A DYNAMIC PROGRAMMING ALGORITHM FOR SCHEDULING IN-VEHICLE MESSAGES

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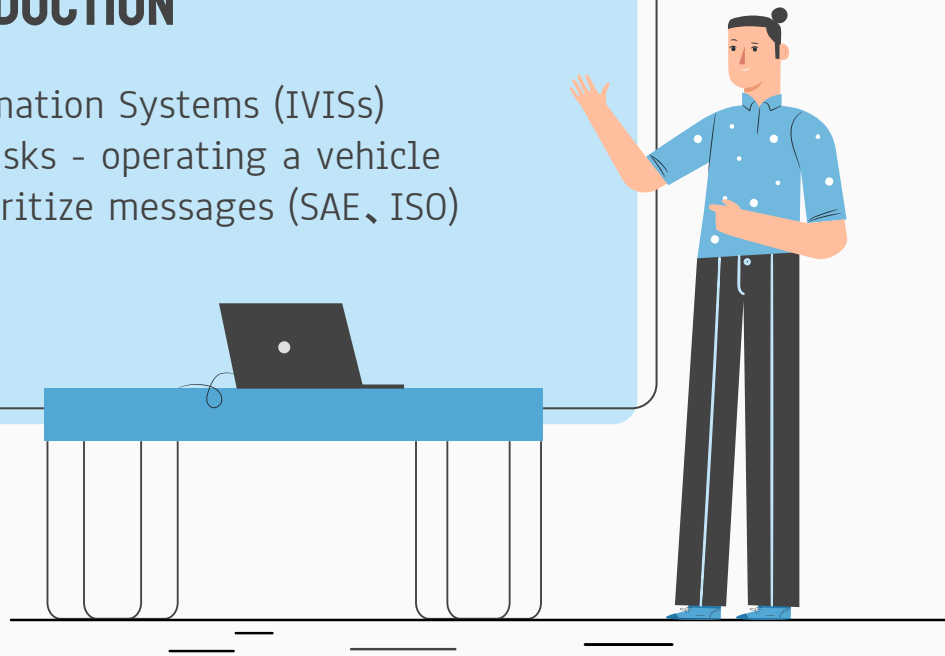


INTRODUCTION In-Vehicle Information Systems (IVISs)

NEW SENSOR CAPABILITIES

Radar sensors : blind spot monitoring
Cameras : displaying highly detailed and realistic images

GLOBAL POSITIONING SYSTEM

a satellite-based radionavigation system that provides geolocation and time information to a GPS receiver anywhere

INTERNET OF THINGS

connect and exchange data with other devices and systems over the Internet or other communications networks

WIRELESS COMMUNICATION

Wi-Fi、Bluetooth

INTRODUCTION Complex dynamic tasks - operating a vehicle

SUBTASKS

Operators frequently perform several subtasks. Drivers tended to shed nondriving secondary tasks as roadway demands increase

TASK MANAGEMENT

Drivers don't always effectively manage tasks. Task management is a critical contributor to performance in complex dynamic multitask situations.

MULTIPLE INFORMATION SYSTEMS

Interactions with multiple IVIS were significantly more detrimental to driving than interactions with single IVIS

INTRODUCTION Other method to prioritize messages (SAE、ISO)

Establish message priority:

1. Subjective rank ordering of message urgency by drivers

2. Priority assignment based on expert judgment

INTRODUCTION Other method to prioritize messages (SAE、ISO)

"Highest Priority First" algorithm Disadvantage:

1. Display obsolete message
2. Inability to display a message
3. Delay the display of a high-priority message
4. Failing to consider the value of future messages

INTRODUCTION Other method to prioritize messages (SAE、ISO)

