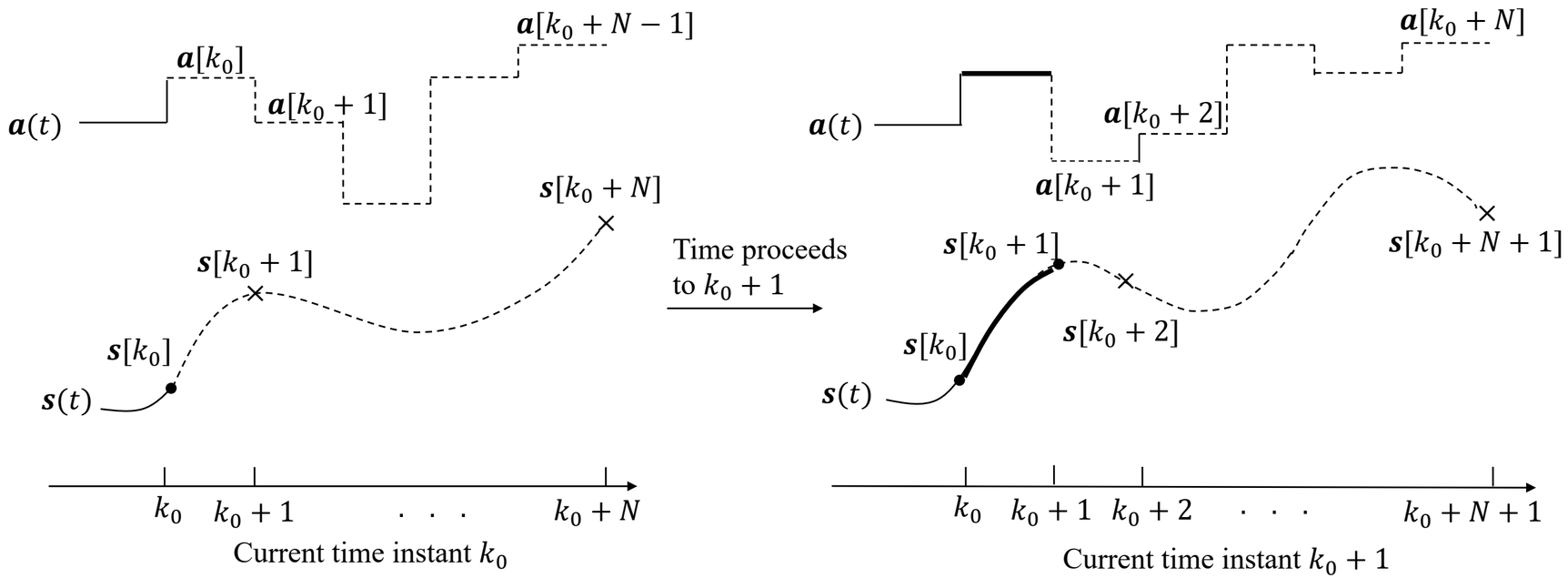
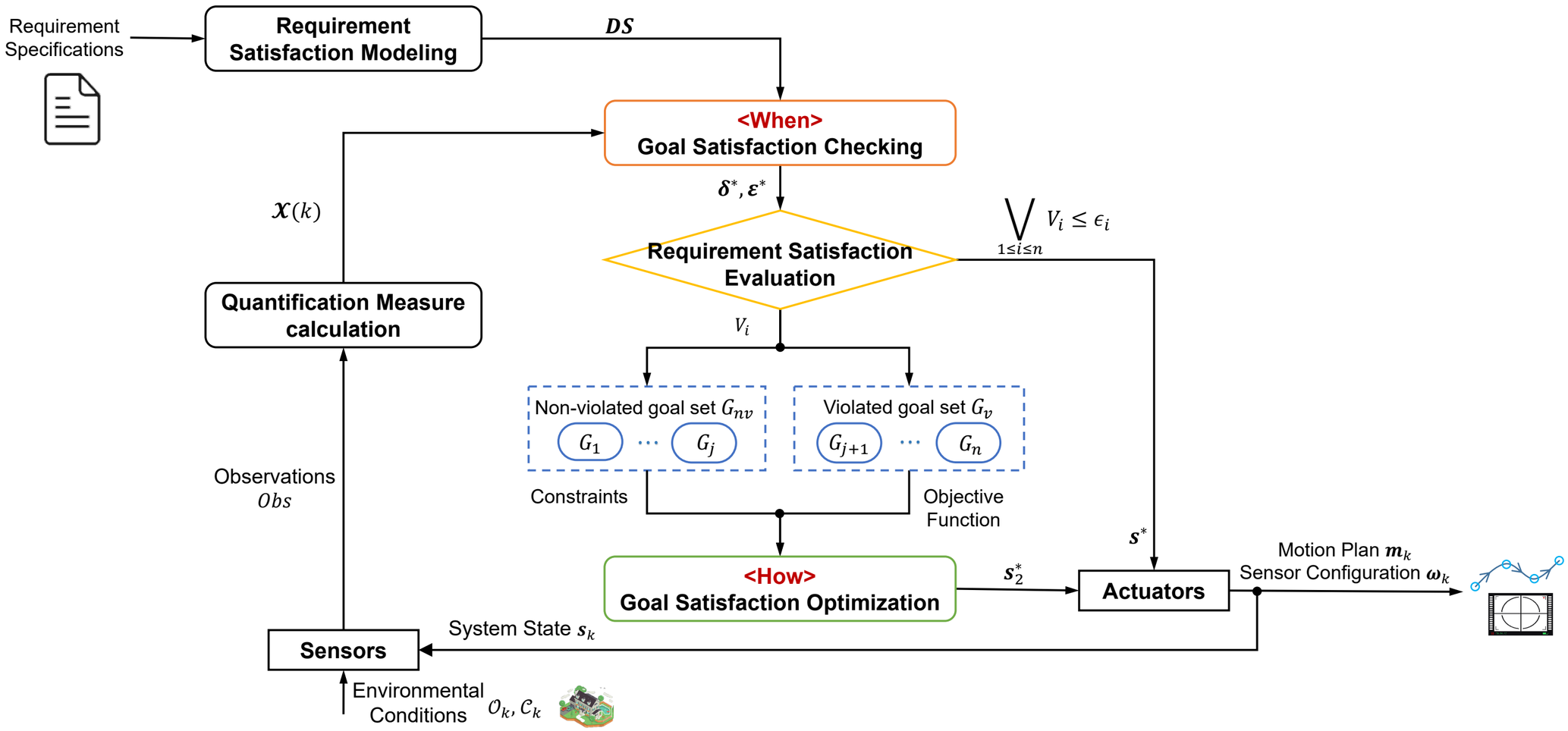
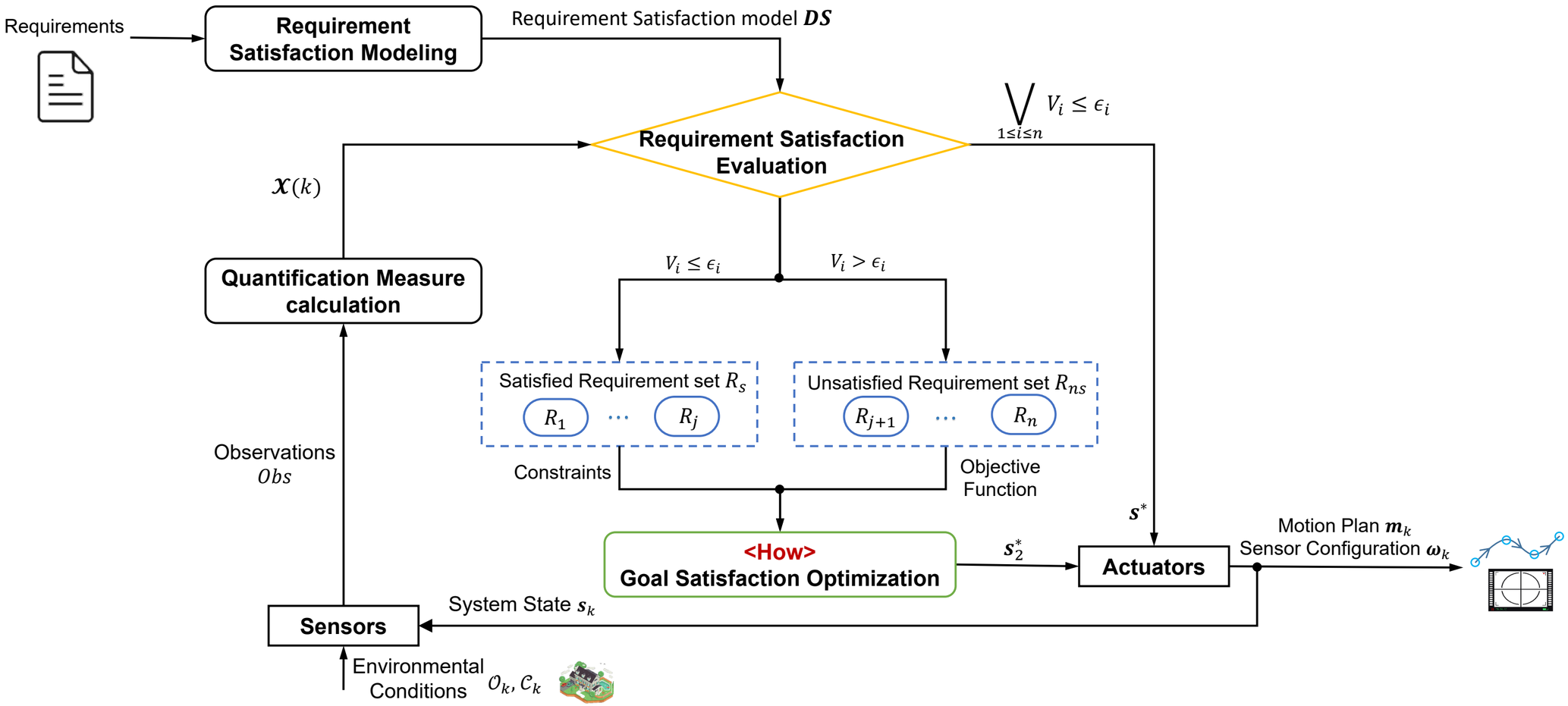
