



OSAKA UNIVERSITY



National Institute of Informatics

MAPE-K Loop-based Goal Model Generation Using Generative AI

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GORA

- Effective process for eliciting, analyzing, and documenting goals
- Define a **goal model**
 - Diagrammatic representation of goals
 - Goals are structured using AND/OR-refinements
- Advantages:
 - Structural description
 - Step-wise refinements
- Difficulties:
 - Incomplete or inconsistent goals
 - Ambiguity and subjective



LLMs

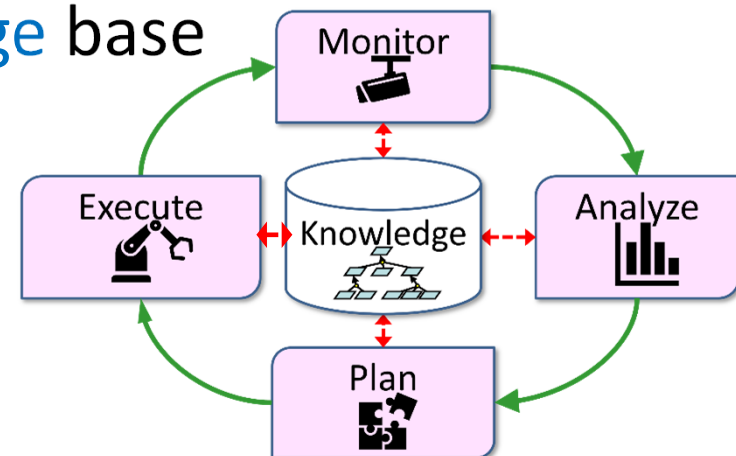


GitHub
Copilot

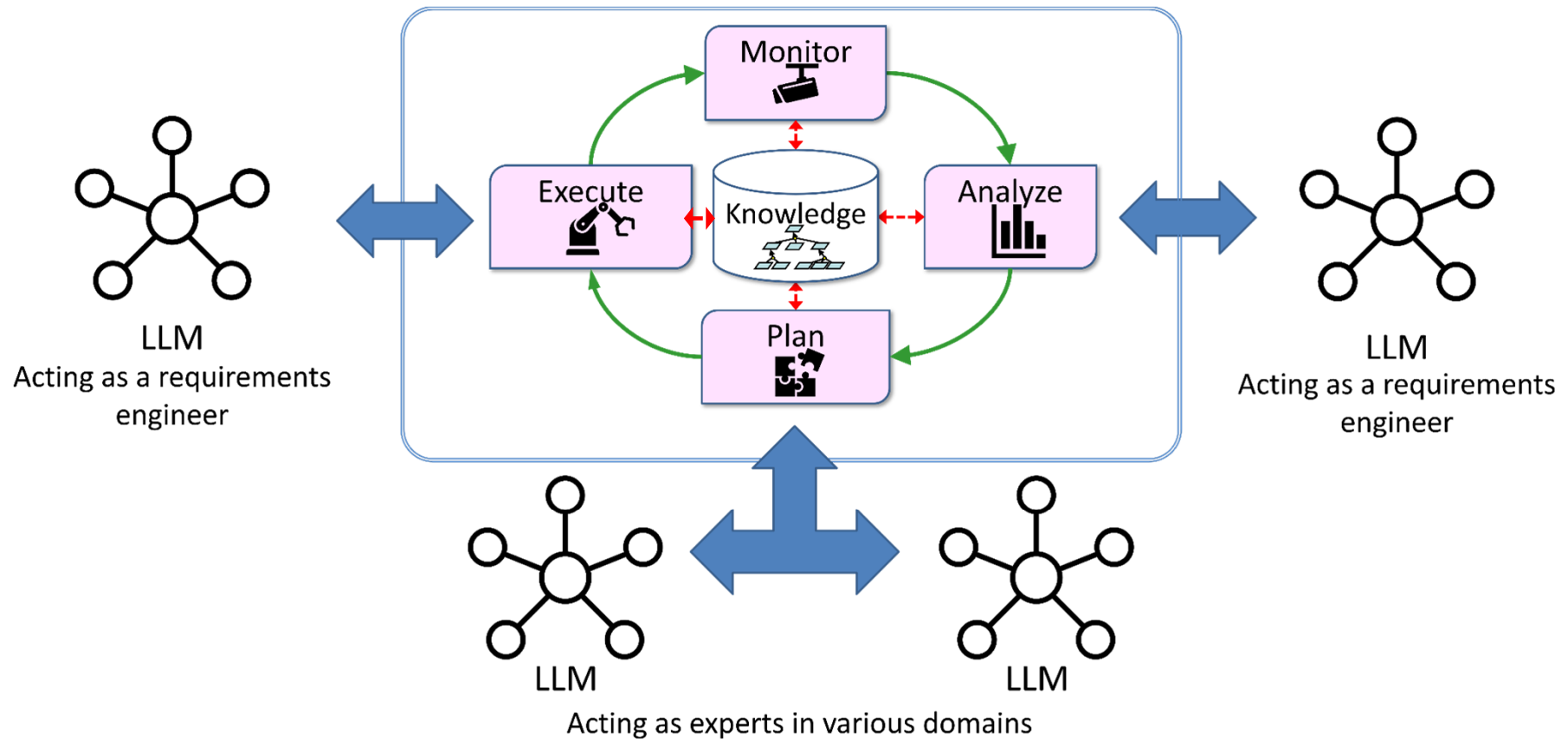
- LLMs: Large language models
 - Sophisticated deep learning models designed to understand and generate natural language
 - Representative LLM: GPT-4, Alpaca, Copilot, ...
- Some studies apply LLMs to generate models in the software development
 - Code, UML, ...
 - Using existing artifacts stored in Web
 - Requirements model
 - Less stored in Web
 - Ambiguous

