How to select your RTOS?

Bits&Chips Micro-event: Embedded Operating Systems

Jan 29th 2004 Ger Schoeber



Overview

- Resumé of the speaker
- Operating System
- Real-Time
- A use case
- The selection method explained
 - Application areas & characteristics
 - RTOS characteristics
 - "musts & wants", weighing factors (Kepner Tregoe)
 - Devils advocate
- Is there a new future for the method?



Ger Schoeber

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Devils advocate
Is there a new future for the method?

1984 Philips I&E

 1989 High Tech Automation (since 2000: Ordina TA)

• 2001

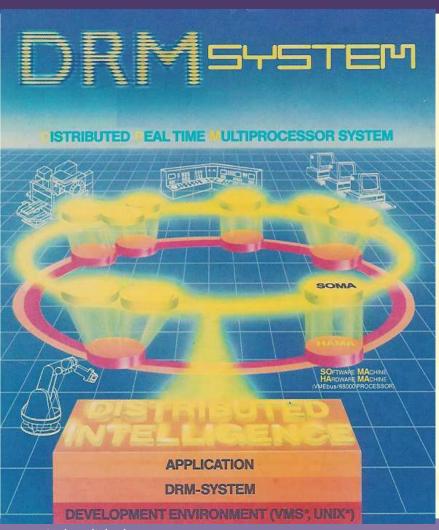




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1984 – 1989: Philips I&E



Distributed
Real-time
Mulitprocessor
Operating System

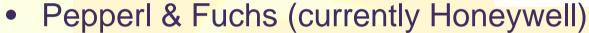
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1989 – 2001: High Tech Automa









- Alcatel
- Vanderlande Industries
- **High Tech Automation**
- Philips Semiconductors











Philips Medical Systems **Philips Semiconductors** Siemens VDO Car Systems **FEI Electron Optics** Océ Technologies Stork PMT Heidelberg Contiweb Philips ED&T Philips CE CDS Philips IA (Jabil)



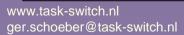
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2001 - today: Task Switch

Guest lectures Hogeschool van Utrecht Philips DN Softworks Mgt support / Prj control Philips Centre for Technical Training Lecturer System Architecting Ordina Technical Automation Coaching Architect Philips Digital Systems Lab Project Evaluation Workshops Project Evaluation / Improvement Workshop ALVA Nederland BV Philips Semiconductors BL-Storage Mgt supp / SA supp / Prj control Dräger Medical Coaching Architect PT Embedded, Computable, LAC, Bits&Chips Articles, Presentations

Management Presentation



Philips Semiconductors ICE

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Task Switch

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Services:

- Personal Coaching (Architects, Managers, Engineers)
- Evaluation and Improvement Workshops
- System / Software Architect -interim
- Project Management -interim



Market:

Technical Automation, Embedded Systems



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Is there a new future for the method?

Why using an OS?

- Offering services to the application(s)

Hardware abstraction

- File and device I/O
- Communication and network I/O
- Hardware control, graphics

Services

- Scheduling
- Communication
- Synchronisation



What makes an OS Real-Time?

Application areas & characteristics
RTOS characteristics
ants", weighing factors (Kepner Tregoe)

- Deterministic
- Guaranteed worst case interrupt latency
- Guaranteed worst case context switch time
- Hard / firm / soft real-time:
 catastrophic / quality reduction / acceptable



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Deterministic

The worst-case **execution time** of each of the system calls is **calculable**.

Needs:

Mininum, average, maximum number of clock
 cycles required by each system call.

Numbers might differ per processor type.

Worst case performance of the application software can be analysed using Rate Monotonic Analysis (RMA).



Rate Monotonic Scheduling...

- Assign the priority of each task according to its period: the **shorter** the period the **higher** the priority.
- Works for fixed-priority pre-emptive RTOS.
- The worst-case schedulable bound is about **69.3** % (= $\ln 2$). ($Wn = n * (2^{(1/n)} - 1)$)
- Maximum utilisation is reached when all tasks are harmonic.



Is there a new future for the method?

Interrupt latency

From interrupt arriving at the processor until the start of the associoated interrupt service routine (ISR).