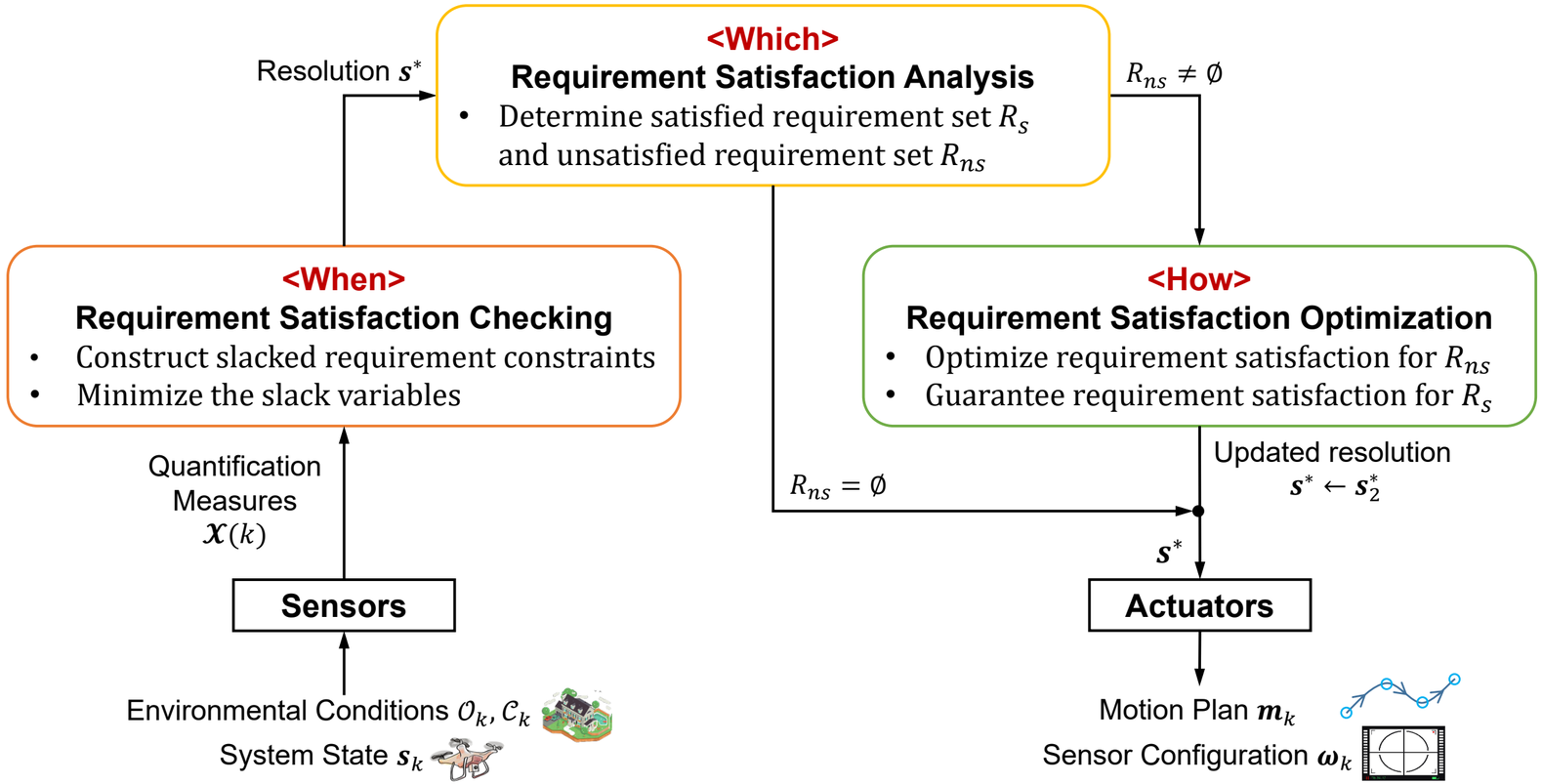
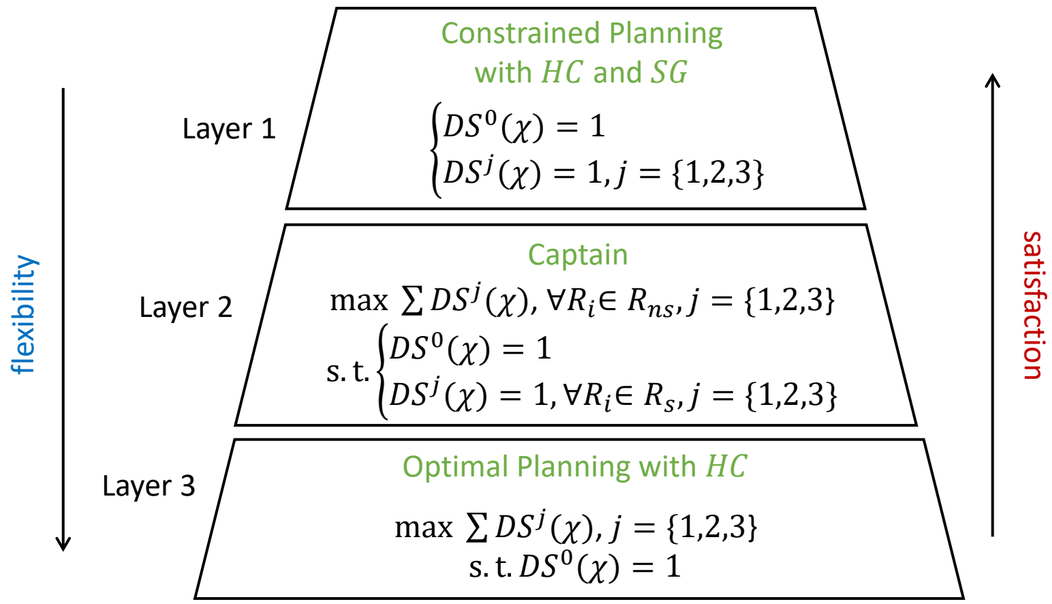