MAPE-K loop

- A mechanism for implementing autonomy
 - Used for developing self-adaptive systems
- Controls a system by continuously executing four steps, i.e., **monitor**, **analyze**, **plan**, and **execute**
 - Includes a shared **knowledge** base



Goal model generation using several experts acted by LLMs

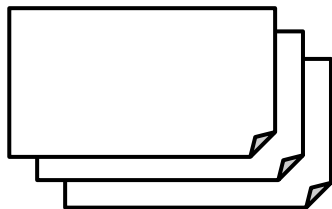


Template prompt

A prompt for generating the initial goal model

Template

- 1: <Role definition>
- 2: <Instruction>
- 3
- 4 : #Constraints
- 5: <Constraints description>



- 1: I want you to act as a requirements engineer.
- 2: Please construct a goal model in accordance with the following constraints.
- 3:
- 4: # Constraints
- 5: - The goal model should contain general requirements for a library management system.
- 6: - Goals in the goal model should be described in a numbered list.
- 7: - AND/OR-refinement links should be used to refine requirements into subgoals.

Library management system, - Viewpoint: performance

Plan

Current goal model

- Goal 1: Develop a user-friendly Library Management System (LMS)
- Goal 2: Efficiently manage library resources
- Goal 3: Provide advanced search capabilities
- Goal 4: Enhance user services
- Goal 5: Ensure system security

Opinions of Expert A

Speed and Efficiency
Intuitive User Interface
Search Capabilities
Notification System
Reliability
Data Security
Remote Access
Scalability

Opinions of Expert B

Scalability
Search Efficiency
Automation
Integration
Backup and Recovery
User Interface
Security
Reporting
Accessibility
Updates and Maintenance

Scalability:
Search Efficiency:
Automation:
Speed and Efficiency:
Intuitive User Interface:
Search Capabilities:
Notification System:

Execute

Next goal model

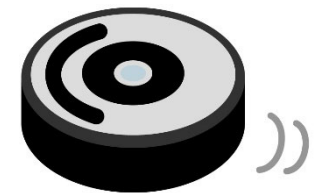
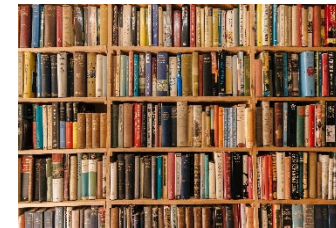
Embedded by a requirements

engineer (Expert)

