Goal-directed Software Assistant for a Plan Advisory System

MAS.761 Final Project

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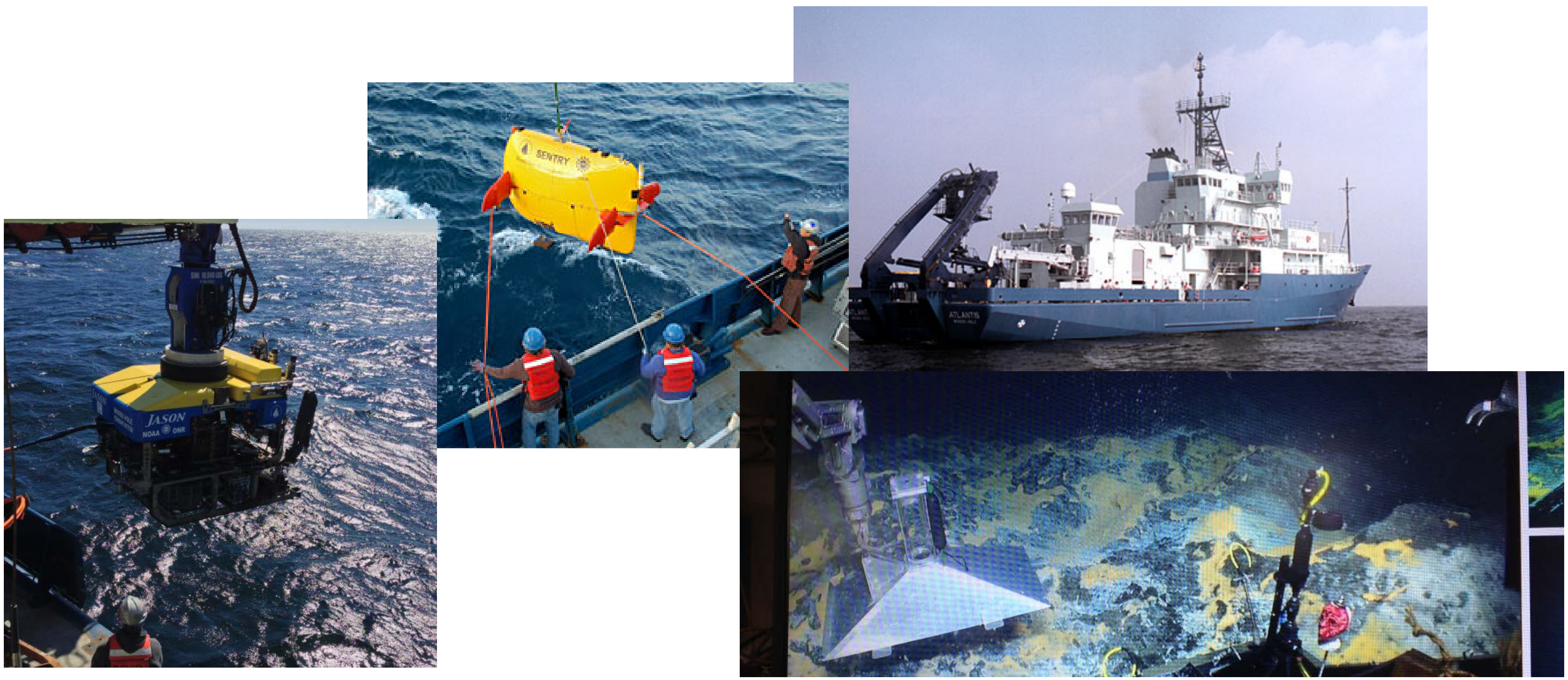
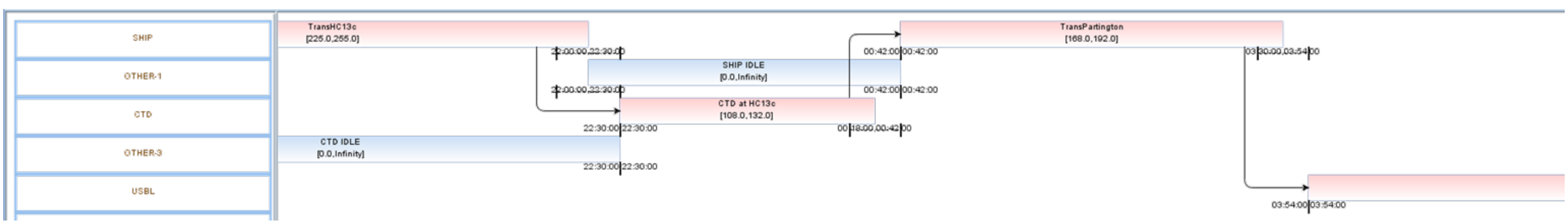
Plan Advisory System for Deep Sea Explorations