$\boldsymbol{a}(t)$
$\boldsymbol{a}[k_0]$
$\boldsymbol{a}[k_0+1]$
$\boldsymbol{a}[k_0+N-1]$
$\boldsymbol{s}[k_0+N]$
$\boldsymbol{s}[k_0+1]$
$\boldsymbol{s}[k_0]$
$\boldsymbol{s}(t)$
k_0
k_0+1
. . .
k_0+N
Current time instant k_0
Time proceeds to k_0+1
$\boldsymbol{a}(t)$
$\boldsymbol{a}[k_0+1]$
$\boldsymbol{a}[k_0+2]$
$\boldsymbol{a}[k_0+N]$
$\boldsymbol{s}[k_0+1]$
$\boldsymbol{s}[k_0]$
$\boldsymbol{s}(t)$
$\boldsymbol{s}[k_0+2]$
$\boldsymbol{s}[k_0+N+1]$
k_0
k_0+1
k_0+2
. . .
k_0+N+1
Current time instant k_0+1

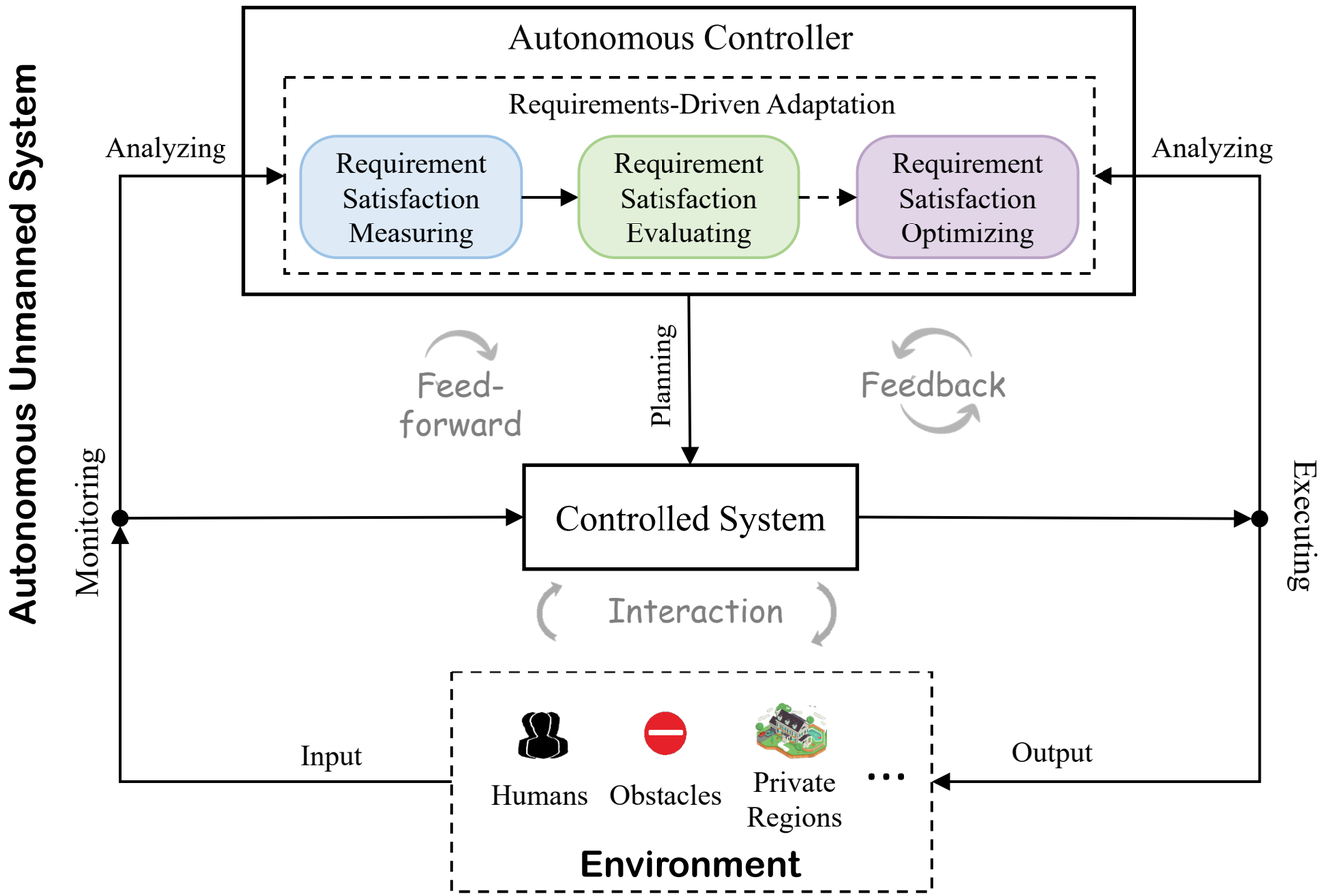
Parm.	***Setting 1***	***Setting 2***	***Setting 3***
l	2.5m	20m	20m
v	[-1,1]m/s	[-10,10]m/s	[-10,10]m/s
ω	0%~100%	0%~100%	0%~100%
r_a	0.2m	0.2m	0.2m
τ	0.5s	0.5s	0.5s
η_1, η_2	0.5,0.2	0.5,0.2	0.5,0.2
Scale	10x10x10m^3	500x500x100m^3	10^3x10^3x100m^3
r_o, r_c	0.3m,0.5m	5m,5m	5m,5m
ρ_o, ρ_c	[0%,100%]	(1.64%,2.41%)	(2.87%,2.84%)
D_o, D_C	0.2m,0.3m	5m,10m	5m,10m
Δ_o, Δ	15s, 30s	60s, 90s	90s, 150s
A_o, A	90%, 80%	90%, 80%	90%, 80%
E_o, E	20 unit,40 unit	100 unit,150 unit	200 unit,300 unit