- Goal 1: Develop a user-friendly Library Management System (LMS)
- Goal 2: Efficiently manage library resources
- Goal 3: Provide advanced search capabilities
- Goal 4: Enhance user services
- Goal 5: Ensure system security
- Goal 6: Ensure system scalability
- Goal 7: Improve search efficiency
- Goal 8: Enhance system automation
- Goal 9: Maintain speed and efficiency
- Goal 10: Create an intuitive user interface
- Goal 11: Implement robust search capabilities
- Goal 12: Design reliable notification system
- Goal 13: Plan for future scalability

Case studies

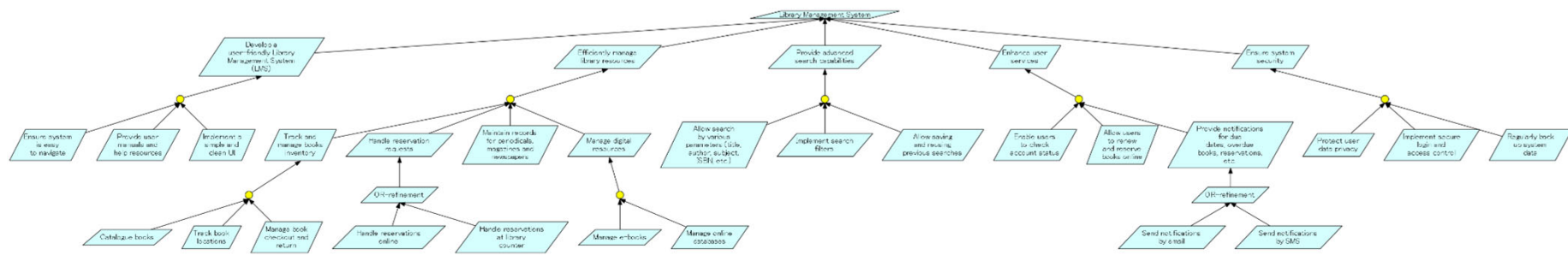
- RQs
 - RQ1: Can generative AI produce accurate goal models?
 - RQ2: Can the MAPE-K loop efficiently construct a goal model using a generative AI-based tool?
 - RQ3: Can various experts played by generative AI contribute to expand a goal model?
- Two case studies
 - Case 1: Library management system
 - Case 2: Cleaning robot
- Sequentially adding non-functional requirements
 - Performance, maintenance, security, human-centered design (HCD)



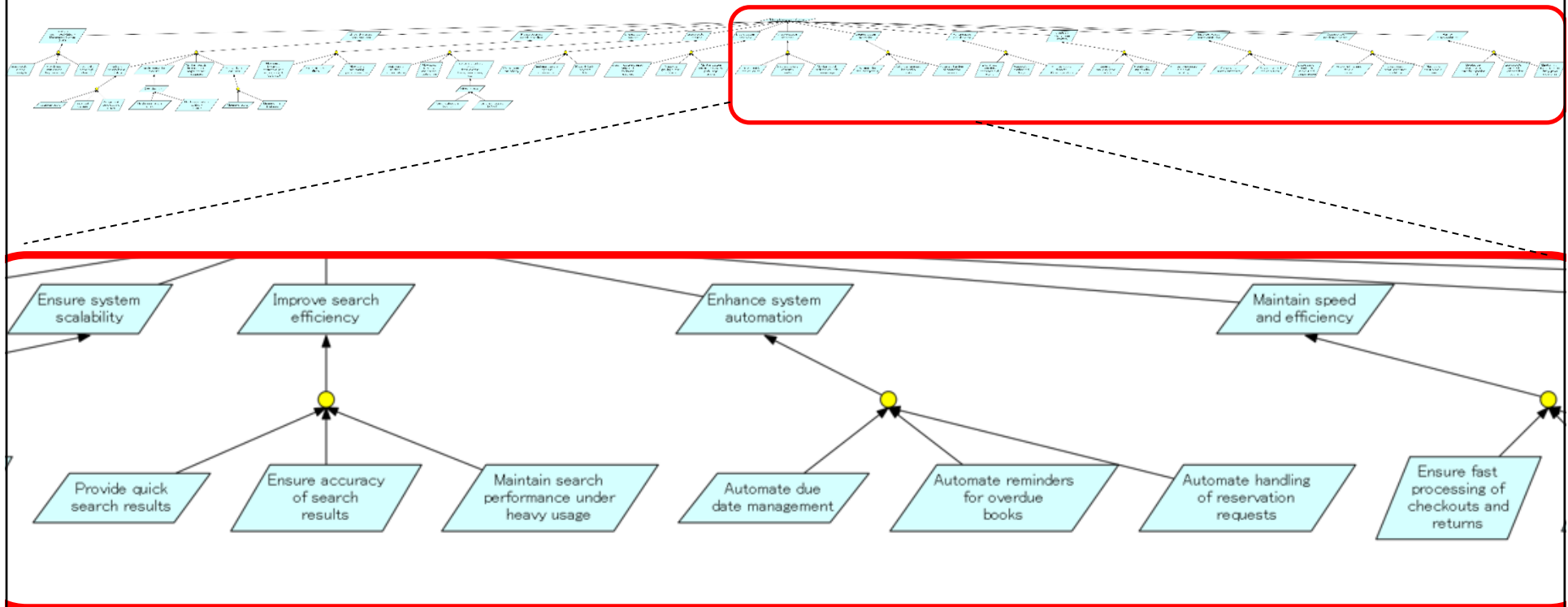
Library management system (Initial goal model)

