Performance Improvement of Collaborative Engineering Systems by the application of Qualitative Reasoning

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Outline

- Definition of Collaborative Engineering Systems
- Stages in system development
  - Modeling
  - Performance Evaluation
  - Performance Improvement
- Conclusion
- Future Work

What are Collaborative Engineering Systems?

(CES) have two characteristics :

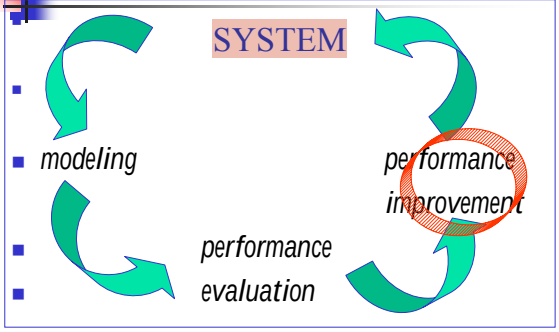
- 1. People (collaborators) come together and constitute a system
- 2. Aim of the system is to offer service to end-users.

Examples of CES

Examples	Collaborators	End-users	Service offered
Bank	Manager Teller Accountant	Customers	financial
Hospital	Doctor Nurse Medical assistant Pharmacist	Patients	medical
University	Principal Staff Clerks	Students	educational

Our Ultimate Goal

System Development Cycle



STAGE1 : *modeling*

Multi-Context-Map (MCM) technique

MCM is a descriptive model that captures workflow in the system in great detail

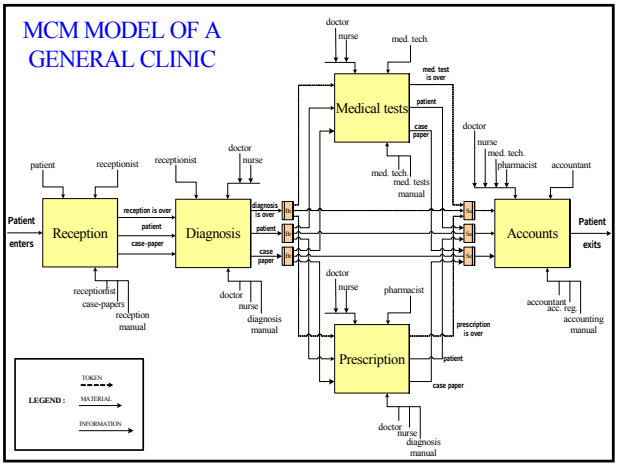
Three distinct flows in MCM

Token (T)

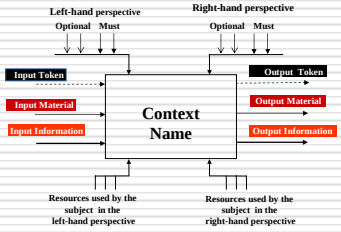
Material (M)

Information (I)

MCM MODEL OF A GENERAL CLINIC



CONTEXT : Basic unit in Collaborative Model



STAGE2 : *performance evaluation*

Simulate the MCM operation

General Purpose System Simulator (GPSS)