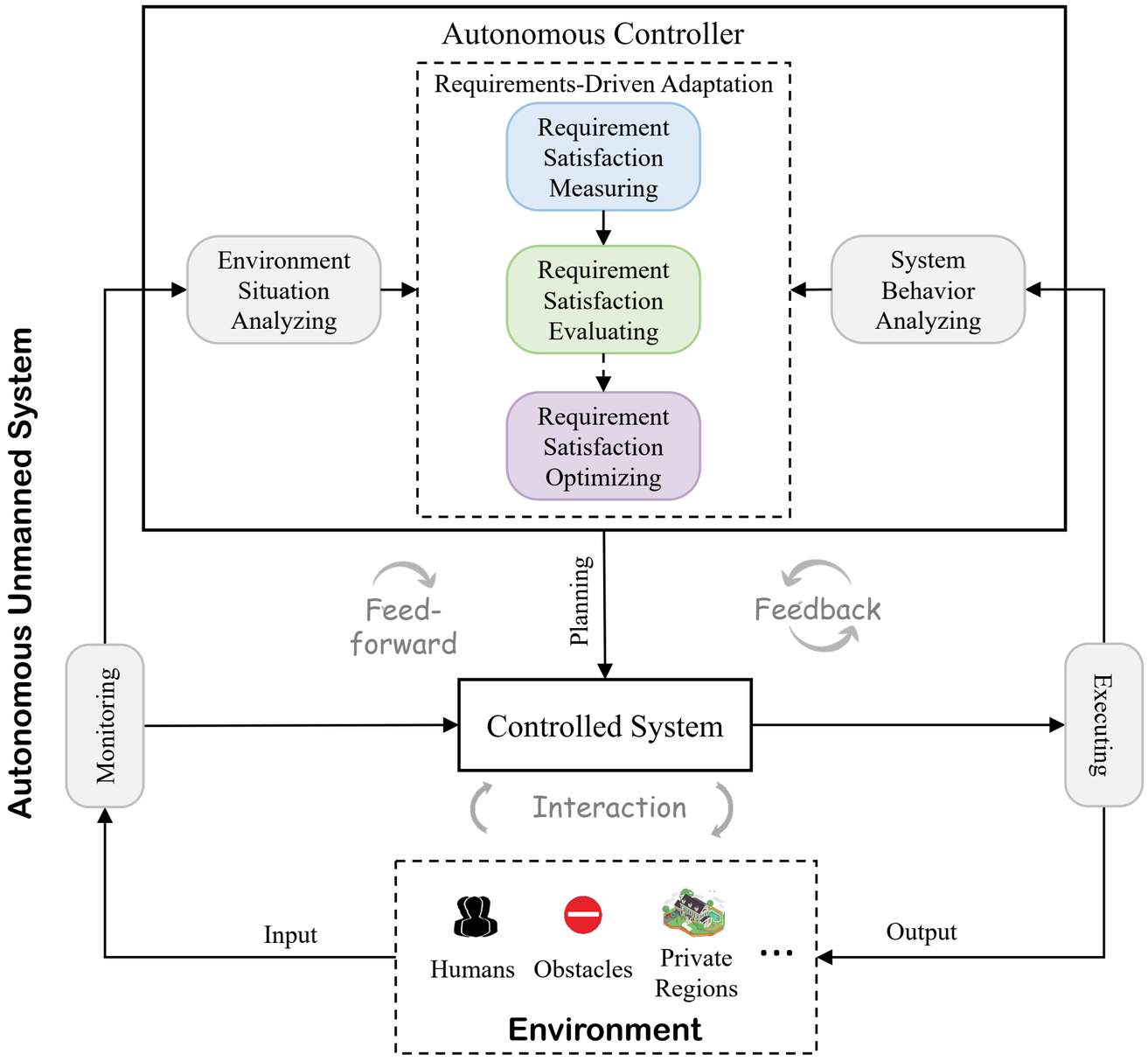

Requirement Specifications
Requirement Satisfaction Modeling
DS
<When>
Goal Satisfaction Checking
δ*, ε*
Requirement Satisfaction Evaluation
⋁ V_i ≤ ε_i
1≤i≤n
V_i
Non-violated goal set G_nv
G_1 ··· G_j
Violated goal set G_v
G_j+1 ··· G_n
Constraints
Objective Function
s*
<How>
Goal Satisfaction Optimization
s_2*
Actuators
Motion Plan m_k
Sensor Configuration ω_k
X(k)
Quantification Measure calculation
Observations Obs
System State s_k
Sensors
Environmental Conditions
O_k, C_k