- Processor must finish executing the current instruction.
- The interrupt type must be recognised (hardware).
- The CPU's context must be saved.
- The ISR associated with the interrupt is started.
- If interrupts are disabled (e.g. during a system call), the worst-case interrupt latency increases by the maximum amount of time that they are turned off.



Context switch

The selection method explained
Application areas & characteristics
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Is there a new future for the method?

From **suspending** one process from execution by the CPU until another process is **started**.

- The context of the process must be saved.
- The process administration within the kernel is updated (scheduling).
- Possibly control MMU (hardware).
- The context of the next process must be loaded.



A use case

The selection method explained
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Is there a new future for the method?

A use case 1/2

Context:

- Consumer product
- Multi-processor architecture
- High volume
- Low BOM
- Short market introduction window
- Contains pSOS+

Issue:

pSOS+ end of life

Other OS's in the market?

- Which?
- Characteristics:
 - Leaflets / sales
 - Benchmarking
 - -Technical
 - Usage/introduction
 - Costs (development seat, run-time licenses)
- Fit for purpose:
 - Now (short term)
 - Future (long term)



Fac.

- pSOS+: ISI->
- WindRiver supports
- → Boldly go for VxWo

Analysis: △ pSOS+ / VxWorks?

- SDE
- HW support
- Licences
- API syntax/semantics
- Footprint
- Performance



Resumé of the speaker Operating System Real-Time

A use case

The selection method esplained

Application areas & characteristics

RTOS characteristics

"musts & wants", weighing factors (Kepner Tregoe)

Devils advocate

Is there a new future for the method?

A use case 2/2

Technology versus Requirements driven:

Adapt product to known technical solution

Starting point

Find technical solution that best fits your product



Resumé of the speaker Operating System Real-Time A use case

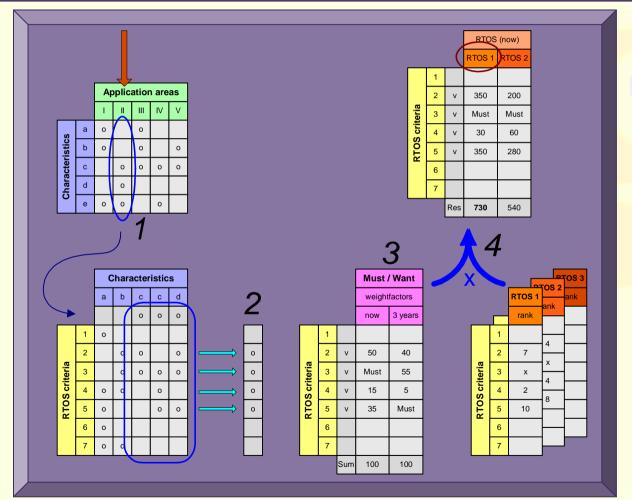
The selection method explained

Application areas & characteristics RTOS characteristics

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Is there a new future for the method?





A method that starts from the application point of view



History, evolution and future (?) of the selection method

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High Tech Automation (Ordina TA):

1993-1994

- Organisations struggle finding the right RTOS
- Started a study comparing characteristics of available RTOS
- Results presented to large group of organisation representatives

Philips CFT + High Tech Automation:

1995-1997

- Initiative to develop a selection method based on Kepner Tregoe
- Additional effort in benchmarking RTOSes
- 2 Reports available on the method & evaluated RTOSes

Task Switch:

2004

- Ideas to update method data + benchmarking courant RTOSes
- Ordina TA showed interest
- Others? → ger.schoeber@task-switch.nl



