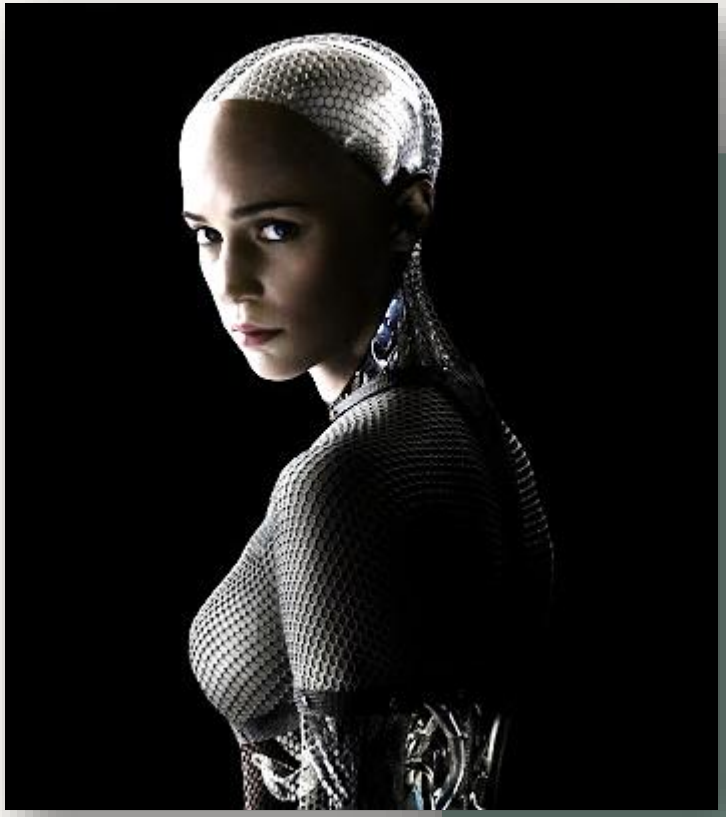
AKADEMIA
GÓRNICZO-HUTNICZA
IM. STANISŁAWA STASZICA
W KRAKOWIE

INŻYNIERIA
MECHATRONICZNA

Advanced AI models in engineering

What parts does it contain?



dr hab. inż. Ziemowit Dworakowski

KATEDRA ROBOTYKI I MECHATRONIKI
WYDZIAŁ INŻYNIERII MECHANICZNEJ I ROBOTYKI

30/09/26

- Transports medication, laboratory specimens, medical supplies between locations
- Operates within normal functioning hospital
- Uses existing corridors and elevators
- Does not require human escort
- Collisions with people are unacceptable
- Operates autonomously for substantial part of the day
- Delivery requests arrive dynamically
- Some deliveries are more urgent than others
- Must not interfere with critical hospital procedures



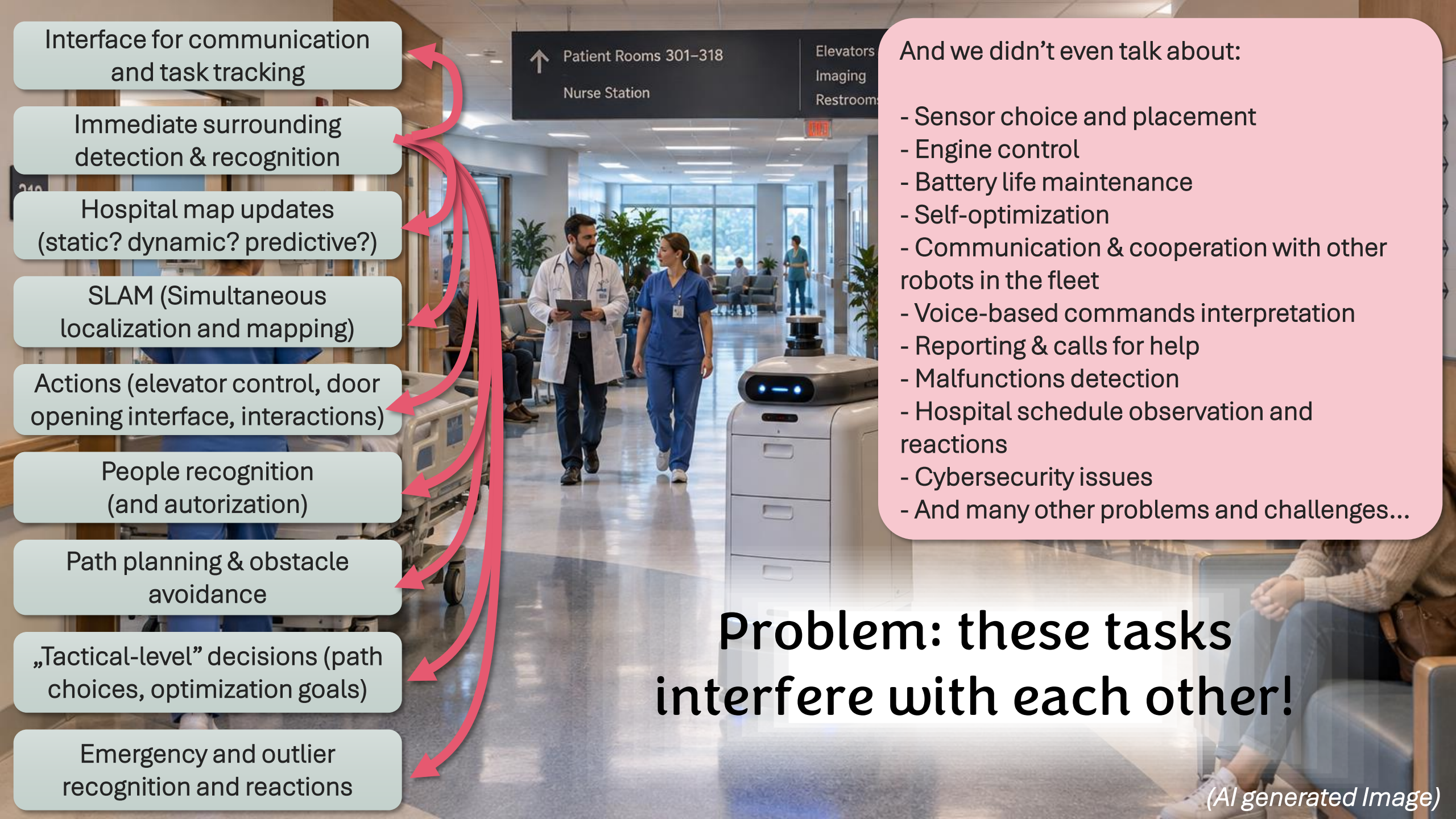
(AI generated Image)


Patient Rooms 301–318
Nurse Station
Elevators
Imaging
Restrooms
312
Oncology
Radiology
Laboratory
Pharmacy
The door is blocked, but it won't be in a moment
Don't move in front of the bed
Nurse is occupied, need to wait
Elevator, people waiting, must wait for my turn
Visitor, can freak out, proceed carefully
This perso won't move out of the way
(AI generated Image)



We need to simplify and decompose the problem somehow...