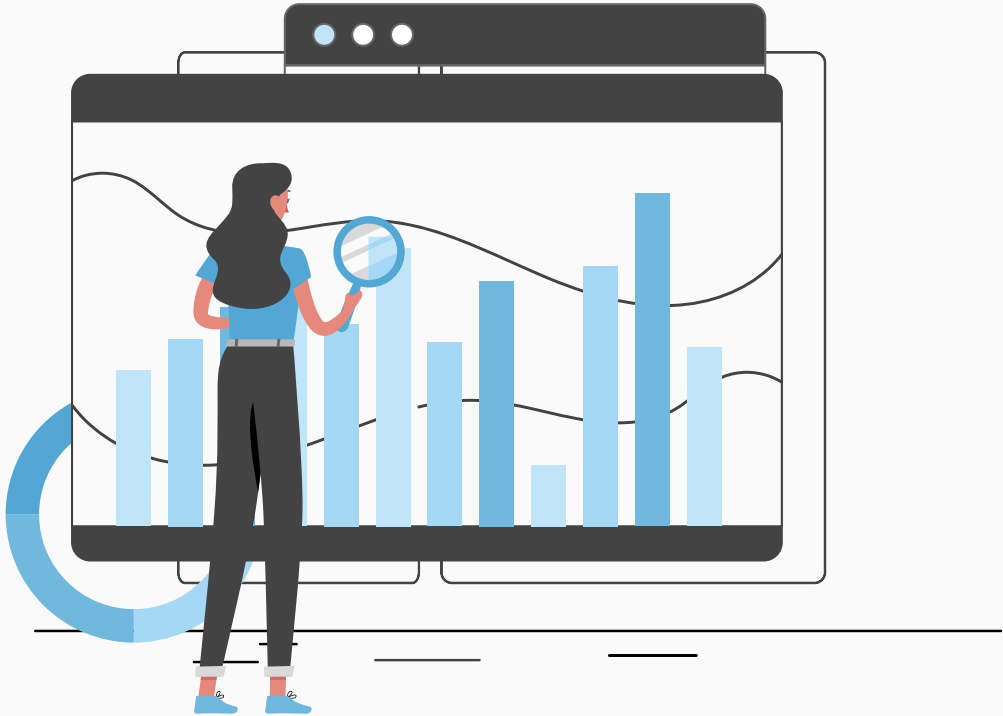
TABLE I
PRIORITIZATION CRITERIA IN SAE J2395

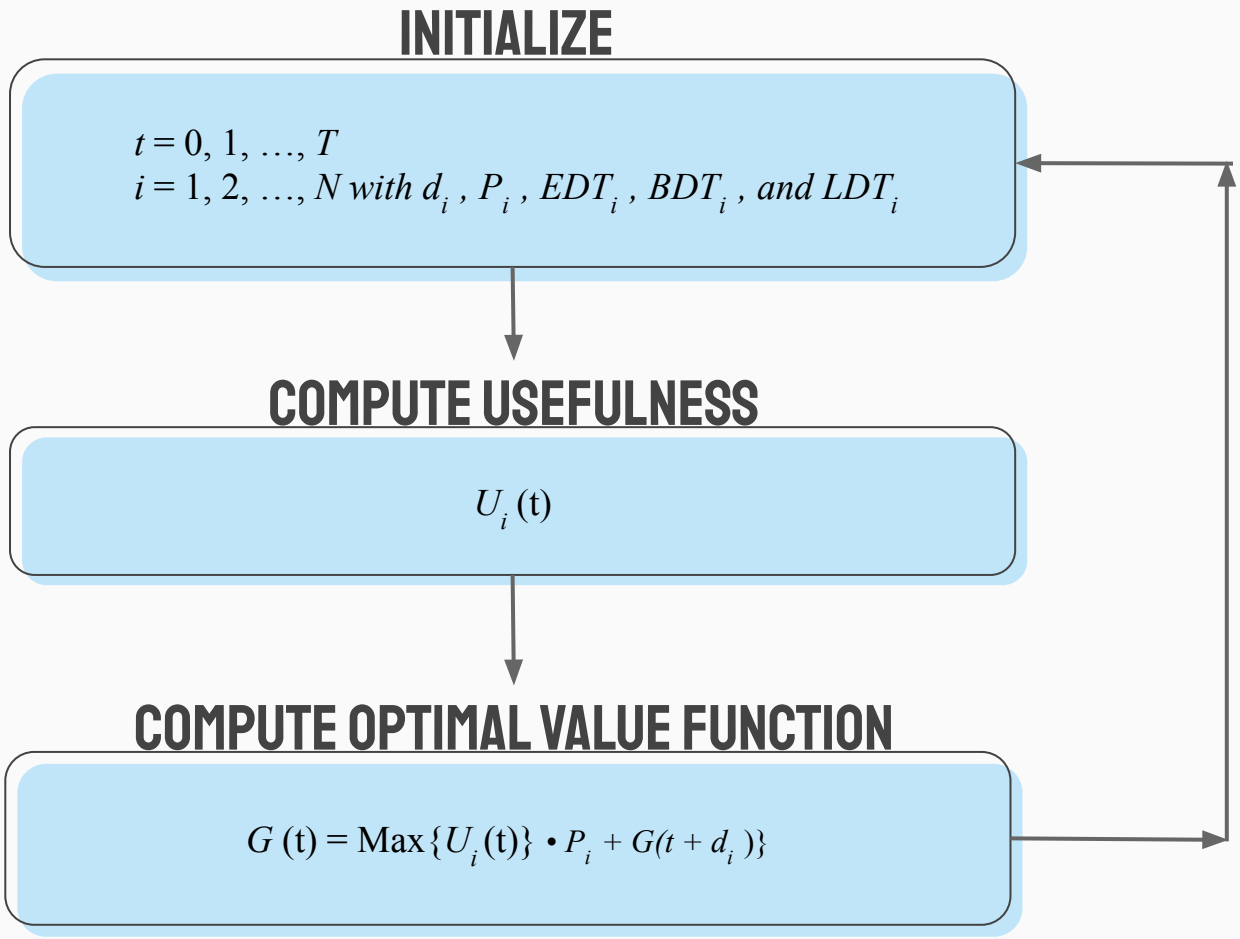
Criteria	Levels	Examples
Safety Relevance	Directly	A message relaying an imminent collision notification.
	Indirectly/Somewhat	A suggested navigation route that reduces travel time/distance.
	Not	An incoming call indicator on a cellular phone.
Operational Relevance	Highly	Notification of an engine temperature warning.
	Moderately	The distance to the destination on a navigation system.
	Little or No	The stereo indicator on an entertainment system.
Time Urgency	Emergency: 0-3 s	Brake immediately
	Immediate: 3-10 s	Road work area within 5 seconds.
	Near Term: 10-20 s	Obstacle within 15 seconds in the vehicle's path.
	Preparatory:20-120 s	Prepare to take action to the information within 60 seconds.
	Discretionary: > 120 s	No direct action or decision required by driver.