- I am working with the Woods Hole Oceanographic Institute to apply state-of-the-art planning and scheduling algorithms on managing expedition cruise plans.

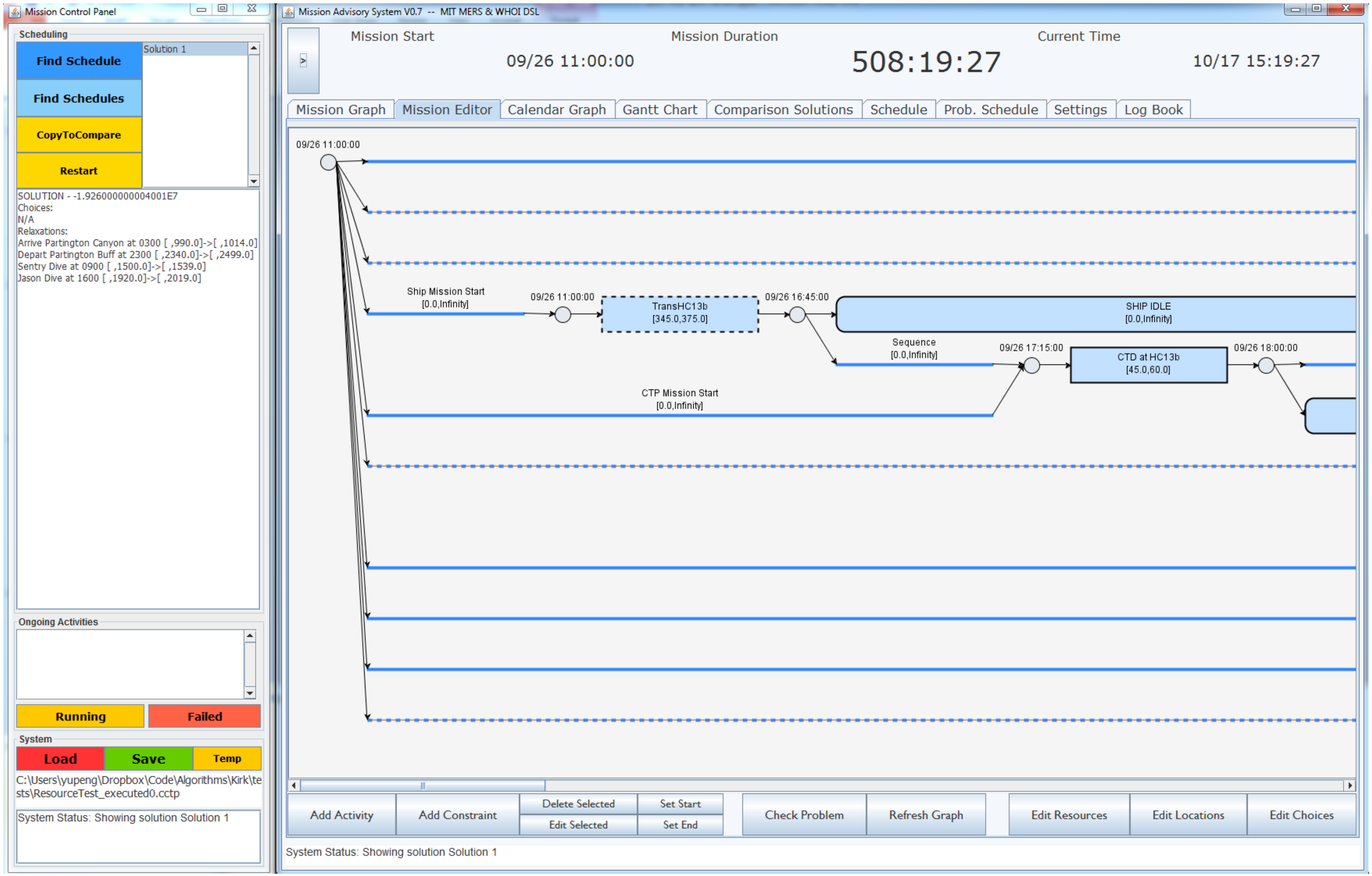


Mission Advisory System for WHOI

- During an expedition cruise, the chief scientist needs assistance for planning and scheduling to maximize the science return, esp. when things go wrong.
  - Task sequencing and scheduling.
  - Goal relaxation and failure recovery.
  - Human resources and assets management.



The Interface



Too Complicated for Geologists

	A	B	C	D	E
1	Title	Component	Parent	Action	Description
2	**Mission Executive Window**				
3		Mission Start Time Label		No action.	Show the start time of the mission.
4		Mission Duration Label		No action.	Show the duration of the current mission.
5		Current Time Label		No action.	Show current time.
6		Show/Hide Control Window Btn		Show/Hide the mission control window.	Let the user control whether the control panel is visible.
7		System Status TxtBx		No action.	Show system status messags.
8	**Mission Graph Tab**				
9		Mission Graph		No action.	Present the current plan and problem in a PERT chart.
10	Input Interruption	Double Click Target Activity	None	Bring up the interruption handler window.	Direct access for reporting any unexpected plan exceptions.
11	Mark Event Executed	Double Click Target Event	None	Bring up the event completion window.	Direct access for changing the state of an event (i.e. execution).
12	**Interruption Handler Window**				
13	**Weather Tab**				
14		Bad Weather RdBtn		Select bad weather as the cause of down time.	Choose bad weather as the cause of downtime and select all dependent assets.
15	**Ship Tab**				
16		Mechanical RdBtn		Select mechanical failure as the cause of ship down time.	Choose mechanical failure as the cause of ship downtime and select all affected assets.
17		Electrical RdBtn		Select electrical failure as the cause of ship down time.	Choose electrical failure as the cause of ship downtime and select all affected assets.
18		Communication RdBtn		Select communication failure as the cause of ship down time.	Choose communication failure as the cause of ship downtime and select all affected assets.