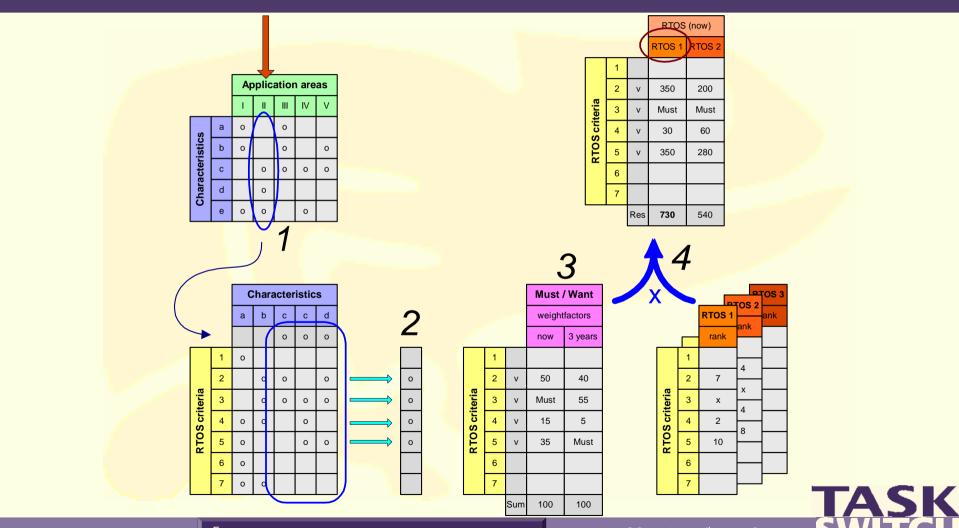
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The selection method explained

Application areas & characteristics RTOS characteristics "musts & wants", weighing factors (Kepner Tregoe) Devils advocate

Is there a new future for the method?

The complete method



Application areas

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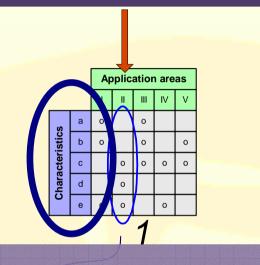
"musts & wants", weighing factors (Kepner Tregoe)
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Resumé of the speaker **Operating System** The selection method explained

Application characteristics

Is there a new future for the method?



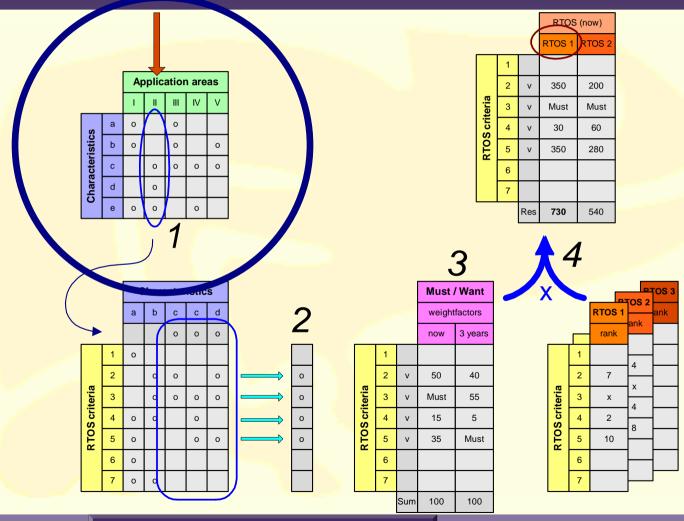
Monitoring Device interfacing Data acquisition Signal processing Level of robustness

Quantity Development costs Product price Upgradability Life span Level of optimisation Successive generations Level of standardisation Hard real-time constraints Data communication Control **Database**



Application areas X Application characteristics

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Application areas Consumer X Products Application characteristics

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		ð	+++	very important	$\uparrow \uparrow$	strong positive trend
		GE		very unimportant	$\downarrow\downarrow$	strong negative trend
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					Dome	estic				
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Development costs	+++	↑	++	\rightarrow	++	$\uparrow \uparrow$	++	\uparrow	+++	1
Product price	+	$\uparrow \uparrow$	++	↑	+	~	+	~	0	~
Upgradability		~	-	↑		~		↑	+	\uparrow
Life span		\downarrow		\downarrow	-	\downarrow		~	-	\downarrow
Level of optimisation	+++	\downarrow		\downarrow	+++	\downarrow	++	\downarrow	0	~
Succesive generations	+	\uparrow	++	\uparrow	0	~	0	↑	+	$\uparrow \uparrow$
Level of standardisation	++	\uparrow		\	1	↑	+	\uparrow	+	$\uparrow \uparrow$
User interfacing	+	1	++	↑	+	↑	0	\uparrow	+	$\uparrow \uparrow$
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Hard real-time constraints	-	~	-	۲	-	~	++	$\uparrow \uparrow$	+	\uparrow
Data communication	+	~	0	1	0	~)	1	+	$\uparrow \uparrow$
Control	-	~	-	1	0	↑	+	↑	-	~
Monitoring	-	~	-	1	+	~	+	↑	-	~
Device interfacing	-	~	-	1	-	~	+	↑	+	\uparrow
Data acquisition, signal processing	+	1	+	~	-	↑	+	↑	+	↑
Level of robustness	-	~	-	~		~	++	~	-	~
Database	-	~	-	~		~	+	~	+	↑



