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모델기반설계를 이용한 요구사항 기반 검증의 단순화

Application Engineer 홍 혁 기 부장





Key takeaways

- Verify and validate requirements earlier
- Identify inconsistencies in requirements by using unambiguous assessments
- Traceability from requirements to design and test



Challenge: Errors introduced early but found late







Simulink models for specification





Multiple languages to describe complex systems



Ad-Hoc Testing: Explore behavior and design alternatives



Validate behavior earlier with simulation



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Validate Behavior Earlier with Simulation



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Complete Model Based Design





Systematically verify requirements



Integrate with requirements tools and author requirements





Roundtrip workflow with external tools thru ReqIF



Requirements Verification with Simulink



Requirements Verification with Simulink





Example: Verifying Heat Pump Controller Requirements

	Requirements in DOORS
1 Requirements for the basic Heatpump Controller	-
Temperature difference is defined as the difference between the room and the set temperature difference has reached a certa The controller shall turn the fan on when the temperature difference has reached a certa level, to circulate the air. The controller shall turn the heatpump on when the temperature difference has reached another level, to heat or cool the space.	erature. ain re
1.1 Idle when Temperature in Range	
If the temperature difference is less than 1 degrees, the system shall be idle with all sign	nals off.
1.2 Activate Fan	•
The fan shall activate when the temperature difference is greater than or equal to 1 deg	rees.
1.3 Activate Heat Pump	•
The pump shall activate when the temperature difference is greater than or equal to 2 de for more than 2 seconds and stay active for at least 2 seconds.	legrees
1.3.1 Cool Mode	
If the room temperature is greater than the set temperature, the system shall cool the sp	pace.
1.3.2 Heat Mode	•
If the room temperature is less than the set temperature, the system shall heat the space	e.
1.4 Max Temperature Difference	
The difference between the room temperature and the set temperature should never exc degrees	ceed 6

Example: Heat Pump Controller Implementation



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Link requirements to implementation in model



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Work with Model and Requirements with Requirements Perspective



Track Implementation and Verification

dex	ID	Summary	Implemented	Verified
crs_req_func_spec	-	-		
~ 🖹 1	#1	Driver Switch Request Handling		
1.1	#2	Switch precedence		
1.2	#3	Avoid repeating commands		
> 🖹 1.3	#4	Long Switch recognition		
■ 1.4	#7	Cancel Switch Detection		
li 1.5	#8	Set Switch Detection		
■ 1.5 ■ 1.6	#8 #9	Set Switch Detection Enable Switch Detection		
■ 1.5■ 1.6	#8 #9	Set Switch Detection Enable Switch Detection	Implementation Stat	us Verification Statu
■ 1.5■ 1.6	#8 #9	Set Switch Detection Enable Switch Detection	Implementation State	US Verification Statu Passed
■ 1.5■ 1.6	#8 #9	Set Switch Detection Enable Switch Detection	Implementation State	US Verification Statu Passed Failed
 ■ 1.5 ■ 1.6 	#8 #9	Set Switch Detection Enable Switch Detection	Implementation State Implemented Justified	US Verification Statu Passed Failed Unexecuted

Isolate Component Under Test with Test Harness



Test Sequence Block: Step-based and temporal test sequences

	- (010)	E .		10 6	and a			Oliabtaia	a East
Symbols		Step			Tran	sition		N	y rasi
Input		Initialize	alizo data input	10	1.	true		O Fast	
·. 🕑 control_out		Tset = 23	alize uata iripul }:	15.				Slow	
Output		Troom_in	n = 23;					O None	
1. 🦲 Tset								Onone	
2. 🧾 Troom_in		Cold_Ou %% Che	tside ck heating mo	de	1.	Troom_in	<= 14	Hot_Outside	V
Local		Troom_in	n = 23 - ramp(e)	et*0.2);					
Constant		Hot Out	side		1	Troom in	>= 28	Return Idle	v
Parameter		%% Che	ck cooling mod	de	78			Contraction Contract	100
Data Store Memory		i room_li	1 = 23 + ramp(et*0.2);					
		Return_I %% Retu Troom_in	dle um to idle mod n = Troom_in-r	le amp(et*0.2);	1.	Troom_in	<= 22	End	۷
Step Hierarchy		End							
Initialize	^	moon_i	1-22						
Cold Outside									
Hot Outside	~								

Test Assessments: Formalize and execute requirements R2019a

Activate Heat Pump

If the temperature difference exceeds 2 degrees for more than 2 seconds, then the pump shall activate for at least 2 seconds When < condition 1> is true, Then < condition 2> must be true for some time

Simple concept

$$(|x_1 - x_2| \ge x_3) \stackrel{\varepsilon}{\leftarrow} \land \Box_{[0,t_1)}(|x_1 - x_2| \ge x_3) \rightarrow \Box_{[0,t_2)}x_4 \quad \text{Hard to formalize}$$

MTL logic

Translate textual requirements into unambiguous Temporal Assessments

- Compose assessments using form based editor
- View assessments as English-like sentence
- Link to requirements
- Review and debug temporal assessment results



Translate textual requirements into unambiguous Temporal Assessments

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Translate textual requirements into unambiguous Temporal Assessments



+ Add Symbol 📋 Delete

true -

> + set_temp =
> + room temp

Mathematical threshold
 The PumpCmd

RESPONSI

TRIGGER

Translate textual requirements into unambiguous Temporal Assessments

EN NAME

. LOGICAL AND TEMPORAL ASSESSMENT:

- Compose assessments
 using form based editor
- View assessments as English-like sentence
- Immediate
 Instant statute

 distry
 With no delay...