19		Human Factor RdBtn		Select human fatigue as the cause of ship down time.	Choose human factor as the cause of ship downtime and select all affected assets.
20	**ROV Tab**				
21		Mechanical RdBtn		Select mechanical failure as the cause of ROV down time.	Choose mechanical failure as the cause of ROV downtime and select all affected assets.
22		Electrical RdBtn		Select electrical failure as the cause of ROV down time.	Choose electrical failure as the cause of ROV downtime and select all affected assets.
23		Communication RdBtn		Select communication failure as the cause of ROV down time.	Choose communication failure as the cause of ROV downtime and select all affected assets.
24		Human Factor RdBtn		Select human fatigue as the cause of ROV down time.	Choose human factor as the cause of ROV downtime and select all affected assets.
25	**AUV Tab**				
26		Mechanical RdBtn		Select mechanical failure as the cause of AUV down time.	Choose mechanical failure as the cause of AUV downtime and select all affected assets.
27		Electrical RdBtn		Select electrical failure as the cause of AUV down time.	Choose electrical failure as the cause of AUV downtime and select all affected assets.
28		Communication RdBtn		Select communication failure as the cause of AUV down time.	Choose communication failure as the cause of AUV downtime and select all affected assets.
29		Human Factor RdBtn		Select human fatigue as the cause of AUV down time.	Choose human factor as the cause of AUV downtime and select all affected assets.
30	**CTD Tab**				
31		CTD Failure RdBtn		Select CTD failure as the cause of down time.	Choose CTD failure as the cause of CTD downtime and select all affected assets.
32	**CORE Tab**				
33		CORE Failure RdBtn		Select CORE failure as the cause of down time.	Choose CORE failure as the cause of CORE downtime and select all affected assets.
34	**MULTIBEAM Tab**				
35		MULTIBEAM Failure RdBtn		Select MULTIBEAM failure as the cause of down time.	Choose MULTIBEAM failure as the cause of MULTIBEAM downtime and select all affected assets.
36	**Affected Assets Panel**				
37		SHIP ChkBx		Select SHIP as affected asset.	Choose SHIP as an affected asset of the downtime.