Application areas Professional Products Application characteristics

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Application areas & characteristics

RTOS characteristics

↑↑ strong positive trend

"musts & wants", weighing factors (Kepner Tregoe)
Devils advocate

+++ very important

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Upgradability	++	~	0	~	++	<u> </u>	+	<u> </u>	+	<u> </u>	+++	~	0	<u> </u>	++	<u> </u>	+	~	0	↑
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Level of optimisation	-	~		~		~	-	~		~		~	0	~		~	-	~	+	~
Succesive generations		↑		~	+	~		~	+	↑		~		1		↑		~	-	~
Level of standardisation		↑		~	+	1	++	↑	-	$\uparrow \uparrow$		~	+	1	++	↑	-	1	-	\uparrow
User interfacing		1	•	1	+	1	+	↑	0	1	0	\uparrow	-	1	-	↑	++	1		~
Real-time response time (µs)	1000	\uparrow	1	1	10	1	100	↑	500	1	100	\uparrow	100	1	10	↑	10	1	1	\uparrow
Level of concurrency	-	~		1	+	1	+	1	+	1	-	1	+	↑	+	1	+	1	+	\uparrow
Hard real-time constraints	-	~	++	1	+	~	+	~	+	1	0	1	+	~	+	~	+	~	++	\uparrow
Data communication	+	\uparrow	-	1	++	1	+	\uparrow	+	1	0	١	+	~	++	~	0	~	++	1
Control	-	↑	++	1	++	\uparrow	++	\uparrow	++	\uparrow	-	~	-	~	-	~	+	\uparrow	-	~
Monitoring	+	↑	+	↑	+	~	+	\uparrow	+	\uparrow	+	\uparrow	+	~	+	~	+	\uparrow	+	\uparrow
Device interfacing	+	1	+	1	+	\uparrow	+	1	+	\uparrow	+	1	+	↑	-	~	+	1	+	↑
Data acquisition, signal processing	0	~	+	↑	-	\uparrow	+	1	+	$\uparrow \uparrow$	+	↑	+	↑	+	\uparrow	+	~	+++	~
Level of robustness	+	~	++	~	+	~	+	~	++	~	-	۲	+	~	+	~	+	~	+	~
Database	+	~	+	~	+	1	+	~	+	\uparrow	+	\uparrow	0	~	+	\uparrow	0	~	0	~

Context:

- Consumer product
- Multi-processor architecture
- High volume

Product price

- Low BOM
- Short market introduction window

reas Consumer Products

haracteristics

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The selection method explained

RTOS characteristics

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Is there a new future for the method?

Contains pSOS+ / End-of-life									Ŋ	+++	very impo	rtant	<u> </u>	strong positive trend
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Quantity	++	\uparrow	++	\downarrow	++	1	++	1		-	$\uparrow \uparrow$			
Development costs	+++	\uparrow	++	\downarrow	++	$\uparrow \uparrow$	++	1	+	++	\uparrow			

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Level of optimisation	+++	\downarrow	+++	\downarrow	+++	\downarrow	++	\downarrow	0	~
Succesive generations	+	\uparrow	++	\uparrow	0	~	0	\uparrow	+	$\uparrow \uparrow$

Succesive generations	+	++	0 ~	0	+
Level of standardisation	++ 1	++ 1	- 1	+ 1	+ 11
User interfacing	+	++ 1	+	0 1	+ ↑↑
Real-time response time (µs)	1000 ↑	2000 ↑	000 1	10 1	100
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Hard real-time constraints				++ 11	+ 1