 Immediate
 Immpdiate

 Immediate
 Immpdiate

 Immediate
 Immediate

 Immediate
 Immediate

min-time (sec): 2

 trigger: becomes true and stays true for at least condition: abs(set temp-room temp) > thresho...

- Link to requirements
- Review and debug te assessment results

Assessm...

1

 At any point of time, if abs(set_temp - room_temp) > threshold becomes true and stays true for at least 2 seconds then, starting from rising edge of trigger, with no delay, PumpCmd must stay true for at least 2 seconds

Temporal Assessment Editor

None

Translate textual requirements into unambiguous Temporal Assessments

- Compose assessments
 using form based editor
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Translate textual requirements into unambiguous Temporal Assessments

- Compose assessments using form based editor
- View assessments as English-like sentence

Link to requirements

Temporal Assessment Editor . LOGICAL AND TEMPORAL ASSESSMENTS EN NAME true 4 Assessm... > At any point of time, if abs(set_temp - room_temp) > 4: Activate Heat Pump (my_requir#5) TRIGGER threshold becomes true and stays true for at least 2 seconds then, starting from rising edge of trigger, with no At rising delay, PumpCmd must stay true for at least 2 seconds RESPONSI ▶ t set_temp ≡ ► room temp threshold ► PumpCmd + Add Assessment - 📋 Delete + Add Symbol 📋 Delete



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Model: ssc_	house_heating_system_1	単当年C
▼ TEST HAP	RNESS*	
Harness:	ssc_house_heating_system_1_Harness1	- C #
▶ SIMULATI	ION SETTINGS OVERRIDES	
IPUTS		
MULATION O	UTPUTS	
GICAL AND 1	TEMPORAL ASSESSMENTS*	
NAME	ASSESSMENT	REQUIREMENTS + VISUAL REPRESENTATION
Activate Pum	▼ At any point of time	None
	 trigger: becomes true and stays true for at least 	TRIGGER
	min-time (sec): compty> time-reterance: compty> delay: with no delay response: compty>	Select a time reference
		*

Demo : Temporal Assessments



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Execute assessments to verify requirements



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Locate implementation of requirement using link

File Edit Display Analysis Report Help File Edit Display Analysis Report Help View: Requirements · Search Type: Functional Index Summary Implemented Verified Index: 1.3 Custom ID: 4 Summary: Activate Heat Pump Controller Description Rationale Int. Idle when Temperature in Range Int. Intervalue Heat Pump Intervalue Heat Pump Int. Activate Heat Pump Intervalue Heat Pump Intervalue Heat Pump Intervalue Heat Pump Int. Activate Heat Pump Intervalue Heat Pump Intervalue Heat Pump Intervalue Heat Pump Int. Activate Heat Pump Intervalue Heat Pump Intervalue Heat Pump Intervalue Heat Pump Int. Activate Heat Pump Intervalue Heat Pump Intervalue Heat Pump Intervalue Heat Pump Int. Activate Heat Pump Intervalue Heat Pump Intervalue Heat Pump Intervalue Heat Pump Int. Activate Heat Pump Intervalue Heat Pump Intervalue Heat Pump Intervalue Heat Pump Intervalue Heat Pump Intervalue Heat Pump Intervalue Heat Pump Intervalue Heat Pump	ference is seconds and
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set 1.3 Activate Heat Pump greater than or equal to 2 degrees for more than 2	seconds and
■ 1.3.1 Cool Mode stay active for at least 2 seconds.	
ii 1.3.2 Heat Mode	
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after(2,sec) [mag_T(T_req,T_meas) >= 3]	- 1
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Activate_Pump S	
	,

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Observers: Separate test/verification logic from design



- Access nested signals without signal lines or changing dynamic response
- Avoid modifying interface for testing
- Simplify design and test by avoiding additional signal lines

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R2019a

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Demo : Observers





Summary

- Verify and validate requirements earlier
- Identify inconsistencies in requirements by using unambiguous assessments
- Traceability from requirements to design and test





Learn More

Key products covered in this presentation:

- Simulink Requirements
- Simulink Test
- Simulink Real-Time



Learn more at Verification, Validation and Test Solution Page: <u>mathworks.com/solutions/verification-validation.html</u>