- There are more than 200 operations in the UI!
- The learning curve is very steep, and no scientist is willing to devote that much time studying the operations.

What's the Problem?

- There are two challenges for the users of a high-functionality program:
  - Identify the problem(s) that can be addressed by the program.
  - Understand the operations to achieve the desired outcome(s).

Previous Approaches

- Previous approaches to this problem focus on the second challenge:
  - Tutorials with step by step instructions are widely used to assist the users in completing their tasks.

- The first challenge is caused by a gap between the **users' goals** and the **problems solvable** by these tutorials.

I want to address my problem: **x**.

?

Tutorial #1 for problem α

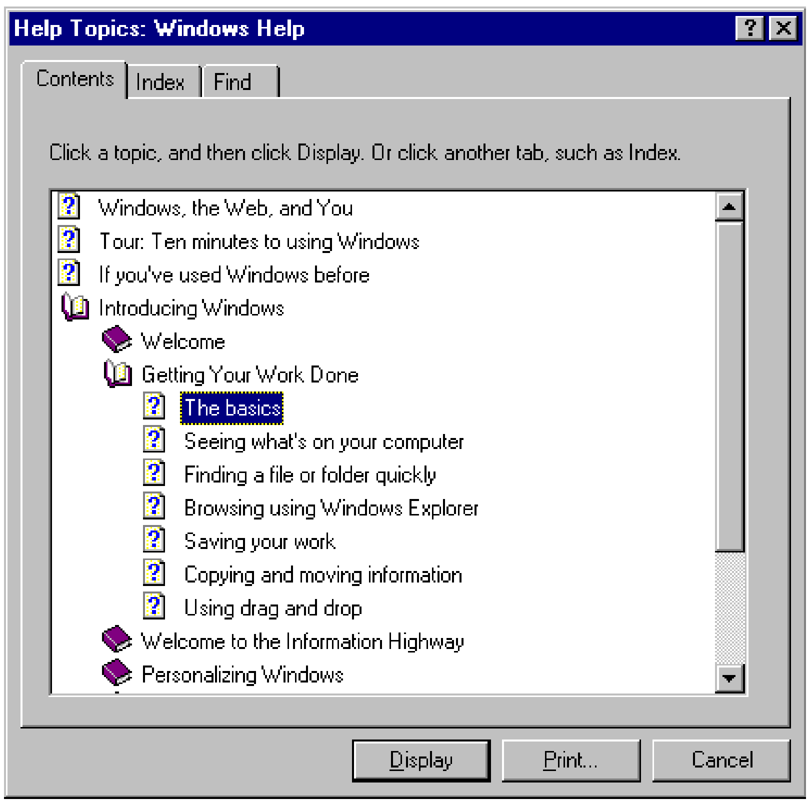
Tutorial #2 for problem β

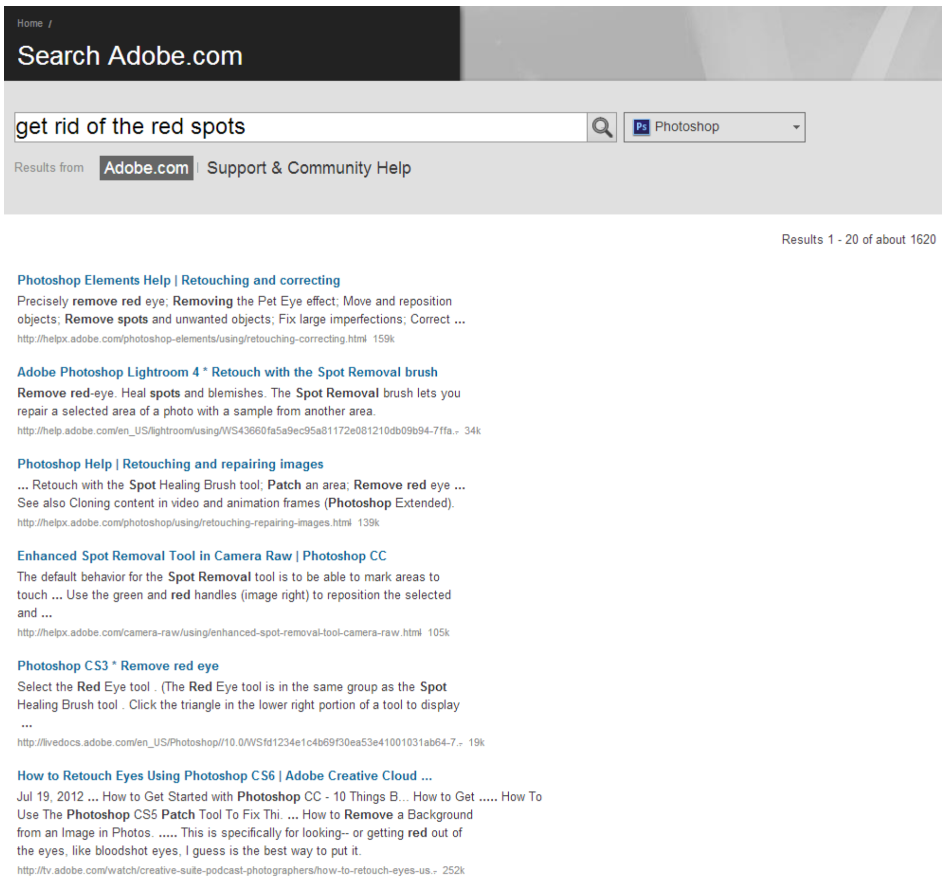
Tutorial #3 for problem γ

… …

Previous Approaches

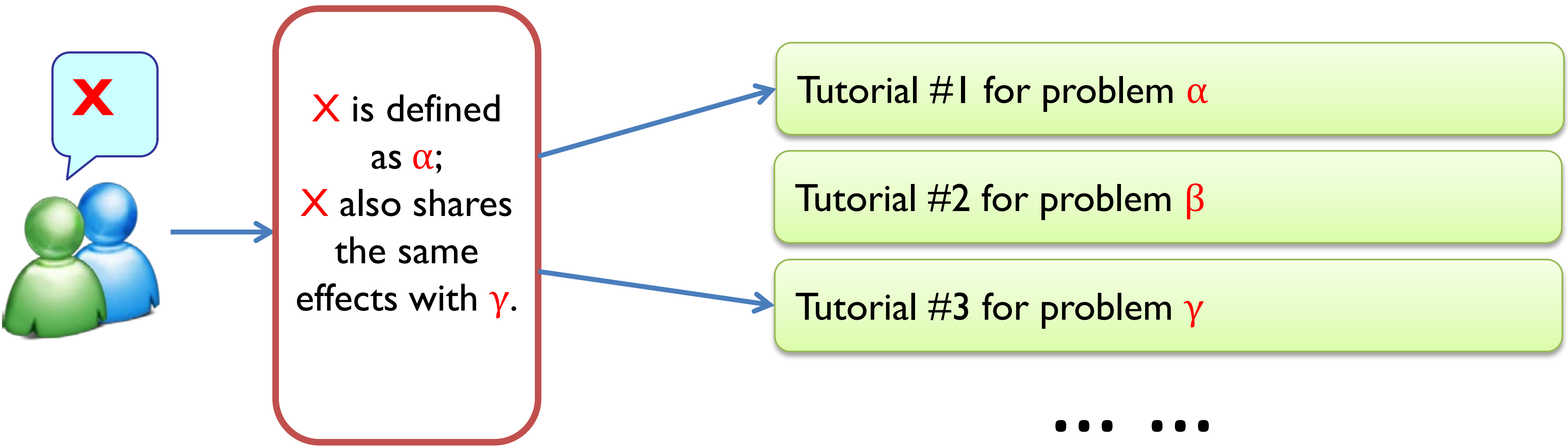
- There is a mismatch between the users’ and programs’ problem descriptions.
  - Command dictionary and keyword search are commonly used, but not very helpful.