Data communication	+ -	0 1	0 ~	0 1	+ 1
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Monitoring			+ ~	+ 1	- ~

Device interfacing	- ~	-	~	Mes		+	1	+	
Data acquisition, signal processing	+ 1	+	~	-	1	+	↑	+	↑
Level of robustness	1	_		rans.	~	4-4-	_		~

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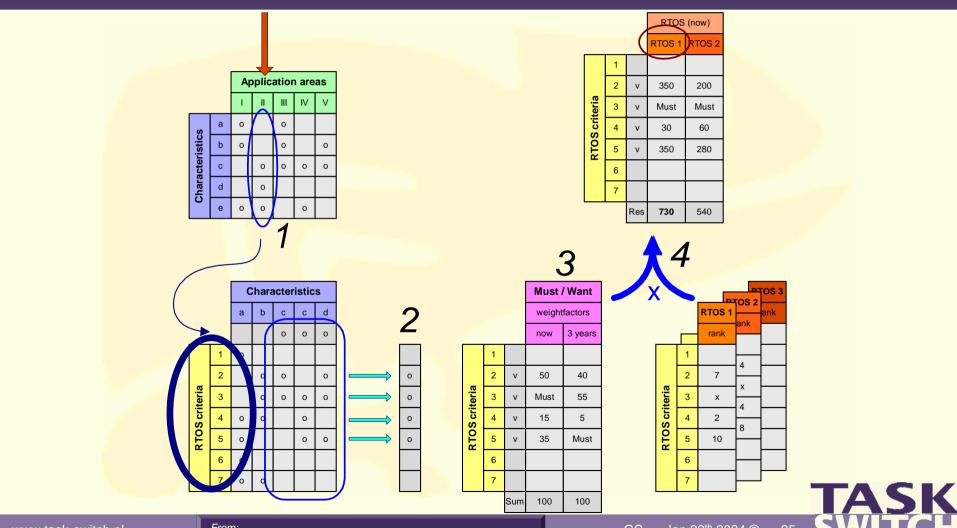
Real Time Operating Systems – An evaluation method and results" Philips CFT and High Tech Automation

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RTOS characteristics



Real-Time Operating Systems

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OSE - THE NEW GENERATION RTOS































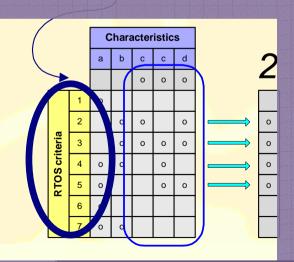


RTOS characteristics

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SENERAL

Supplier
Price / performance ratio
Development environment
Platform dependencies
Adherence to standards
Installed base
Quality of documentation
Product stability
Available expertise



Tunability Scalability Security Multi-processor support Memory management File device I/O management Interprocess communication Synchronisation mechanismes Process / thread support Resource scheduling Interrupt handling Fine-grained performance Application-oriented performance Re-entrancy Application Programming Interface (API) Time management Error / exception handling **ROM-ability** Data communication support Peripheral driver support User interface support Database support Compiler quality / efficiency

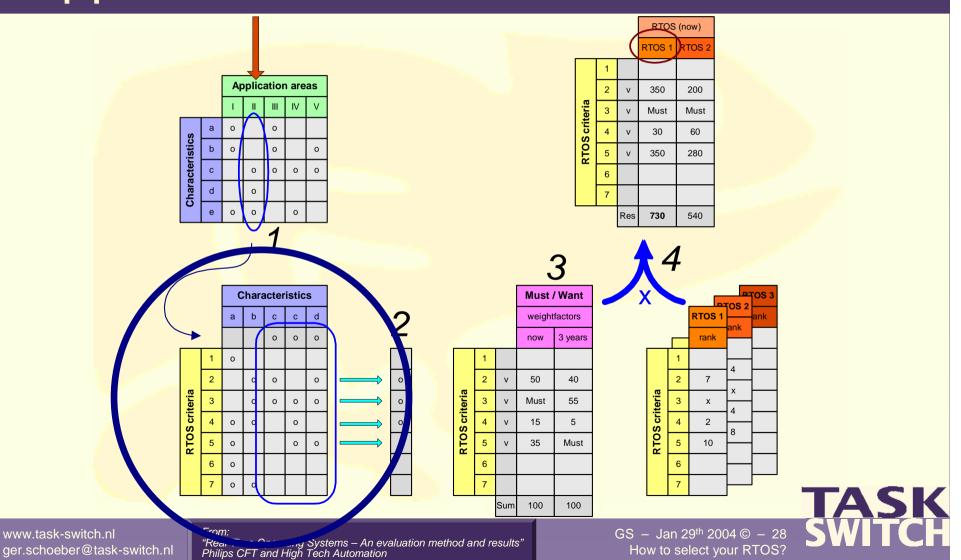
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From:
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Philips CFT and High Tech Automation