TABLE II
EXAMPLE APPLICATION OF POI FROM SAE J2395

Safety	Operation	Time	Example Message	Priority Order Index
Directly	Highly	Emergency 0-3 s	Collision imminent	1
Directly	Highly	Immediate 3-10 s	Object in roadway	2
Directly	Moderate	Emergency 0-3 s	Lane ends 500 feet	3
Directly	Moderate	Immediate 3-10 s	Hood ajar	4
Directly	Little/No	Emergency 0-3 s	Driver fatigue detected	5
Directly	Highly	Near Term 10-20 s	Tire pressure falling	6
Directly	Moderate	Near Term 10-20 s	Lane ends in 1 mile	7
Somewhat	Highly	Emergency 0-3 s	Vehicle in blind spot, avoid lane change	8
Directly	Little/No	Immediate 3-10 s	Passenger door ajar	9
Directly	Highly	Preparatory 20-120 s	Accident ahead	10
Somewhat	Highly	Immediate 3-10 s	Enter street address number	11
Directly	Little/No	Near Term 10-20 s	Approaching school zone	12
Directly	Moderate	Preparatory 20-120 s	Narrow bridge ahead, slow down	13
Somewhat	Moderate	Emergency 0-3 s	Incoming phone call	14
Somewhat	Moderate	Immediate 3-10 s	Call waiting	15
Directly	Highly	Discretionary > 120 s	ESC disabled	16
Somewhat	Highly	Near Term 10-20 s	Ambulance approaching	17
Directly	Moderate	Discretionary > 120 s	Road may be icy	18

02.
DP MODEL




INITIALIZE
$t = 0, 1, \ldots, T$
$i = 1, 2, \ldots, N$ with d_i , P_i , EDT_i , BDT_i , and LDT_i
COMPUTE USEFULNESS
$U_i(t)$
COMPUTE OPTIMAL VALUE FUNCTION
$G(t) = \text{Max}\{U_i(t)\} \cdot P_i + G(t + d_i)\}$