My Vision

- Use commonsense reasoning to resolve the mismatch between the users' and programs' knowledge bases, hence bridge the gap between their problem descriptions.



Demo: the Captain Kirk Knowledge Base

Captain Kirk Knowledge Base

Tell me your problem:

storm,is,coming

Tell me what to do (Kirk + c4) Clear outputs

Solution:

The original problem is "storm,is,coming".

It is explained by concepts "storm", "bad weather", "high wave",

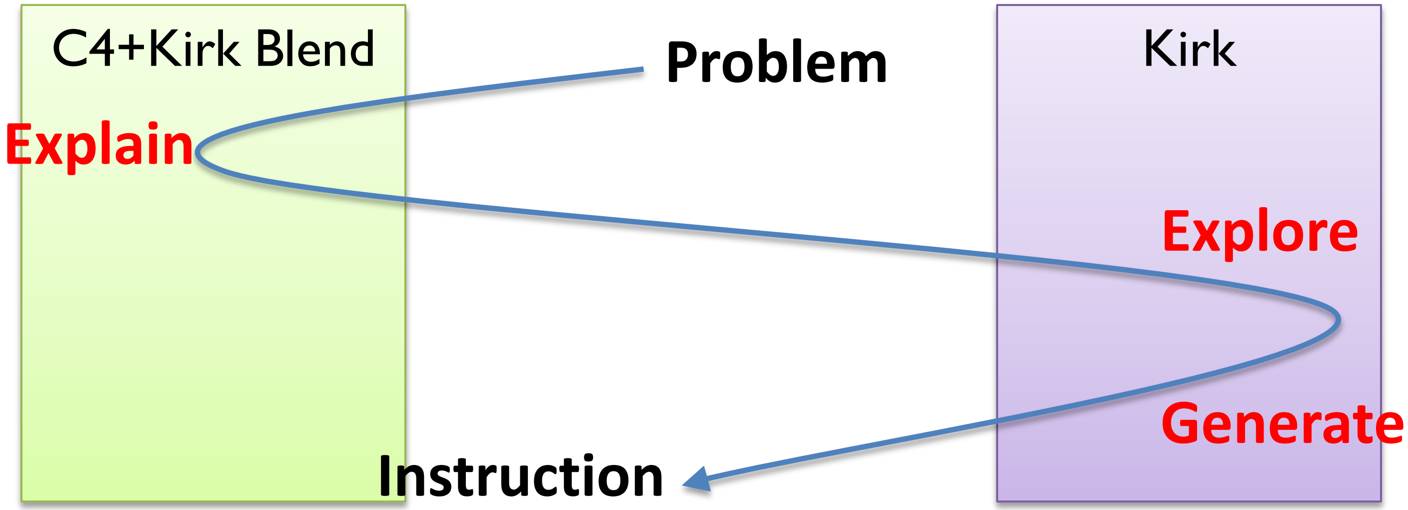
Their consequences include "ship down time", "rov down time", "auv down time", "ctd down time", "core down time", "multibeam down time",

Use the following tools to address the issue, prioritized based on likelihood:

1. At down time scheduling panel:
Select CORE as affected asset;
Set the start and duration of the downtime;
Set the uncertainty in the duration of CORE downtime

How it works?

