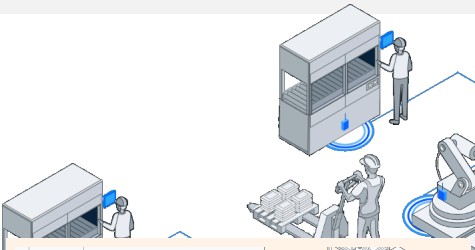

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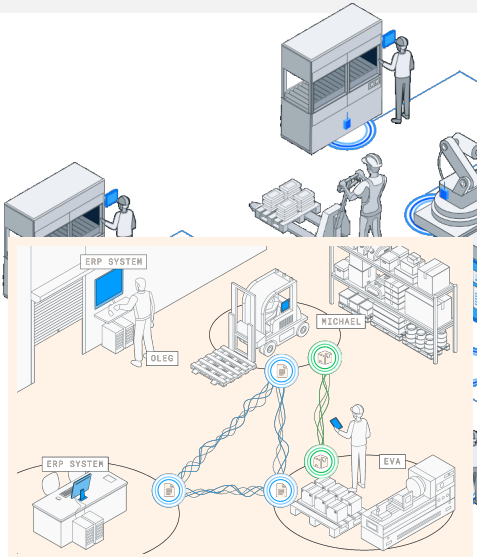

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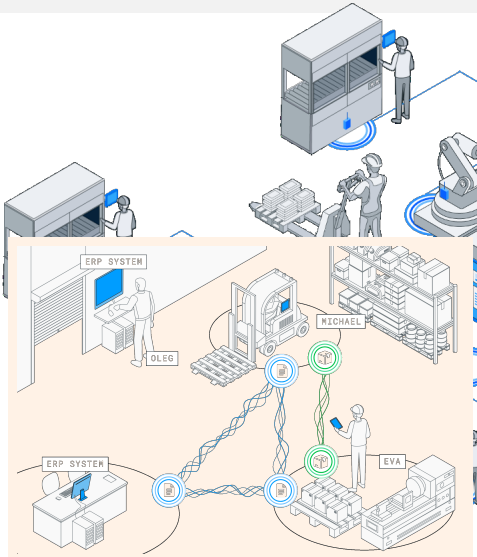

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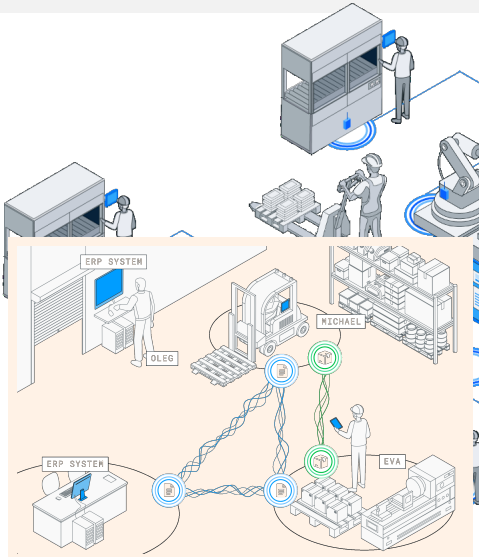

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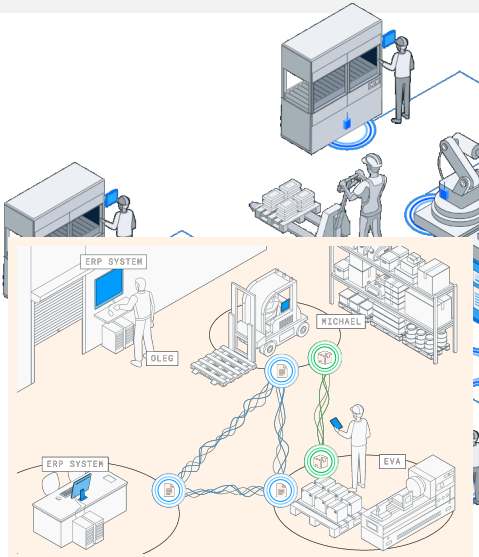

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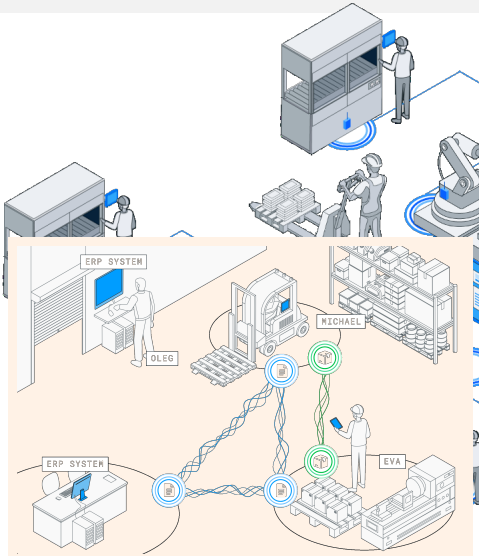

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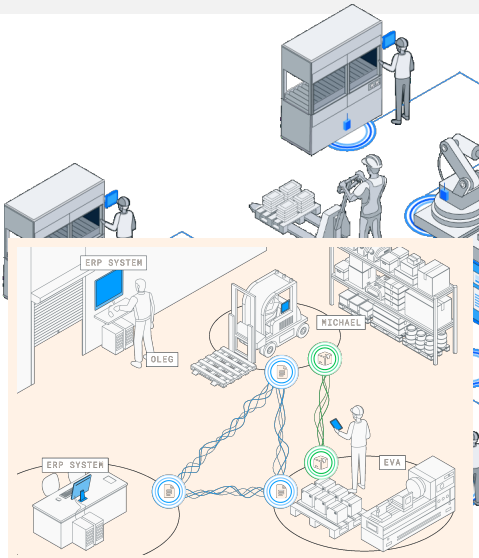

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- logs are local to twins
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- replicated logs are merged

Distribute all

Are there any non-distributed applications?

Robots (e.g., rescue missions or space applications)

Collaborative applications (`https://automerge.org/`)

Home automation

Distribute all

The cloud...always?

Is it safe to let your fridge and mobile go in the cloud to interact?

Where is your data?

Where is your privacy?

Distribute all

"Anytime, anywhere..." really?

like during the AWS's outage on 25/11/2020

or almost all Google services down on 14/12/2020

DSL typical availability of 97% (& some SLA have no lower bound); checkout
`https://www.internetsociety.org/blog/2022/03/what-is-the-digital-divide/`

Distribute all

Also, taking decisions locally

can reduce downtime

shifts data ownership

gets rid of any centralization point...for real

A motto

design (well)

+

project

+

run

A motto

design (well)

+

project

+

run

Another motto

execute

+

propagate

+

merge

References I

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