RTOS characteristics X Application characteristics



								Appli	icatio	n Cha	racte	ristics							er
Context:								_								ing	n, ng		m ne
Consumer product			ф			_		tior									Data acquisition, signal processing		se ed
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Quality of documentation	0	+	0	+	+	+	+	+	+	0	0	0	+	-0	0		+	0	
Product stability	+	+	0	+	+	+	+	0	0	0	0	0	o ju	-j-	-}-	+	+	-1-	0
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Technical criteria																			
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Scalability	+	-	+	es ĝia	+	+	+	0	+	0	0	0	oj.	0	0	0	0	÷	0
Security	0	0	0	0		0	0	0									0		
Multi-processor support	-	0	0	ndos.	+	+	+		0	÷	+		0	0	0	0	+		
Memory management	+	0	+	0	0	+	0	0	0	0	+	0	0	0	0	О	0	so gran	wije.
File device I/O management	0	+	0	nga manus punasmon		+	+		0		0	ndje:	0	0	0		0	0	
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Re-entrancy	0	0	0		0	+	+	0	0	-	+	0	+	0	0	0	0	+	0
Application Programming Interface (API)	0	+	0	+		0	0										0		
Time management	0	0	0	0	0	0	0	0	+	Description (Application)									
Error / exception handling	0	+	0	0	0	0	0	0	+	0	+		+	+	0		+		0
ROM-ability	+	0	0		0	0	0	0	0	0	0	0		0	0	0	0	0	-
Data communication support	0	+	0	postacime contaciment	LONGOLINIO LONGOLINIO LONGOLI	0	+	O CONTRACTOR OF THE PERSON OF		Machine Machine III		0	CONTROL DECEMBER DECEMBER	Ten touristation	annumna vancusana vanc	O series accessors accessor	0		0
Peripheral driver support	0	+	0	4-	0	0	+	- cefe-		0	0	0	0	0	+	4-	+	0	
User interface support	0		0	0		0	0	0									0		
Database support	0	-	0			0	0				0						0		
Compiler quality / efficiency ger.schoeber@task-switch.nl Philips CFT	0	+	0		0	+	0	0	0	140	Ho	w to se	o alect v	OUR R	0	0	+	+	0

Kepner Tregoe

- Define the "musts"
- Distribute 100 % over remaining "wants"
- Both:
 - Now
 - E.g.: 3 years time



Musts & Wants

	No	w	3 ye	ears
RTOS criteria	Musts	%	Musts	% 2
Supplier		1		
Price / performance ratio		2		13
Development environment	M			3
Platform dependencies	M		M	
Quality of documentation		12		1
Product stability	M		M	
Available expertise		10		17
Tunability		20		12
Scalability	M		M	
Multi-processor support	M			7
Memory management		17		9
File device I/O management		4		11
Interprocess communication	M		M	
Process / thread support		6		4
Resource scheduling		5		5
Interrupt handling	M		M	
Fine-grained performance		15		6
Re-entrancy	M		M	
Error / exception handling		5		10
ROM-ability	M		M	
Peripheral driver support		3	M	
Compiler quality / efficiency	M		M	
	Sum:	100	Sum:	100