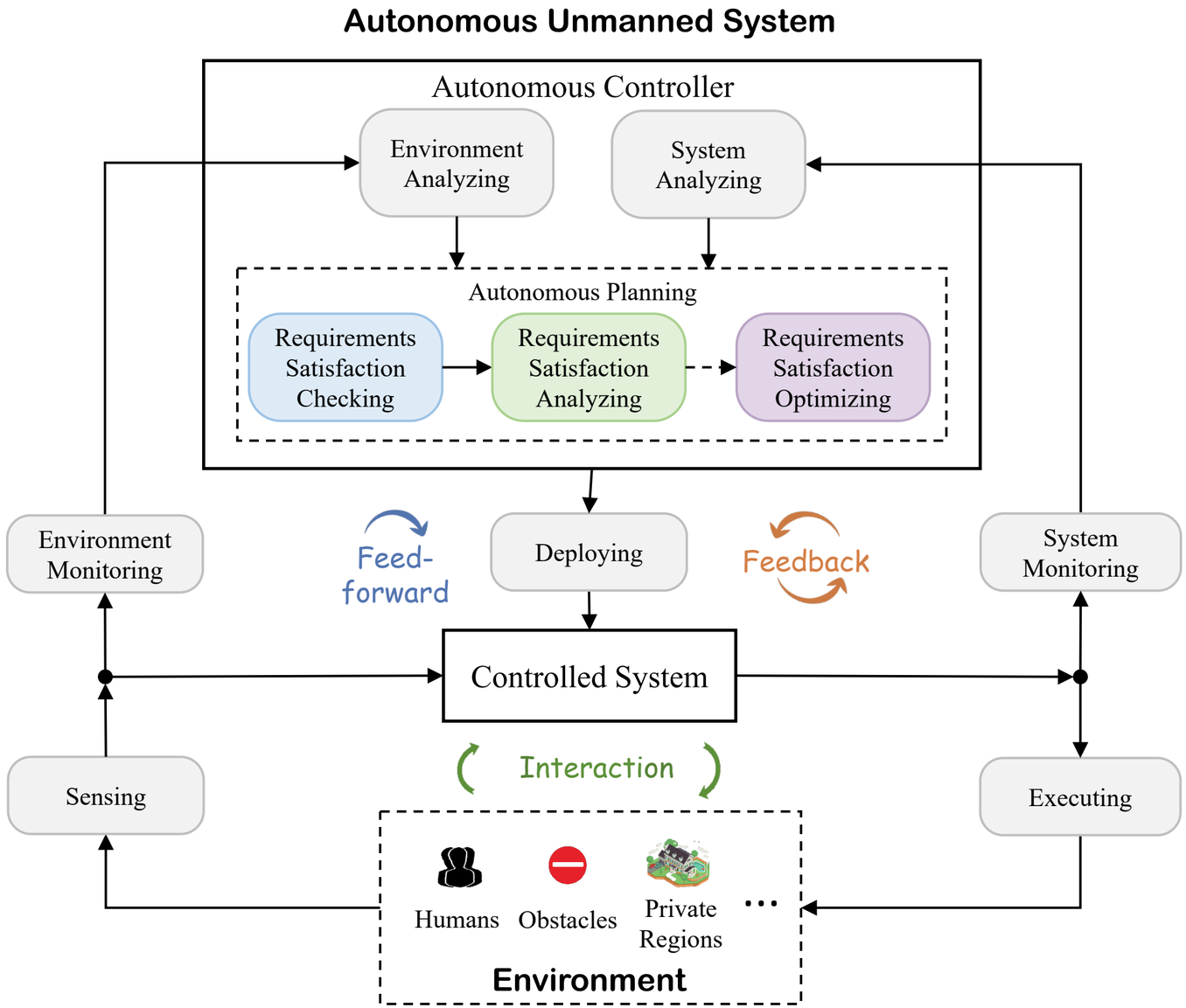

Requirements
Requirement Satisfaction Modeling
Requirement Satisfaction model $\boldsymbol{DS}$
$\bigvee_{1\leq i\leq n} V_i \leq \epsilon_i$
Requirement Satisfaction Evaluation
$\boldsymbol{x}(k)$
Quantification Measure calculation
$V_i \leq \epsilon_i$
$V_i > \epsilon_i$
Satisfied Requirement set R_s
R_1 ... R_j
Unsatisfied Requirement set R_{ns}
R_{j+1} ... R_n
Observations Obs
Constraints
Objective Function
$\boldsymbol{s}^*$
<How>
Goal Satisfaction Optimization
$\boldsymbol{s}_2^*$
Actuators
Motion Plan $\boldsymbol{m}_k$
Sensor Configuration $\boldsymbol{\omega}_k$
System State $\boldsymbol{s}_k$
Sensors
Environmental Conditions
$\mathcal{O}_k, \mathcal{C}_k$