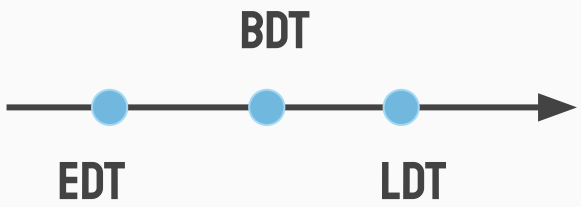
INITIALIZE

$t = 0, 1, \ldots, T$

$i = 1, 2, \ldots, N$ *with* d_i , P_i , EDT_i , BDT_i , *and* LDT_i

d_i Duration

p_i Priority



EDT_i Before which the message will not be useful

BDT_i Best display time

LDT_i After which the message will not be useful

INITIALIZE (CON.)

STRATEGIC RESPONSES

Time constants = 100s

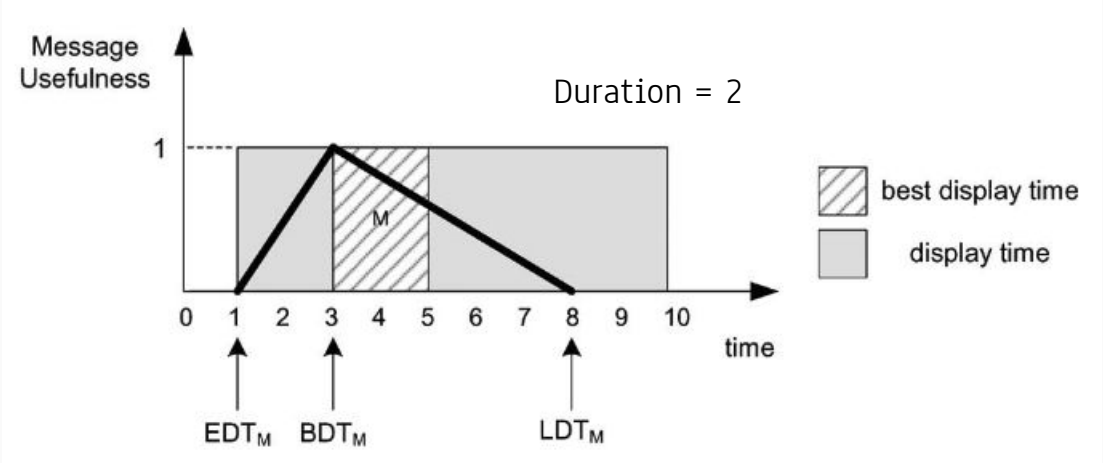
TACTICAL RESPONSES

Time constants = 10s

OPERATIONAL RESPONSES

Time constants = 1s

COMPUTE USEFULNESS



$$\frac{LDT_i - t}{LDT_i - BDT_i}$$

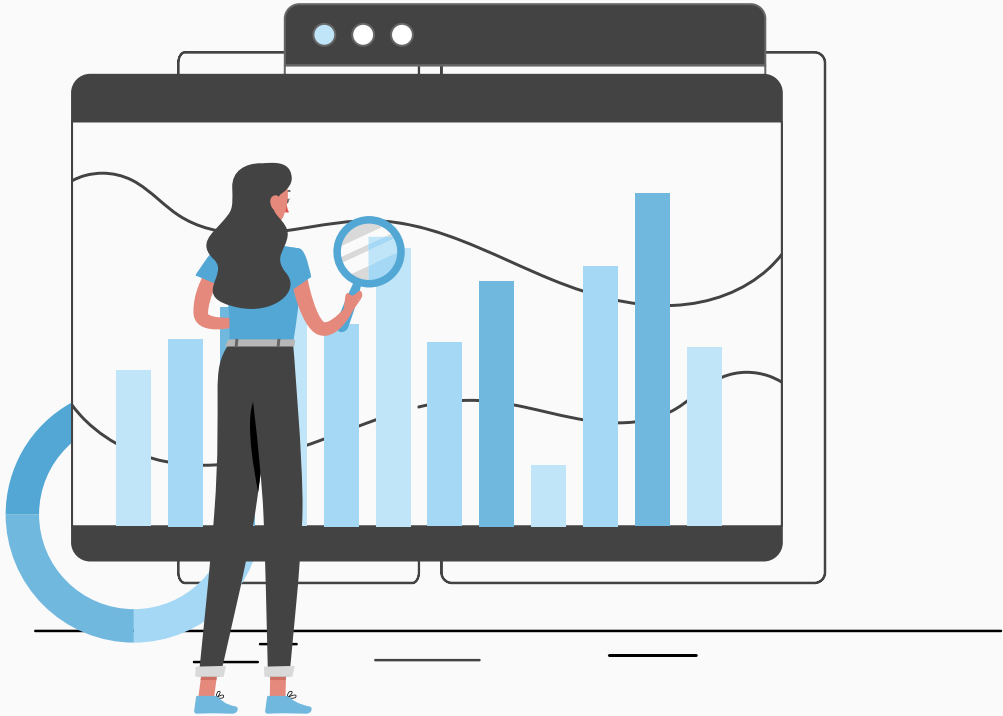
$$U_i(t) = \begin{cases} 0, & \text{if } t = \text{EDT}_i \\ \frac{t - \text{EDT}_i}{\text{BDT}_i - \text{EDT}_i}, & \text{if } \text{EDT}_i < t < \text{BDT}_i \\ 1, & \text{if } t = \text{BDT}_i \\ \frac{t - \text{BDT}_i}{\text{LDT}_i - \text{BDT}_i}, & \text{if } \text{BDT}_i < t < \text{LDT}_i \\ 0, & \text{if } t = \text{LDT}_i. \end{cases}$$