(AI generated Image)



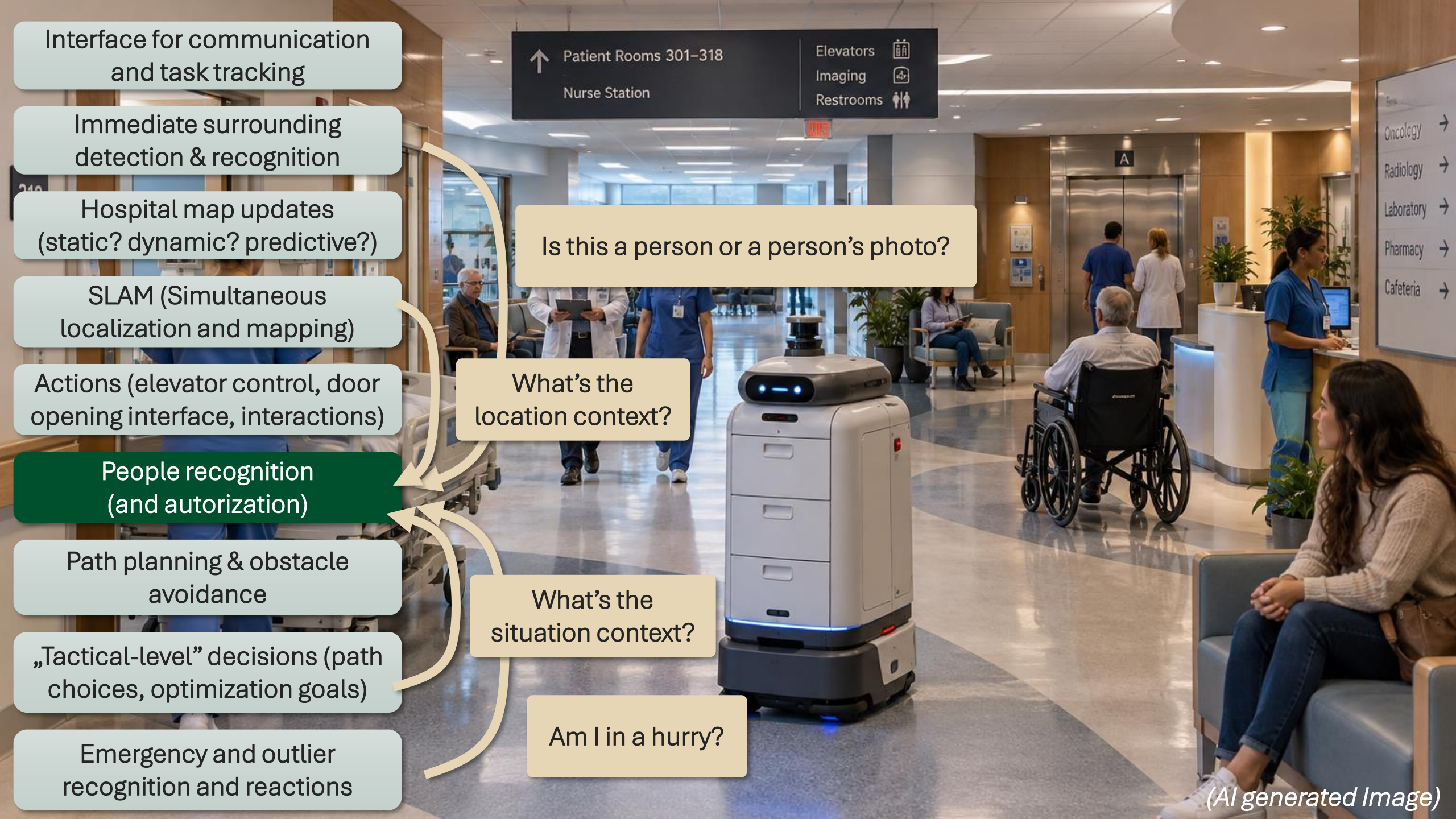
- Interface for communication and task tracking
- Immediate surrounding detection & recognition
- Hospital map updates (static? dynamic? predictive?)
- SLAM (Simultaneous localization and mapping)
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- „Tactical-level" decisions (path choices, optimization goals)
- Emergency and outlier recognition and reactions

And we didn't even talk about:

- Sensor choice and placement
- Engine control
- Battery life maintenance
- Self-optimization
- Communication & cooperation with other robots in the fleet
- Voice-based commands interpretation
- Reporting & calls for help
- Malfunctions detection
- Hospital schedule observation and reactions
- Cybersecurity issues
- And many other problems and challenges...

Problem: these tasks interfere with each other!

(AI generated Image)

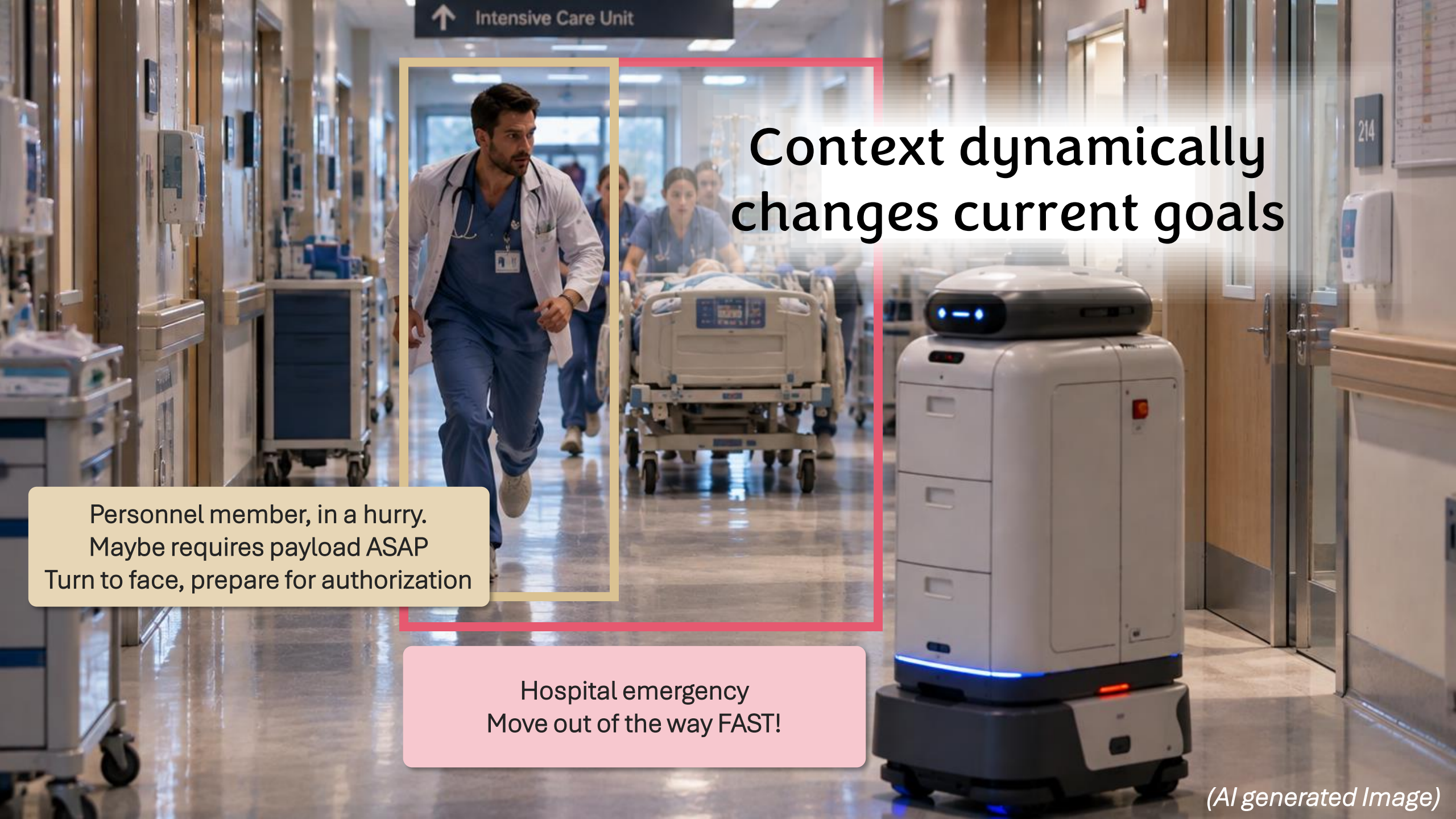

Interface for communication and task tracking
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Is this a person or a person's photo?
What's the location context?
What's the situation context?
Am I in a hurry?
Patient Rooms 301–318
Nurse Station
Elevators
Imaging
Restrooms
Oncology
Radiology
Laboratory
Pharmacy
Cafeteria
(AI generated Image)