Score results

	Weig	hing F		pSOS+		١	/xWork	S
RTOS criteria	Now	3 Yrs	BM	Sc N	Sc 3Y	BM	Sc N	Sc 3Y
Supplier	1	2	7	7	14	7	7	14
Price / performance ratio	2	13	4	8	52	4	8	52
Development environment	M	3	9		27	9		27
Platform dependencies	M	M	10			10		
Quality of documentation	12	1	3	36	3	6	72	6
Product stability	M	M	10			10		
Available expertise	10	17	10	100	170	2	20	34
Tunability	20	12	8	160	96	6	120	72
Scalability	M	M	9			9		
Multi-processor support	M	7	9		63	5		35
Memory management	17	9	8	136	72	9	153	81
File device I/O management	4	11	8	32	88	8	32	88
Interprocess communication	M	M	10			10		
Process / thread support	6	4	6	36	24	10	60	40
Resource scheduling	5	5	9	45	45	8	40	40
Interrupt handling	M	M	10			7		
Fine-grained performance	15	6	8	120	48	8	120	48
Re-entrancy	M	M	10			10		
Error / exception handling	5	10	7	35	70	9	45	90
ROM-ability	M	M	10			10		
Peripheral driver support	3	M	5	15		7	21	
Compiler quality / efficiency	M	M	10			7		
			Sum:	730	772	Sum:	698	627

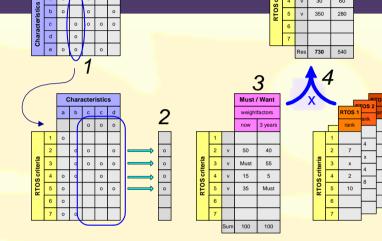


Devils advocate

	Weigl	hing F		pSOS+		V	Works	;	
RTOS criteria	Now	3 Yrs	BM	Sc N	Sc 3Y	ВМ	Sc N	Sc 3Y	
Supplier	1	2	7	7	14	7	7	14	
Price / performance ratio	2	13	4	8	52	4	8	52	
Development environment	M	વ	a		27	g		27	
atement						Proba	abilit	ty	Seriousness
the long term pSOS+ w	vill disap	pear				Ι	lIGH		MEDIUM
•		evelc	pmei	nt tea	am	ME	DIUN	Л	LOW
•		evelc M	ppmei	nt tea	am	ME	DIUN	Л	LOW
increase development d	costs		•	nt tea	am 24		DIUN 60	40	
increase development of Interprocess communication	Costs	M	10			10			
Process / thread support	costs M 6	M 4	10	36	24	10	60	40	
Interprocess communication Process / thread support Resource scheduling	COSTS M 6 5	M 4 5	10 6 9	36	24	10 10 8	60	40	
Interprocess communication Process / thread support Resource scheduling Interrupt handling	COSTS M 6 5 M	M 4 5 M	10 6 9	36 45	24 45	10 10 8 7	60 40	40	
Interprocess communication Process / thread support Resource scheduling Interrupt handling Fine-grained performance	COSTS M 6 5 M 15	M 4 5 M 6	10 6 9 10 8	36 45	24 45	10 10 8 7 8	60 40	40	
Interprocess communication Process / thread support Resource scheduling Interrupt handling Fine-grained performance Re-entrancy	COSTS M 6 5 M 15 M	M 4 5 M 6 M	10 6 9 10 8	36 45 120	24 45 48	10 10 8 7 8 10	60 40 120	40 40 48	
Interprocess communication Process / thread support Resource scheduling Interrupt handling Fine-grained performance Re-entrancy Error / exception handling	COSTS M 6 5 M 15 M 5	M 4 5 M 6 M 10	10 6 9 10 8 10	36 45 120	24 45 48	10 10 8 7 8 10	60 40 120	40 40 48	
Interprocess communication Process / thread support Resource scheduling Interrupt handling Fine-grained performance Re-entrancy Error / exception handling ROM-ability	COSTS M 6 5 M 15 M 5 M M 15 M M M 15 M M M M M M M M M	M 4 5 M 6 M 10 M	10 6 9 10 8 10 7	36 45 120 35	24 45 48	10 10 8 7 8 10 9	60 40 120 45	40 40 48	

Is there a new future for the method?

Resumé of the speaker
Operating System
Real-Time
A use case
The selection method explained
Application areas & characteristics
RTOS characteristics
"musts & wants", weighing factors (Kepner Tregoe)
Devils advocate
Is there a new future for the method?





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