COMPUTE OPTIMAL VALUE FUNCTION

$$G(t) = \max_i \{U_i(t) \cdot P_i + G(t + d_i)\}$$

Maximum future total benefit from time $t+d_i$

03.
EXAMPLE



EXAMPLE

TABLE III
MESSAGE CHARACTERISTICS

Message ID	P	EDT	BDT	LDT	Duration
Message 1	45	5	12	13	3
Message 2	38	13	14	18	2
Message 3	37	2	7	9	3
Message 4	31	11	11	14	3
Message 5	30	5	16	18	2
Message 6	23	7	9	11	2
Message 7	22	7	8	11	3
Message 8	20	1	3	4	3
Message 9	19	1	9	13	3
Message 10	17	4	12	13	3
Message 11	16	0	5	12	3
Message 12	12	0	1	10	3
Message 13	9	0	5	9	2
Message 14	5	12	17	18	2
Message 15	4	0	2	7	2
Idle	0	0	0	20	1

	M1	M2	M3	M4	M5	…	M15	Idle
G(19)	0	0	0	0	0	…	0	0
G(18)	0	0	0	0	0	…	0	0
G(17)	0	9.5	0	0	15	…	0	0
…	…	…	…	…	…	…	…	…
G(1)								

$$G(t) = \max_i \{U_i(t) \cdot P_i + G(t + d_i)\}$$

$G_2(17) = [(18-17)/(18-14)]*38+G(17+2) = 9.5+G(19) = 9.5$

$G_5(17) = [(18-17)/(18-16)]*30+G(17+2) = 15+G(19) = 15$

EXAMPLE

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Message 3	37	2	7	9	3
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Message 6	23	7	9	11	2
Message 7	22	7	8	11	3
Message 8	20	1	3	4	3
Message 9	19	1	9	13	3
Message 10	17	4	12	13	3
Message 11	16	0	5	12	3
Message 12	12	0	1	10	3
Message 13	9	0	5	9	2
Message 14	5	12	17	18	2
Message 15	4	0	2	7	2
Idle	0	0	0	20	1

DP

TABLE V
OPTIMAL ORDERING OF THE MESSAGES

time	G (t)	Message ID	Next renewal point
1	181.171	***Message 15***	***3***
2	179.171	Idle	3
3	179.171	***Message 8***	***6***
4	166.371	Message 13	6
5	159.171	Idle	6
6	159.171	***Message 3***	***9***
7	143.571	Message 3	10
8	129.571	Idle	9
9	129.571	***Message 6***	***11***
10	106.571	Idle	11
11	106.571	***Message 1***	***14***
12	88.5	Message 1	15
13	68	Idle	14
14	68	***Message 2***	***16***
15	43.5	Message 2	17
16	30	***Message 5***	***18***
17	15	Message 5	19
18	0	Idle	19
19	0	Idle	20
20	0	Idle	21

THANK YOU