Surgery
412
Looking at me, I may need to react
Personnel member, in a hurry.
Maybe requires payload ASAP
or will change current order
Turn to face, prepare for authorization
Floor is empty, I’m not in the way
(AI generated Image)



Personnel member, in a hurry.
Maybe requires payload ASAP
Turn to face, prepare for authorization

(AI generated Image)

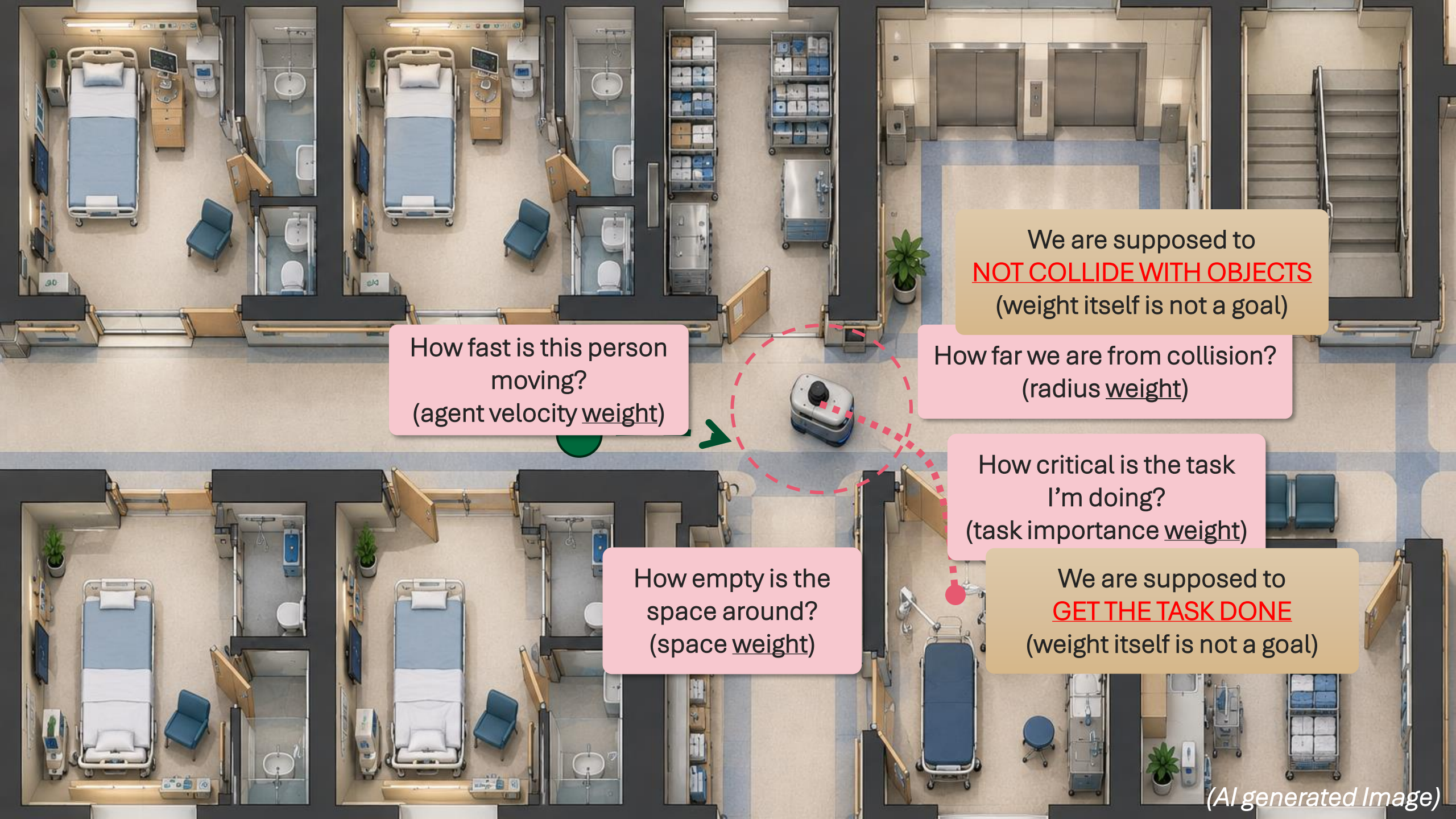


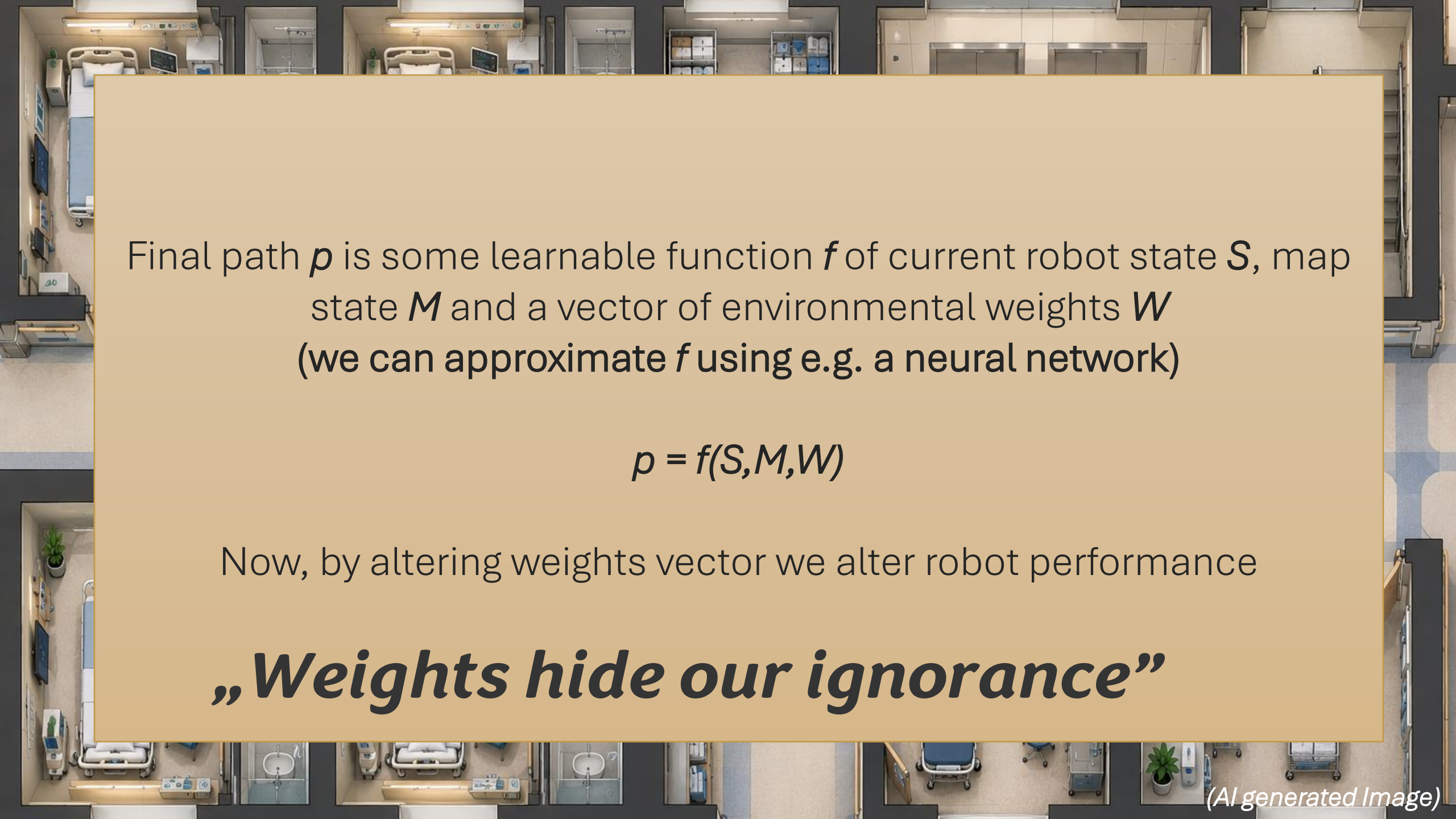
Context dynamically changes current goals