- Given a problem description:
  - **Explain** its meaning by identifying similar known concepts;
  - **Explore** causes and effects through neighboring assertions with causal relations.
  - **Generate** solutions and instructions using neighboring assertions with resolution relations.



Step 1: Find similar concepts

- Explain the user's description using known concepts in **Kirk-kb**.
- The similarity is evaluated using the **C4-Kirk-Blend** kb.

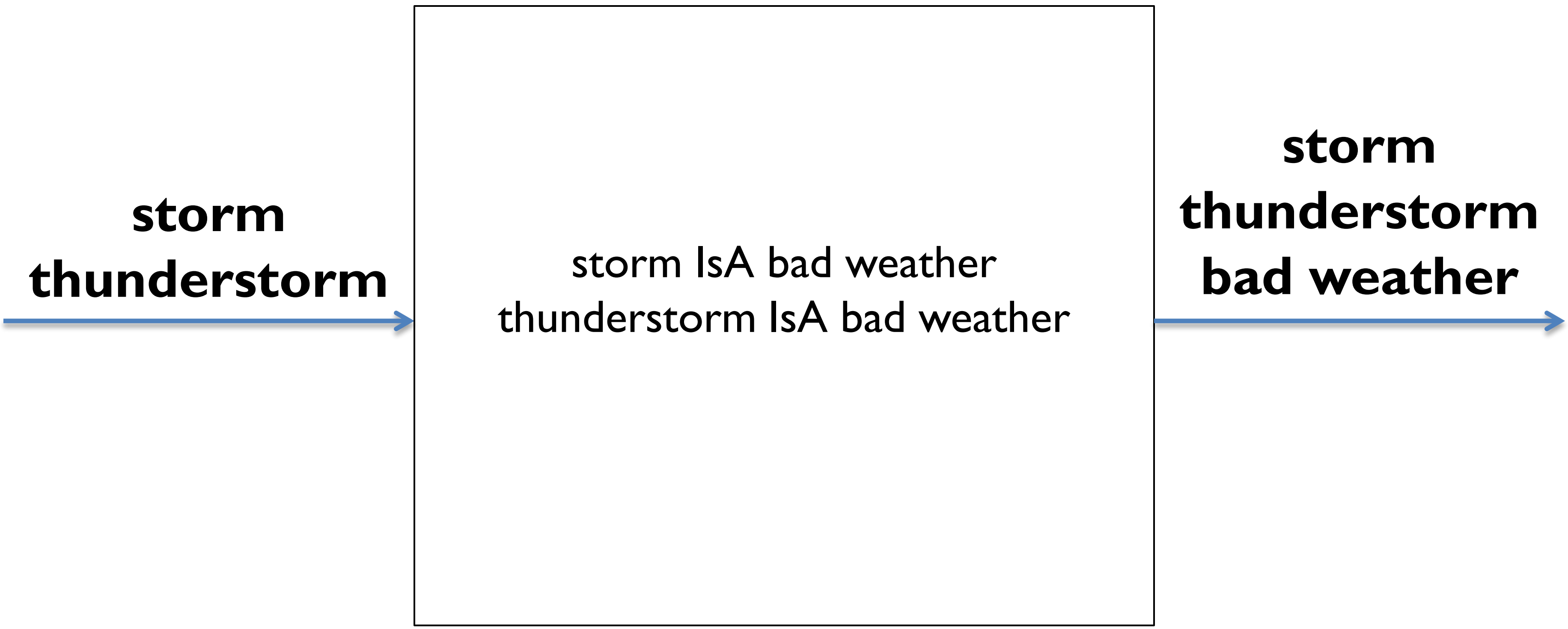
typhoon →

typhoon -- low battery: 0.744272348609702
typhoon -- low water: -0.3701262745244257
typhoon -- multibeam down time: -0.000103761445298952
typhoon -- multibeam down time scheduler: -0.145049072169696
typhoon -- rain: 0.6463570842311839
typhoon -- rov down time: -0.00010376144529895844
typhoon -- rov down time scheduler: -0.14321520410262634
typhoon -- satellite link down: -0.13368756460728107
typhoon -- shaft overheat: -0.3701262745244257
typhoon -- ship communication failure: -0.004030046230603112
typhoon -- ship down time: -0.00010376144529873296
typhoon -- ship down time scheduler: 0.13919460936443573
typhoon -- ship electrical failure: -0.015660917350911102
typhoon -- ship human factor failure: -0.0045961307498643845
typhoon -- ship mechanical failure: 0.004535704379857019
typhoon -- short circuit: 0.490685171277081
typhoon -- sonar broken: -0.13368756460728107
typhoon -- storm: 0.9026540259783965
typhoon -- strong current: 0.5736174980949411
typhoon -- thunderstorm: 0.9458139330890203

storm
thunderstorm →

Step 2: Find related concepts

- Expand the coverage of similar concepts by finding related concepts in Kirk-kb:
  - by identifying assertions with *IsA*, *DefinedAs* and *ConceptuallyRelatedTo* relations.



Step 3: Identify causes and effects

- Identify concepts that are possible causes and effects using neighboring assertions with causal relations, such as Causes, CreatedBy, HasA, etc.

storm
thunderstorm
bad weather

bad weather

Causes ship down time 0.19151911609834685
Causes rov down time 0.19151911609834685
Causes auv down time 0.218064750209997
Causes ctd down time 0.218064750209997
Causes core down time 0.19151911609834685
Causes multibeam down time 0.19151911609834685

storm; thunderstorm; bad weather;