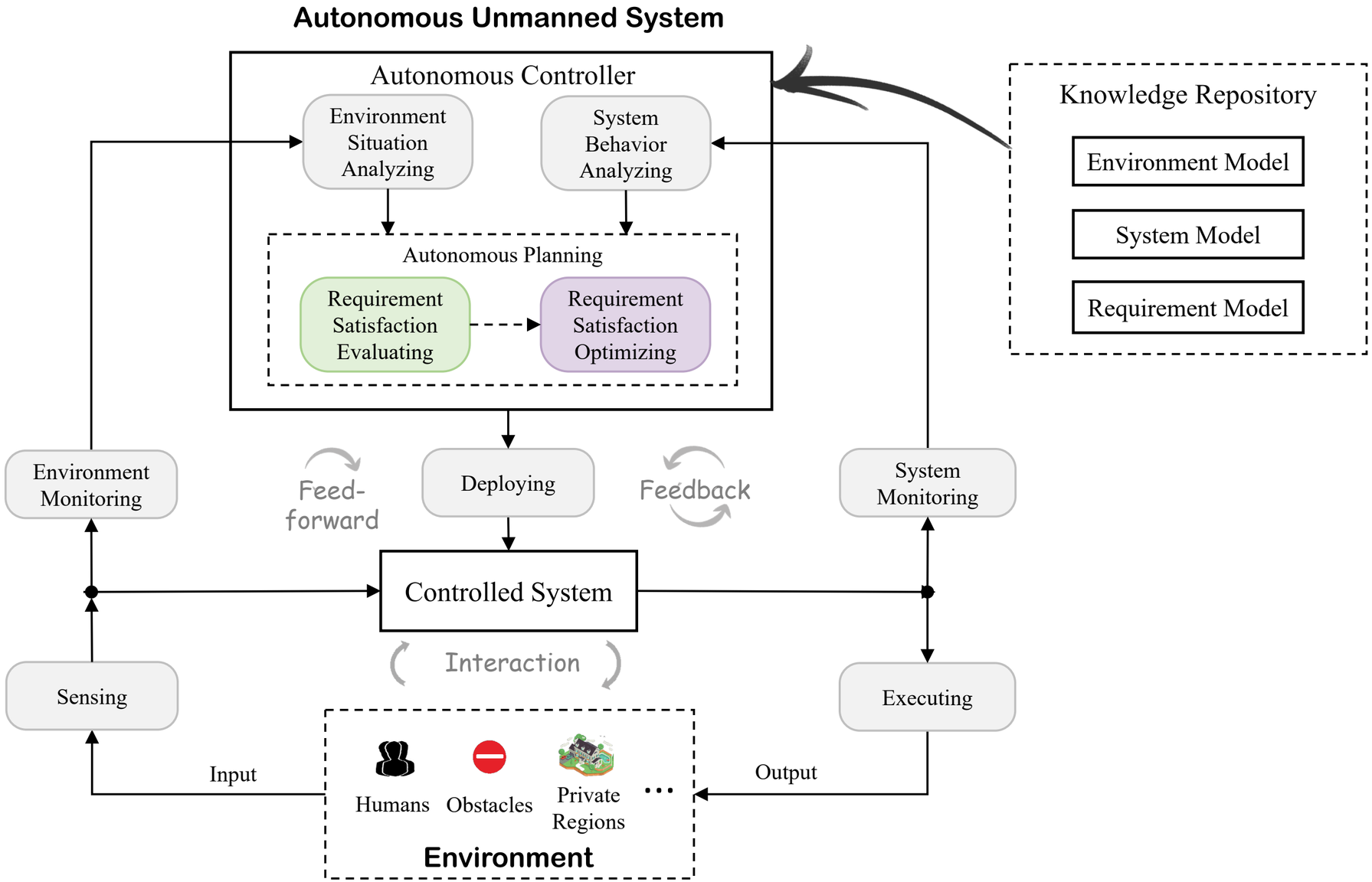

<Which>
Requirement Satisfaction Analysis
• Determine satisfied requirement set R_s and unsatisfied requirement set R_{ns}
Resolution s^*
$R_{ns} \neq \emptyset$
<When>
Requirement Satisfaction Checking
• Construct slacked requirement constraints
• Minimize the slack variables
<How>
Requirement Satisfaction Optimization
• Optimize requirement satisfaction for R_{ns}
• Guarantee requirement satisfaction for R_s
Quantification Measures $\boldsymbol{\mathcal{X}}(k)$
Updated resolution $s^* \leftarrow s_2^*$
$R_{ns} = \emptyset$
s^*
Sensors
Actuators
Environmental Conditions $\mathcal{O}_k, \mathcal{C}_k$
System State s_k
Motion Plan m_k
Sensor Configuration ω_k


Constrained Planning
with HC and SG
Layer 1
$\begin{cases} DS^0(\chi) = 1 \\ DS^j(\chi) = 1, j = \{1,2,3\} \end{cases}$
Captain
Layer 2
$\max \sum DS^j(\chi), \forall R_i \in R_{ns}, j = \{1,2,3\}$
s. t. $\begin{cases} DS^0(\chi) = 1 \\ DS^j(\chi) = 1, \forall R_i \in R_s, j = \{1,2,3\} \end{cases}$
Optimal Planning with HC
Layer 3
$\max \sum DS^j(\chi), j = \{1,2,3\}$
s. t. $DS^0(\chi) = 1$
flexibility
satisfaction


Autonomous Unmanned System
Autonomous Controller
Requirements-Driven Adaptation
Requirement Satisfaction Measuring
Requirement Satisfaction Evaluating
Requirement Satisfaction Optimizing
Analyzing
Analyzing
Feed-forward
Planning
Feedback
Monitoring
Controlled System
Executing
Interaction
Input
Output
Humans
Obstacles
Private Regions
...
Environment


Autonomous Unmanned System
Autonomous Controller
Requirements-Driven Adaptation
Requirement Satisfaction Measuring
Requirement Satisfaction Evaluating
Requirement Satisfaction Optimizing
Environment Situation Analyzing
System Behavior Analyzing
Feed-forward
Planning
Feedback
Monitoring
Controlled System
Executing
Interaction
Input
Output
Humans
Obstacles
Private Regions
...
Environment


Autonomous Unmanned System
Autonomous Controller
Environment Analyzing
System Analyzing
Autonomous Planning
Requirements Satisfaction Checking
Requirements Satisfaction Analyzing
Requirements Satisfaction Optimizing
Environment Monitoring
Feed-forward
Deploying
Feedback
System Monitoring
Controlled System
Interaction
Sensing
Executing
Humans
Obstacles
Private Regions
...
Environment


Autonomous Unmanned System
Autonomous Controller
Environment Situation Analyzing
System Behavior Analyzing
Autonomous Planning
Requirement Satisfaction Evaluating
Requirement Satisfaction Optimizing
Knowledge Repository
Environment Model
System Model
Requirement Model
Environment Monitoring
Feed-forward
Deploying
Feedback
System Monitoring
Controlled System
Interaction
Sensing
Executing
Input
Output
Humans
Obstacles
Private Regions
...
Environment