Personnel member, in a hurry.
Maybe requires payload ASAP
Turn to face, prepare for authorization

Hospital emergency
Move out of the way FAST!

(AI generated Image)


We are supposed to
NOT COLLIDE WITH OBJECTS
(weight itself is not a goal)
How fast is this person moving?
(agent velocity weight)
How far we are from collision?
(radius weight)
How critical is the task I'm doing?
(task importance weight)
How empty is the space around?
(space weight)
We are supposed to
GET THE TASK DONE
(weight itself is not a goal)
(AI generated Image)



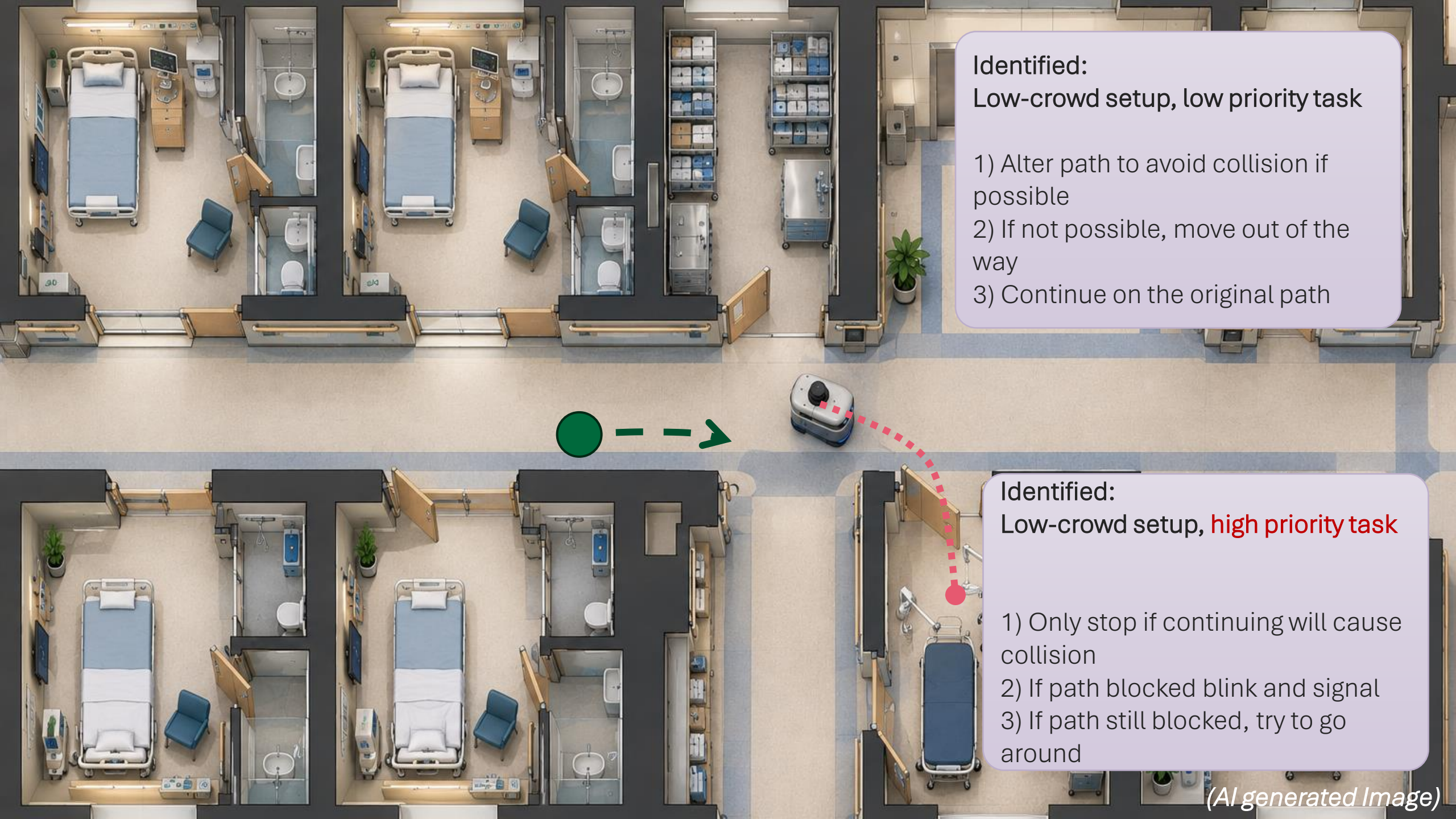
Final path ***p*** is some learnable function ***f*** of current robot state ***S***, map state ***M*** and a vector of environmental weights ***W***
(we can approximate *f* using e.g. a neural network)