ship down time; rov down time;
auv down time; ctd down time;
core down time; multibeam down time;

Step 4: Find solution concepts

- Find solution concepts by exploring neighboring assertions with resolution relations, such as *UsedFor* and *CapableOf*.

ship down time scheduler,UsedFor,ship down time: 4.0147734018392524e-32
rov down time scheduler,UsedFor,rov down time: 2.5236755089281305e-32
auv down time scheduler,UsedFor,auv down time: 2.6670725263397843e-33
ctd down time scheduler,UsedFor,ctd down time: 9.190983966244161e-33
core down time scheduler,UsedFor,core down time: 1.102739126848916e-31
multibeam down time scheduler,UsedFor,multibeam down time: 5.591052950934684e-32

↓

core down time scheduler: 1.102739126848916e-31
multibeam down time scheduler: 5.591052950934684e-32
ship down time scheduler: 4.0147734018392524e-32
rov down time scheduler: 2.5236755089281305e-32
ctd down time scheduler: 9.190983966244161e-33
auv down time scheduler: 2.6670725263397843e-33

Step 5: Generate instructions

- Maps each solution concept to a set of pre-defined instructions, stored in a separated hash table.

ship down time scheduler

↓

At down time scheduling panel:
Select SHIP as affected asset;
Set the start and duration of the downtime;
Set the uncertainty in the duration of SHIP downtime

Limitation

- Efficiency:
  - When Kirk-kb gets large, the expansions will take much longer to compute due to the lack of contraction steps.
- Accuracy:
  - More than half of the solutions generated by this approach are not accurate. This is mainly due to the inconsistent inference result before and after blending c4 and Kirk-kb.
- Coverage:
  - C4 only has a limit coverage of shipboard concepts. For example, "Engine temperature high" is not known by c4.

Contribution

- Design and implemented an assistant program that generates instructions for the users of a high-functionality planning software. The program is capable of:
  - bridging the gap between the user's problem descriptions and the concepts used by the software.
  - explaining the user's problem with known concepts, causes and effects through commonsense reasoning.
  - generating solutions and instructions for the software to address the user's problem.

Question