- Goal 1: Develop a user-friendly Library Management System (LMS)
 - 1.1: AND-refinement
 - 1.1.1: Ensure system is easy to navigate
 - 1.1.2: Provide user manuals and help resources
 - 1.1.3: Implement a simple and clean UI
- Goal 2: Efficiently manage library resources
 - 2.1: AND-refinement
 - 2.1.1: Track and manage books inventory
 - 2.1.1.1: AND-refinement
 - 2.1.1.1.1: Catalogue books
 - 2.1.1.1.2: Track book locations
 - 2.1.1.1.3: Manage book checkout and return
 - 2.1.2: Handle reservation requests
 - 2.1.2.1: OR-refinement
 - 2.1.2.1.1: Handle reservations online
 - 2.1.2.1.2: Handle reservations at library counter
 - 2.1.3: Maintain records for periodicals, magazines and newspapers
 - 2.1.4: Manage digital resources
 - 2.1.4.1: AND-refinement
 - 2.1.4.1.1: Manage e-books
 - 2.1.4.1.2: Manage online databases
- Goal 3: Provide advanced search capabilities
 - 3.1: AND-refinement
 - 3.1.1: Allow search by various parameters (title, author, subject, ISBN, etc.)
 - 3.1.2: Implement search filters
 - 3.1.3: Allow saving and reusing previous searches
- Goal 4: Enhance user services
 - 4.1: AND-refinement
 - 4.1.1: Enable users to check account status
 - 4.1.2: Allow users to renew and reserve books online
 - 4.1.3: Provide notifications for due dates, overdue books, reservations, etc.
 - 4.1.3.1: OR-refinement
 - 4.1.3.1.1: Send notifications by email
 - 4.1.3.1.2: Send notifications by SMS
- Goal 5: Ensure system security
 - 5.1: AND-refinement
 - 5.1.1: Protect user data privacy
 - 5.1.2: Implement secure login and access control
 - 5.1.3: Regularly back up system data

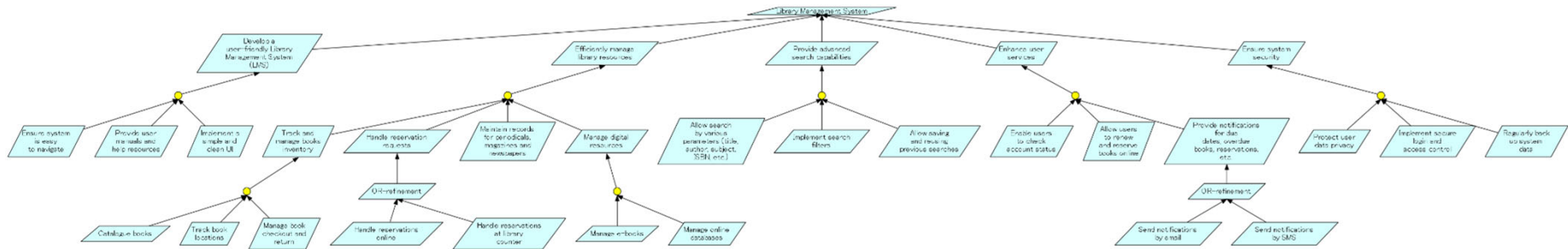
Library management system (Initial goal model)