$$p = f(S,M,W)$$

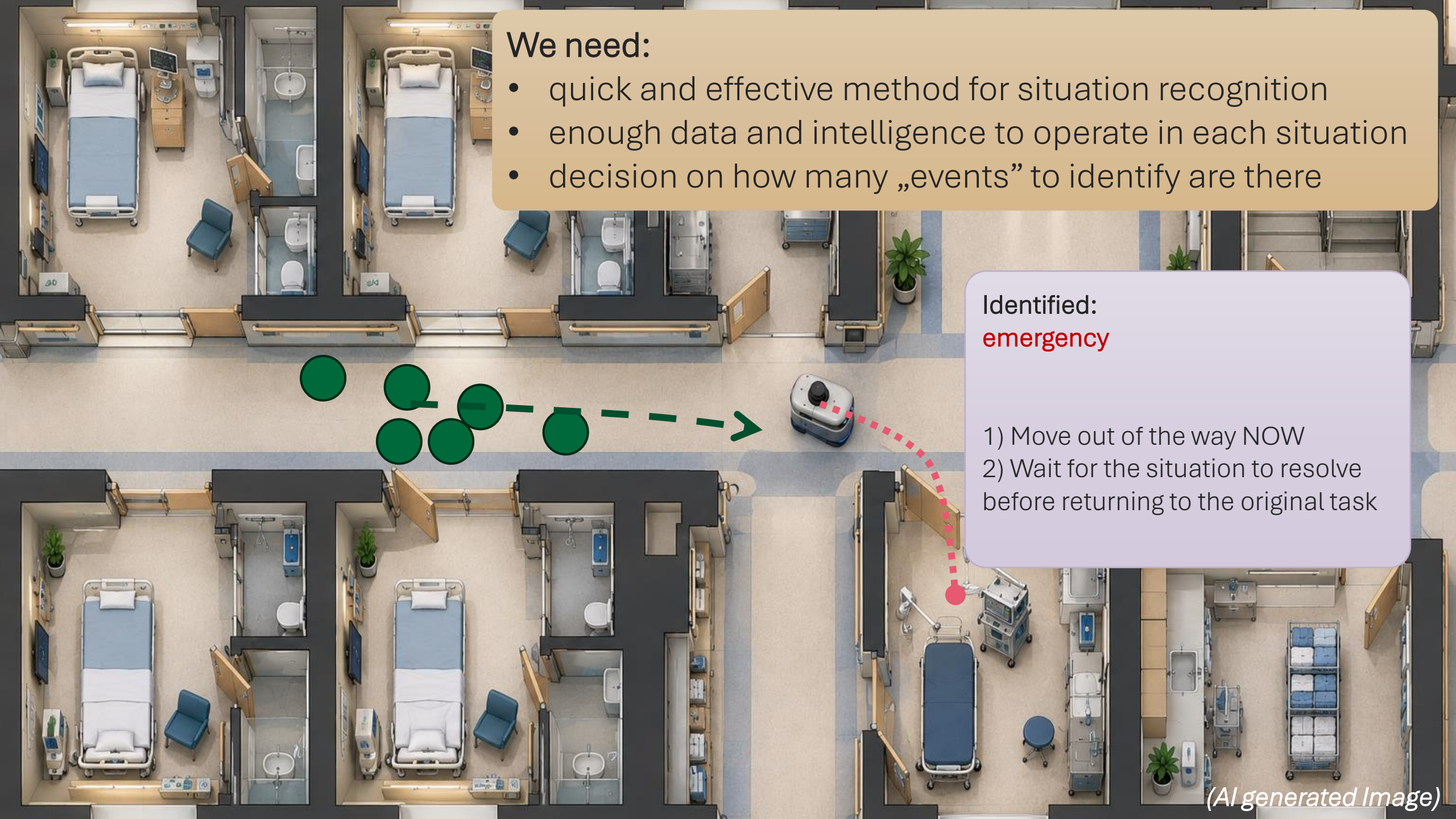
Now, by altering weights vector we alter robot performance

„Weights hide our ignorance”

(AI generated Image)


Identified:
Low-crowd setup, low priority task
1) Alter path to avoid collision if possible
2) If not possible, move out of the way
3) Continue on the original path
Identified:
Low-crowd setup, high priority task
1) Only stop if continuing will cause collision
2) If path blocked blink and signal
3) If path still blocked, try to go around
(AI generated Image)


Identified:
high-crowd setup, high priority task
1) Continue on the path. Stop only when continuing will cause collision. Let the people figure it out
2) Blink and signal
Identified:
high-crowd setup, low priority task
1) Don’t go out in the open, waith for the crowd to dissipate
2) Continue on the original path
(AI generated Image)



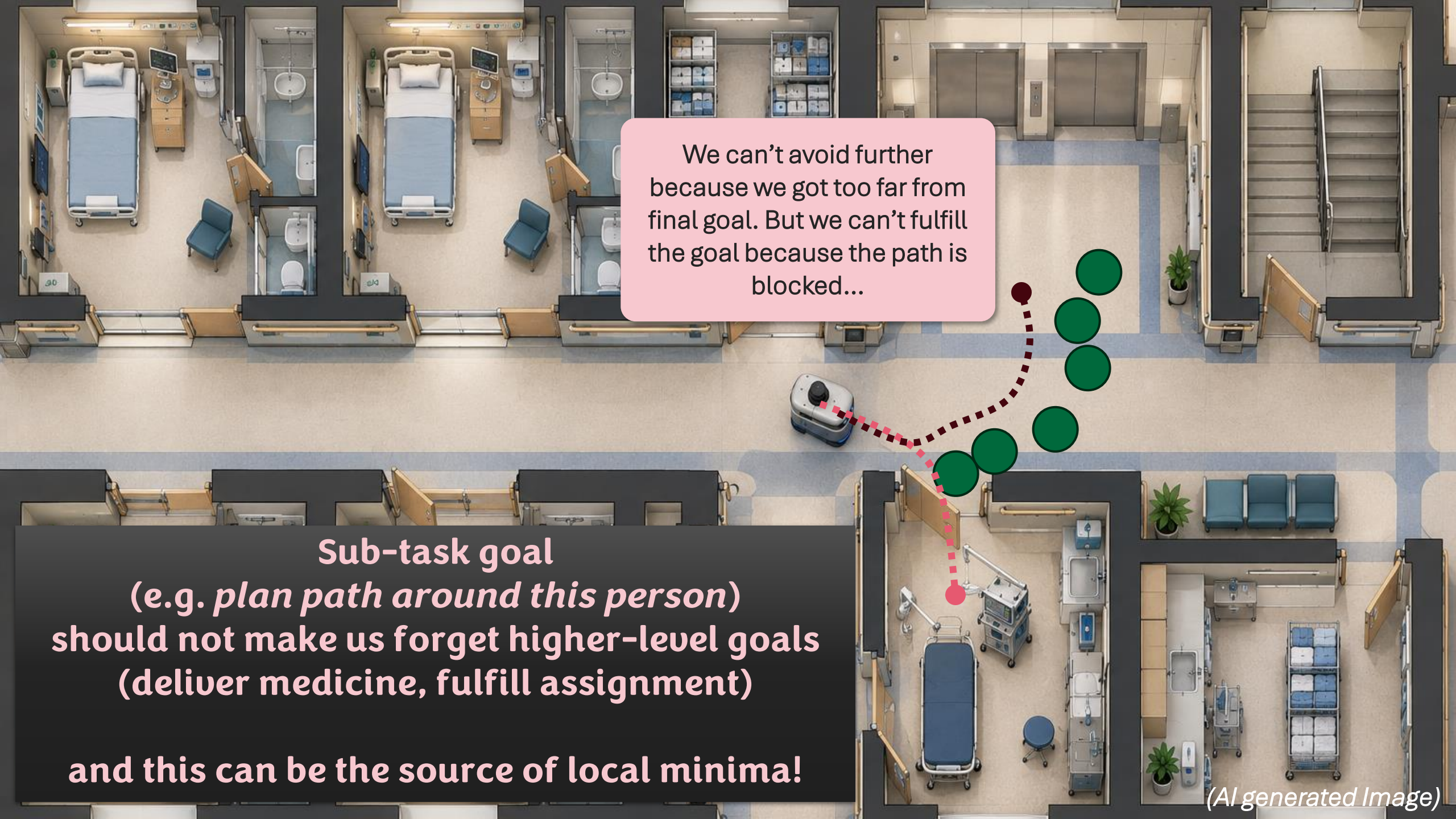
We need:

- quick and effective method for situation recognition
- enough data and intelligence to operate in each situation
- decision on how many „events” to identify are there

Identified:
emergency

1) Move out of the way NOW
2) Wait for the situation to resolve before returning to the original task

(AI generated Image)


We can’t avoid further because we got too far from final goal. But we can’t fulfill the goal because the path is blocked…
Sub-task goal
(e.g. *plan path around this person*)
should not make us forget higher-level goals
(deliver medicine, fulfill assignment)
and this can be the source of local minima!
(AI generated Image)