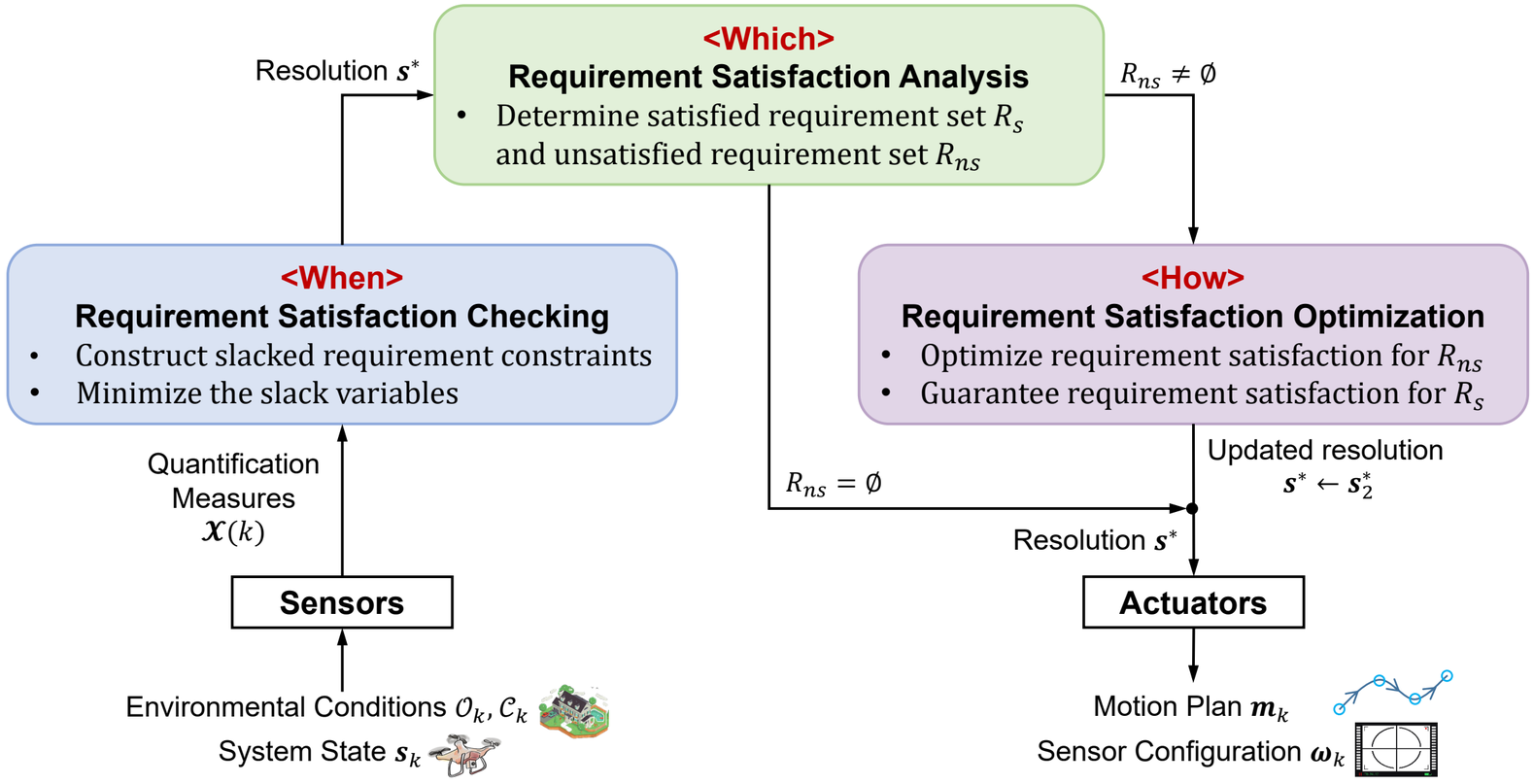
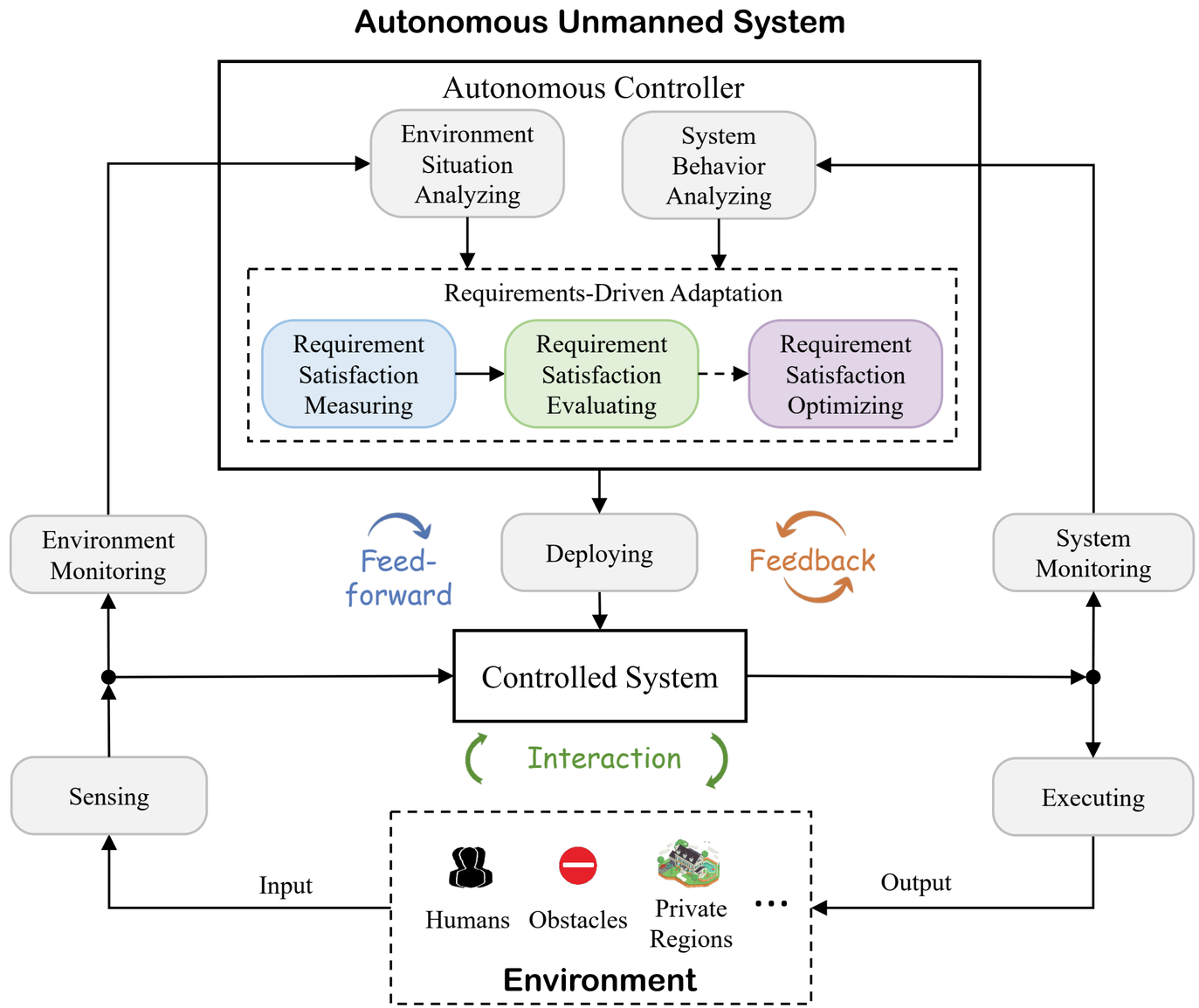