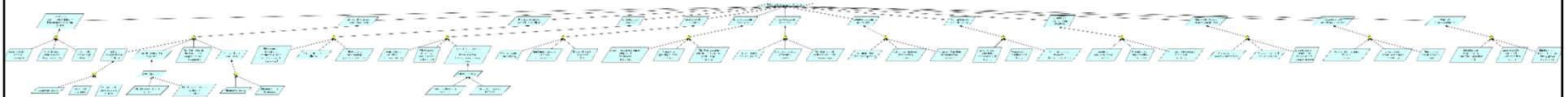
Library management system (After adding performance goals)



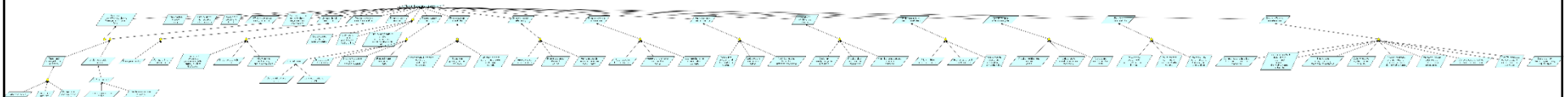
Transition of the goal model



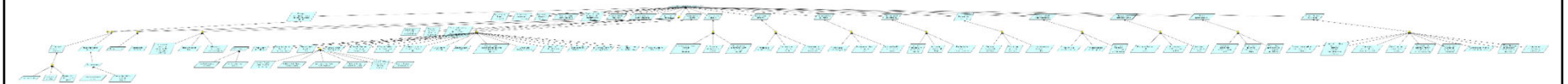
Adding performance goals



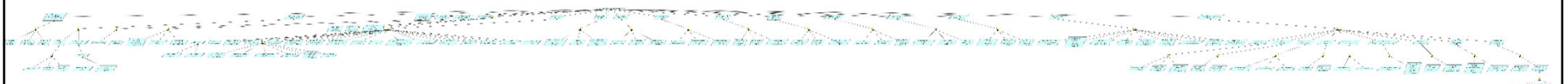
Adding maintenance goals



Adding security goals



Adding HCD goals



		Library system		Cleaning robot	
Performance	Expert	Librarian	System Engineer	Garbage Collector	Cleaning Robot Developer
	Total	8	10	10	10
	Correct	5	3	8	7
	Precision	0.63	0.30	0.80	0.70
Maintenance	Expert	Librarian	System Engineer	GC	CR Developer
	Total	15	15	10	10
	Correct	9	13	10	10
	Precision	0.73	0.87	0.90	1.00
Security	Expert	Librarian	Security Engineer	GC	Security Engineer
	Total	10	10	10	10
	Correct	9	10	8	4
	Precision	0.90	1.00	0.80	0.40
Human Centered Design	Expert	Librarian	HCD Engineer	GC	HCD Engineer
	Total	10	10	10	10
	Correct	10	9	8	8
	Precision	1.00	0.90	0.80	0.80

Discussion

- RQ1: Can generative AI produce accurate goal models?
→ It can create goal models but rather generalized.
- RQ2: Can the MAPE-K loop efficiently construct a goal model using a generative AI-based tool?
→ Yes, but it tends to be flattened. Refactoring is recommended.
- RQ3: Can various experts played by generative AI contribute to expand a goal model?
→ Yes. Various opinions are obtained by various experts. Verification is desired.

Conclusion

- A goal model generation using LLMs
 - Based on MAPE-K mechanism
 - Employ LLMs as various experts
 - Two case studies
- Future work
 - Enhance automation: Opinion determination
 - Integrate case-specific goals