Objective

Adjustable parameters

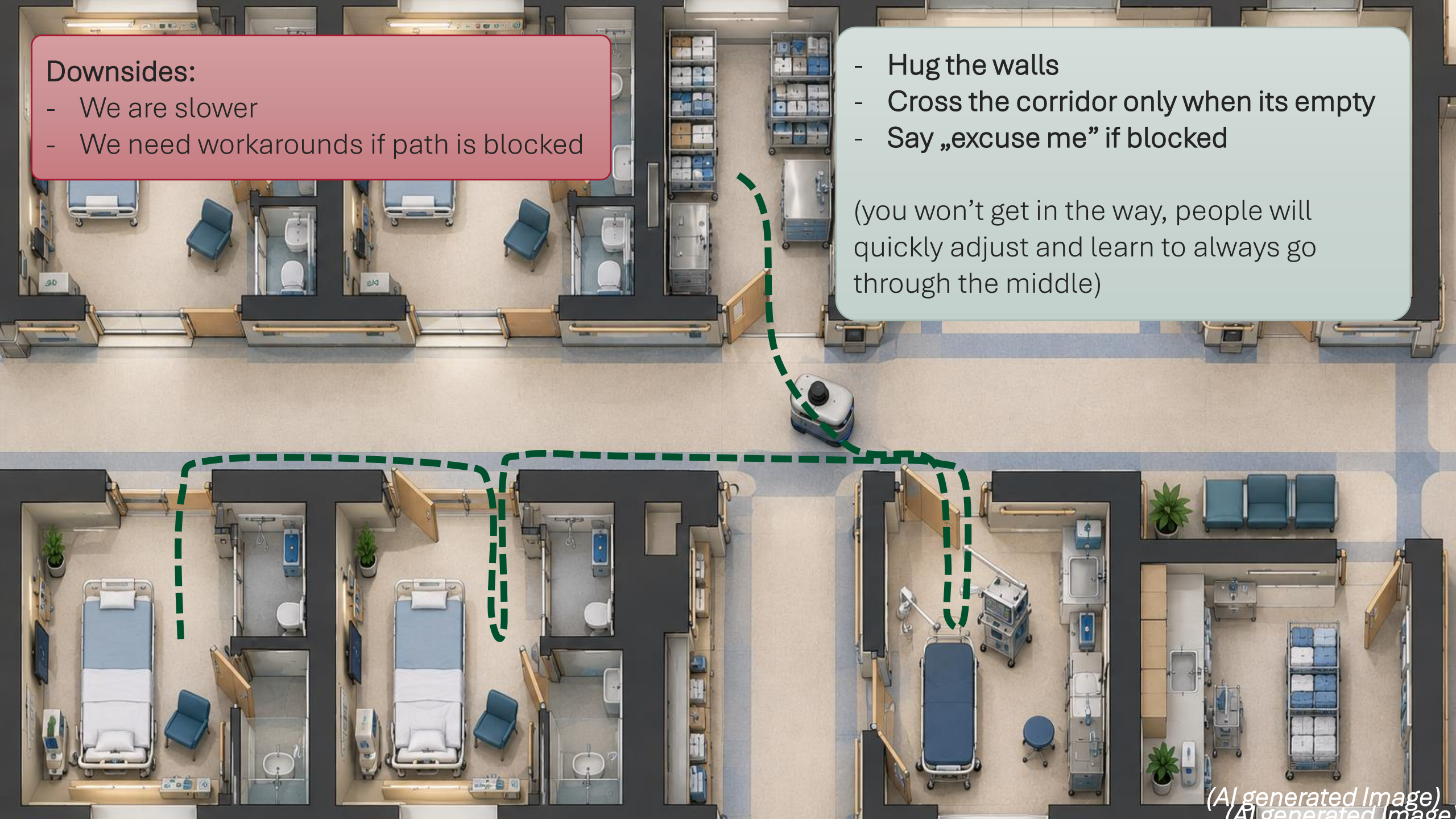
Each of those requires data, time and optimization engine configuration (2nd order optimization!)

With enough degrees of freedom we can always find „an optimum" which is unusable in practice

Lets optimize:

- Path for length, time and energy consumption (multi-criterion)
- Event recognition for accuracy
- Emergency response for speed while maintaining correctness (constrained)
- End goal alignment while maintaining local minima prevention (high exploration)
- Continuous adaptation to changing environment (weight adjustments on-the-fly)

„If you hold a hammer, everything looks like a nail"


Downsides:
- We are slower
- We need workarounds if path is blocked
- Hug the walls
- Cross the corridor only when its empty
- Say „excuse me” if blocked
(you won’t get in the way, people will quickly adjust and learn to always go through the middle)
(AI generated Image)

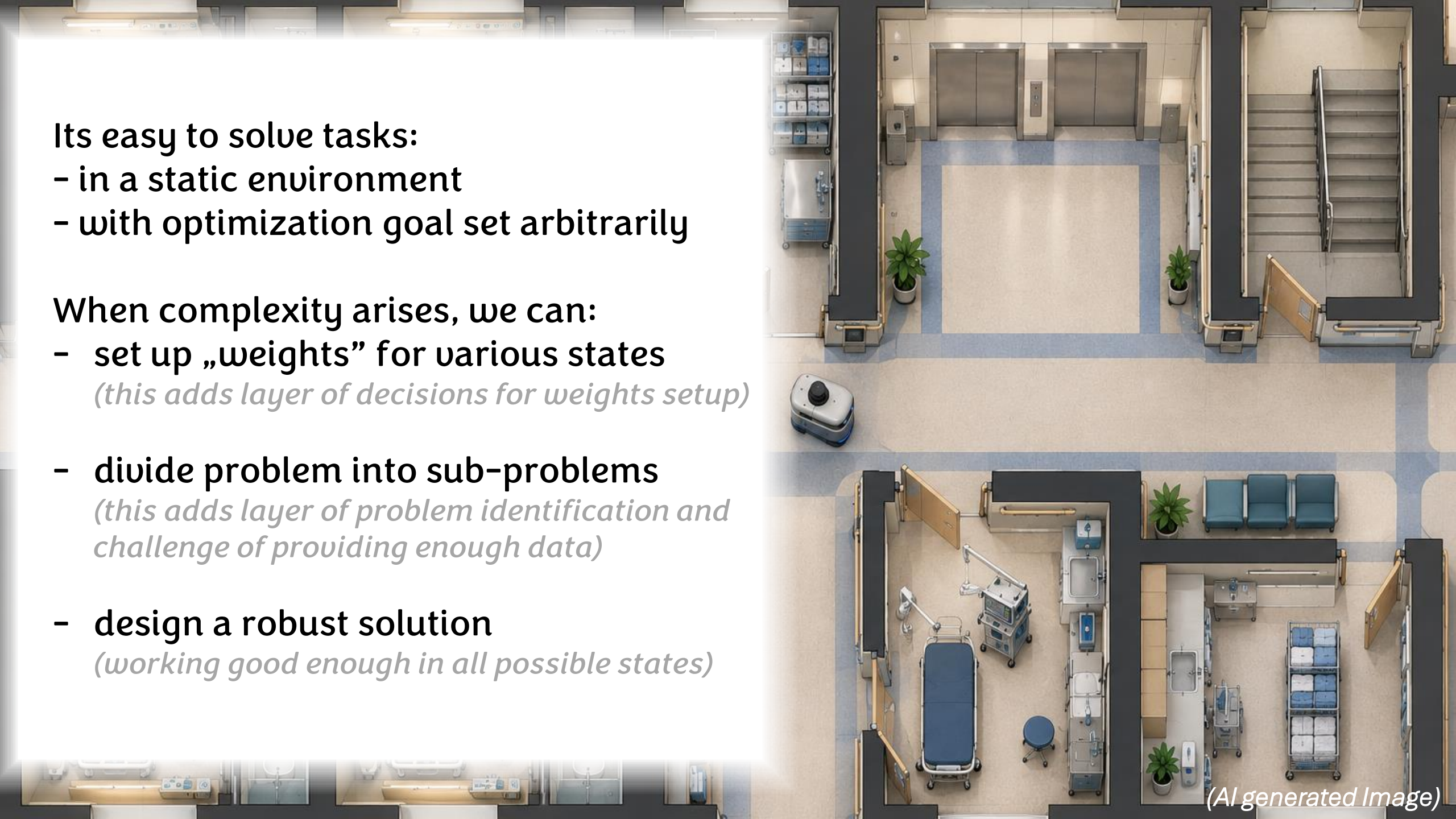
How we represent (parametrize) a problem – plays a crucial role...