<Which>
Requirement Satisfaction Analysis
• Determine satisfied requirement set R_s and unsatisfied requirement set R_{ns}
Resolution s^*
$R_{ns} \neq \emptyset$
<When>
Requirement Satisfaction Checking
• Construct slacked requirement constraints
• Minimize the slack variables
<How>
Requirement Satisfaction Optimization
• Optimize requirement satisfaction for R_{ns}
• Guarantee requirement satisfaction for R_s
Quantification Measures $\boldsymbol{\chi}(k)$
Sensors
Environmental Conditions $\mathcal{O}_k, \mathcal{C}_k$
System State $\boldsymbol{s}_k$
$R_{ns} = \emptyset$
Updated resolution $\boldsymbol{s}^* \leftarrow \boldsymbol{s}_2^*$
Resolution $\boldsymbol{s}^*$
Actuators
Motion Plan $\boldsymbol{m}_k$
Sensor Configuration $\boldsymbol{\omega}_k$

TABLE 1: Representative Non-functional Requirements for Autonomous Unmanned Systems.

Requirements		**Informal Definition for Hard Constraints (HC)**	**Informal Definition for Soft Goals (SG)**
Environment-centric	Safety (R_S)	AUSs are required to keep appropriate distance with people, forbidden areas etc.	The distance between AUSs and obstacles should be keep as expectation.
	Privacy (R_P)	Control over any AUS interfering with private regions.	The distance between AUSs and private regions should be keep more than expectation.
System-centric	Timeliness (R_ξ)	The mission must be completed within time budget	The mission should be completed within time expected to cost.
	Accuracy (R_φ)	The sensor must be accurate for information analyzing	The sensor accuracy should be higher than expectation.
	Energy-saving (R_e)	The energy consumption must be within battery capacity.	The energy consumption should be within expected cost.


Autonomous Unmanned System
Autonomous Controller
Environment Situation Analyzing
System Behavior Analyzing
Requirements-Driven Adaptation
Requirement Satisfaction Measuring
Requirement Satisfaction Evaluating
Requirement Satisfaction Optimizing
Environment Monitoring
Feed-forward
Deploying
Feedback
System Monitoring
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Interaction
Sensing
Executing
Input
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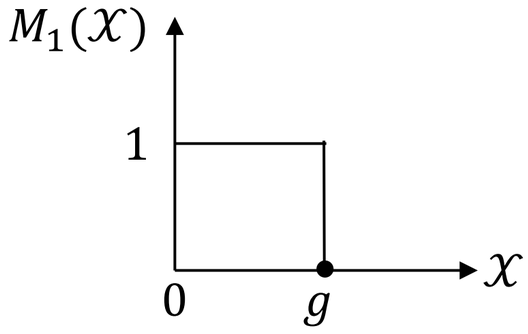
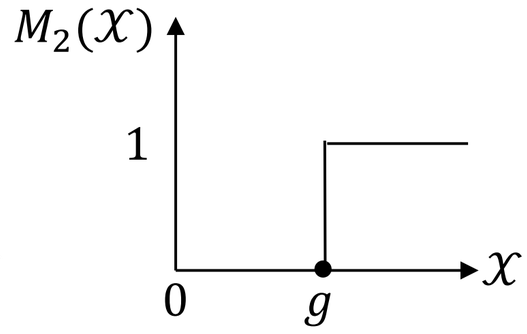
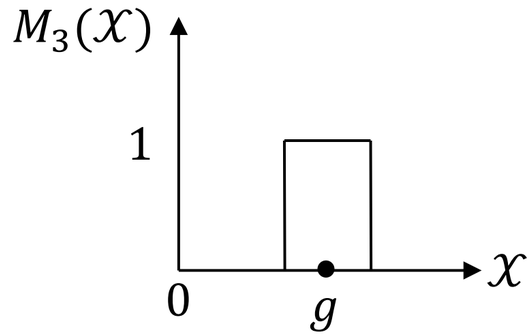
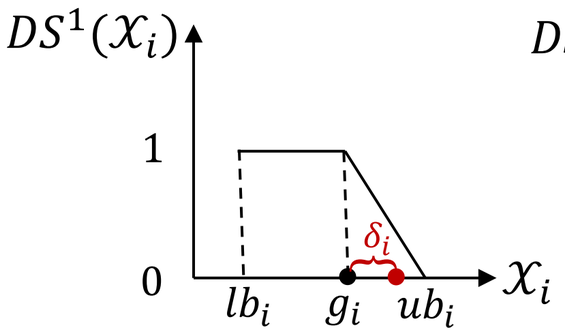
Obstacles
Private Regions
...
Environment

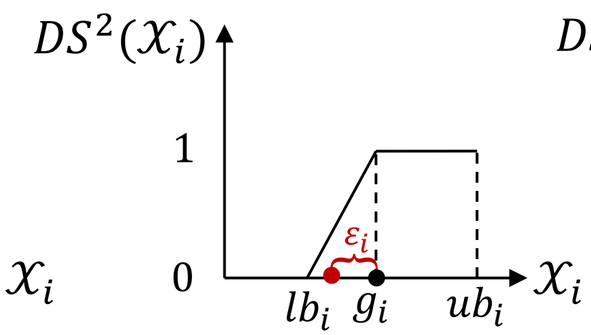

$M_1(\mathcal{X})$
1
0
g
$\mathcal{X}$


$M_2(\mathcal{X})$
1
0
g
$\mathcal{X}$

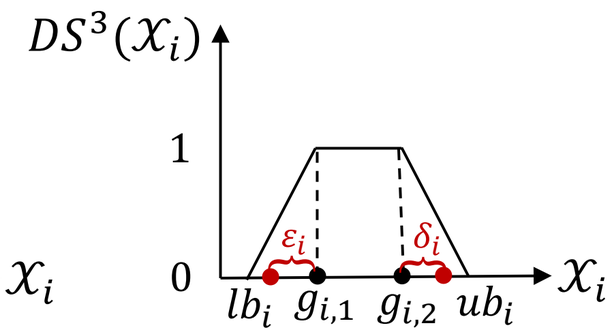

$M_3(\mathcal{X})$
1
0
g
$\mathcal{X}$


$DS^1(\mathcal{X}_i)$
1
0
δ_i
lb_i
g_i
ub_i
$\mathcal{X}_i$

(1)


$DS^2(\mathcal{X}_i)$
1
0
ε_i
lb_i
g_i
ub_i
$\mathcal{X}_i$

(2)


$DS^3(\mathcal{X}_i)$
1
0
ε_i
δ_i
lb_i
$g_{i,1}$
$g_{i,2}$
ub_i
$\mathcal{X}_i$

(3)