Its easy to solve tasks:
- in a static environment
- with optimization goal set arbitrarily

When complexity arises, we can:
- set up „weights” for various states
  (this adds layer of decisions for weights setup)

- divide problem into sub-problems
  (this adds layer of problem identification and challenge of providing enough data)

- design a robust solution
  (working good enough in all possible states)



(AI generated Image)

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Composability & interchangeability

Sub-systems should be designed so they are
- self-contained
- backwards-compatible
- upgradeable once we have better data

(AI generated Image)

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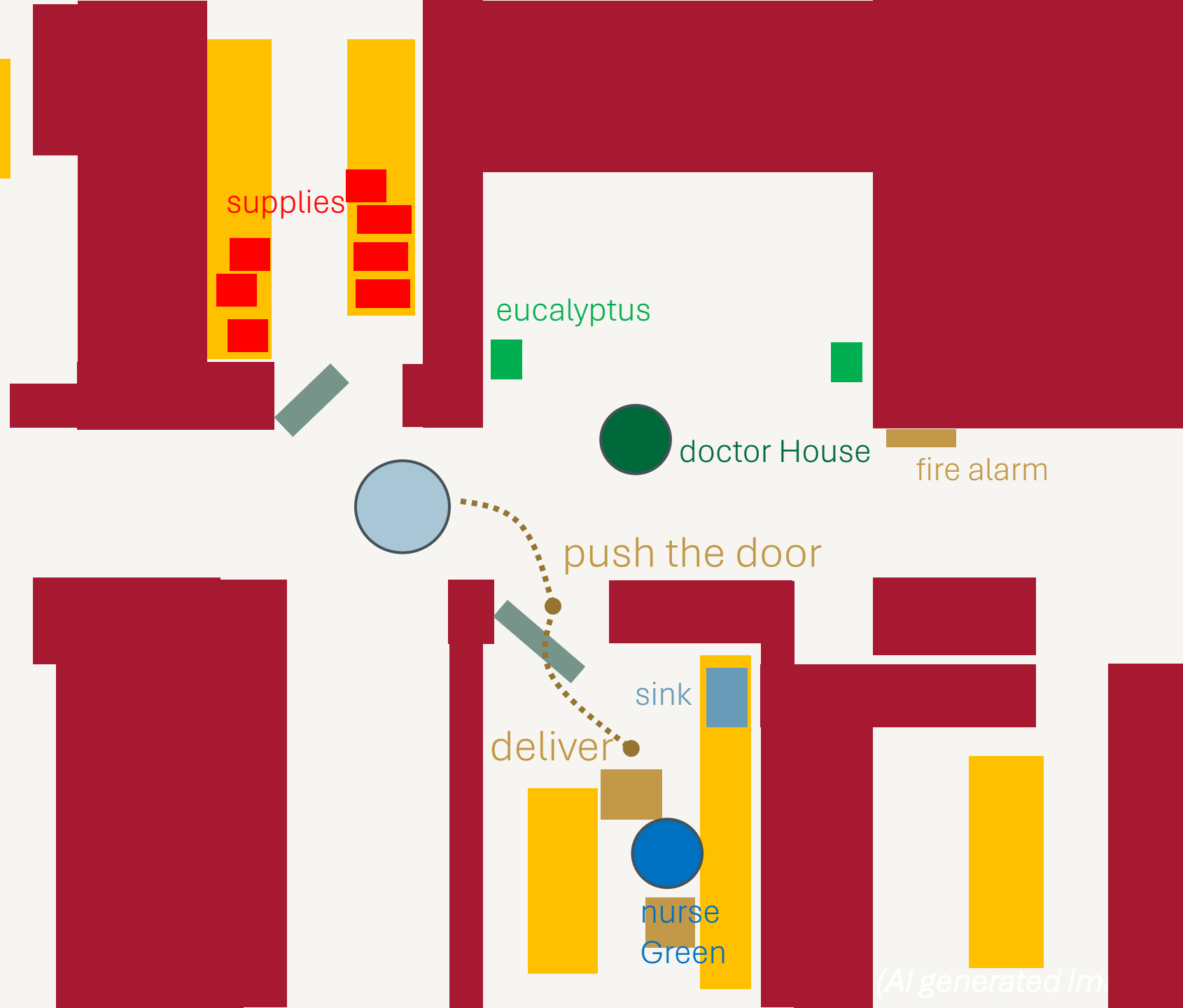
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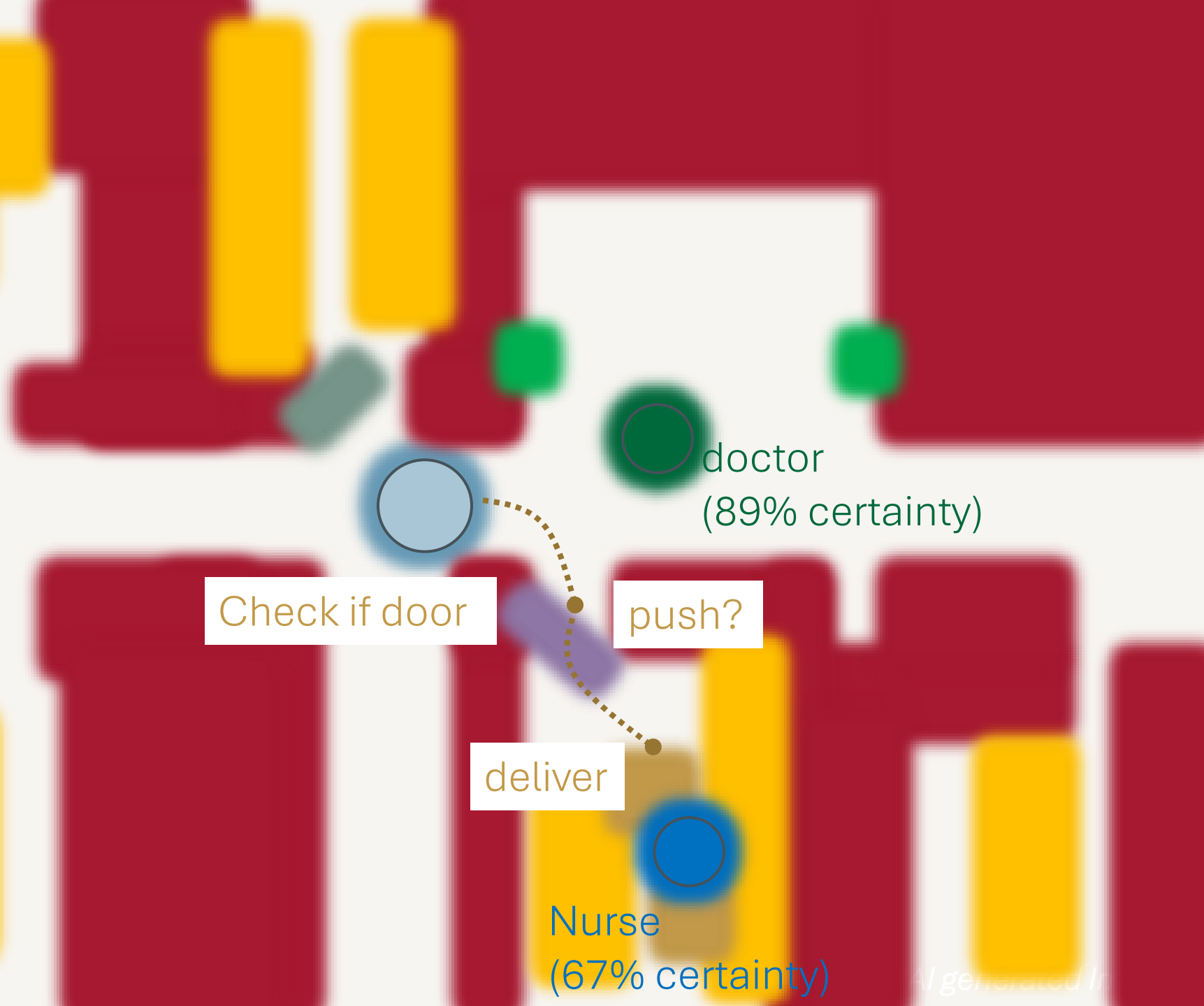
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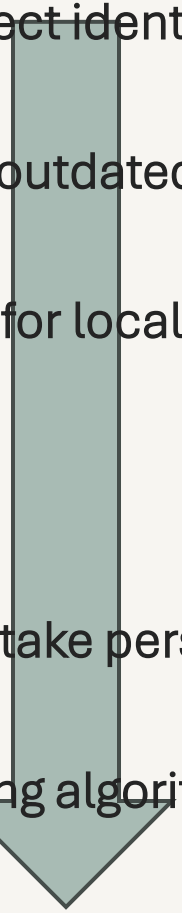
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Errors in object identification

Map can be outdated

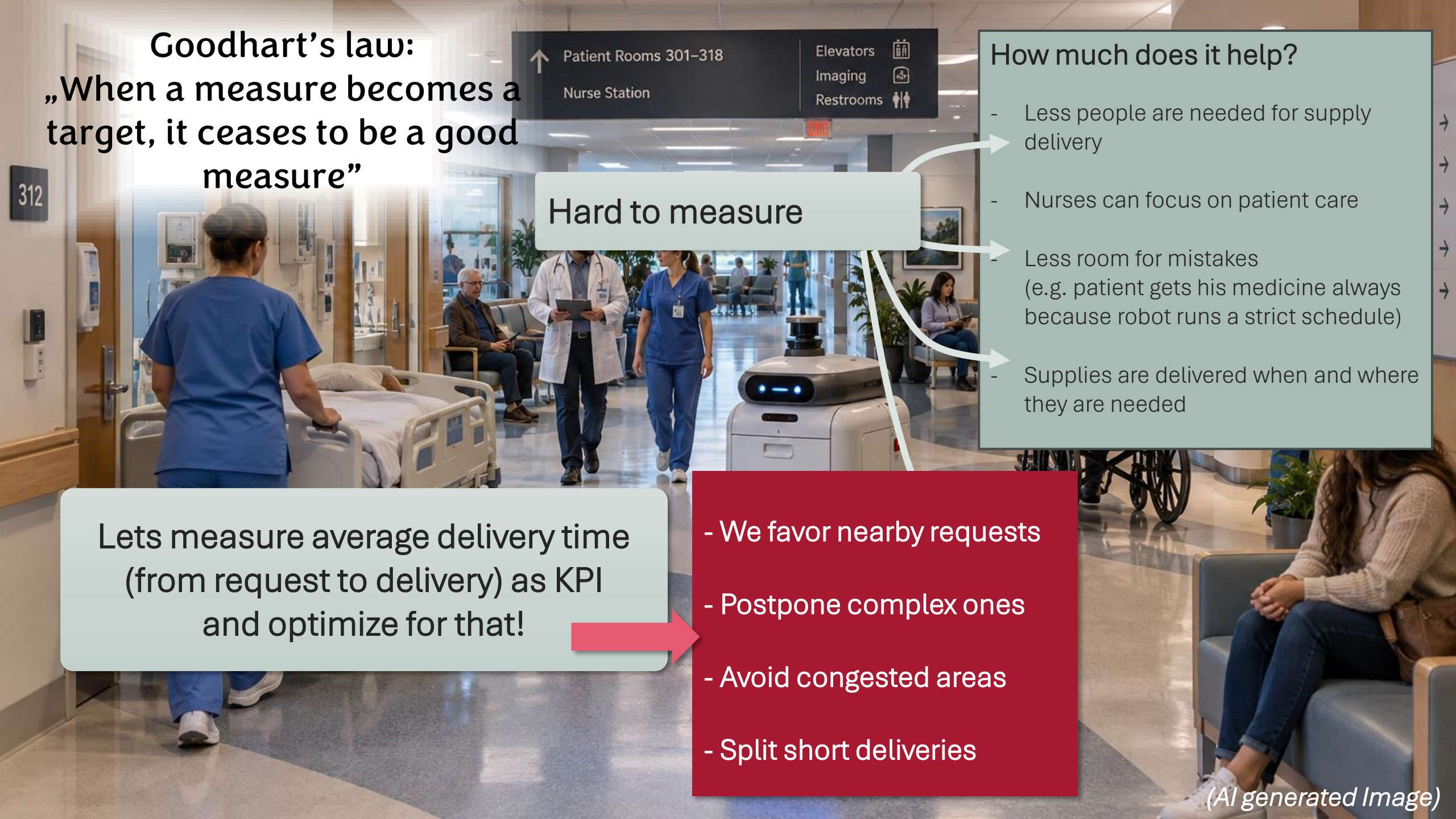
Landmarks for localization might be poorly detected

We can mistake person for a different person

Path planning algorithm hitting a local minimum

UNCERTAIN INPUTS FOR DECISION MAKING

- **Errors in former layers tend to cause more severe errors in latter layers**
- **Uncertainty should be trackable**



Goodhart's law:
„When a measure becomes a target, it ceases to be a good measure"

Hard to measure

How much does it help?

- Less people are needed for supply delivery
- Nurses can focus on patient care
- Less room for mistakes
  (e.g. patient gets his medicine always because robot runs a strict schedule)
- Supplies are delivered when and where they are needed

Lets measure average delivery time (from request to delivery) as KPI and optimize for that!

- We favor nearby requests
- Postpone complex ones
- Avoid congested areas
- Split short deliveries

(AI generated Image)

Takeaways:

- Life is complex and difficult!

- „Everything is composed of everything else" (Terry Pratchett)

- Its easy to think we are solving the real problem while we are actually solving an irrelevant specific case

- We need to decompose problems into components but be aware of interactions

- Parametrization (representation choice) should be a conscious decision (and affects challenge level)

- Errors in sub-systems propagate to higher layers

- Solve problems step-by-step (in layers of complexity) and track uncertainty along the way

- The environment we operate in will change, prepare for that

- People are unpredictable! You need a safe default to fall back to