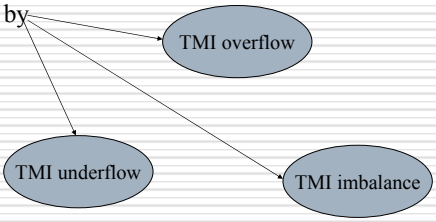
Based on "Waiting-Line Analysis" Theory

GPSS simulation data

Context-Name	λ	μ	ρ	qi	qj	qk	(TMI)q
C1	12.3	13.11	0.938215	0.68	0.243	0.763	4.32
C2	11.2	15.1	0.741722	0.654	0.391	0.123	3.28
C3	13.12	19.01	0.690163	0.84	0.492	0.958	0.659
C4	4.23	8.12	0.520936	0.165	2.546	1.723	0.761
C5	12.4	15.17	0.817403	0.653	6.093	0.789	0.186
C6	5.87	15.69	0.374124	0.98	0.345	0.893	0.341
C7	11	10	0.999999	0.506	1.234	0.123	0.876
C8	12.56	15.13	0.830139	0.675	8.745	0.456	0.176
C9	6.23	8.88	0.701577	3.465	0.4645	0.651	0.965
C10	8.56	10	0.856	0.7643	0.342	5.345	0.782
C11	9.54	10	0.954	0.564	0.6785	0.765	0.999
C12	14.19	15.45	0.918447	0.982	0.987	0.123	0.564
C13	15.37	20.98	0.732602	0.195	3.234	3.245	0.456
C14	3.89	5.55	0.700901	0.835	0.563	0.654	0.345
C15	12.12	15.01	0.807462	1.234	0.987	0.654	1.256
C16	17.32	15.01	0.999999	12.783	1.022	0.723	6.389
C17	12.56	15.12	0.830688	0.763	0.542	0.534	0.568
C18	14.13	15.13	0.933906	0.567	0.238	2.178	0.257
C19	9.1	10.13	0.898322	0.632	0.876	1.234	9.3456

Definition of bottlenecks

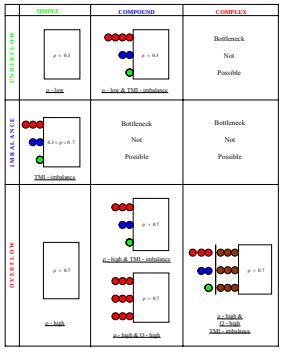
- Any situation which hinders the normal operation of the context.
- Caused by



Bottlenecks in system operation

- Measured by the following parameters :
  - 1. context utilization is low ($\rho < 0.3$)
  - 2. context utilization is high ($\rho > 0.7$)
  - 3. TMI imbalance (at least one of q_i, q_j, $q_k > 1.0$)
  - 4. (TMI)q is long ($q > 1.0$)

Classification of bottlenecks



STAGE3 : *performance improvement*

Improvement by using AI discipline of Qualitative Reasoning

"Imitating the knowledge and heuristics of the human expert in the domain "

Quantitative v/s Qualitative approach

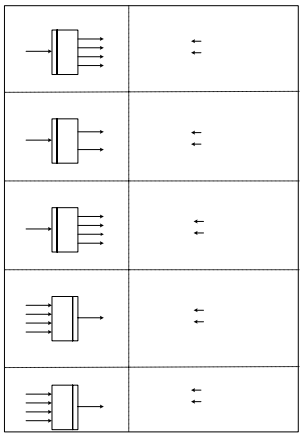
Quantitative	Qualitative (Common sense)
Mathematical equation	Qualitative Relation
Analytic solution	Expert's knowledge
Numerical solution	Expert's experience & heuristics

EXPERT SYSTEM

CLASS 1 RULES — Rules for contexts in isolation

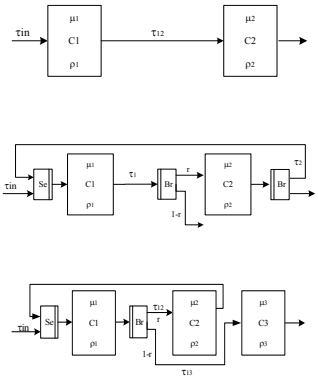
Rule	symptom				state of	solution				
	q_i	q_j	q_k	ρ	$\lambda i, \lambda j, \lambda k$	λi	λj	λk	Combination	μ
1	1	1	1	H	overflow	↓	↓	↓	AND/OR	↑
2	0	1	1	H	overflow/imbalance	↓	↓	↓	AND/OR	↑
3	0	1	1	M	imbalance	○	↓	↓	-	○
4	0	1	1	L	underflow/imbalance	↑	○	○	AND/OR	↓
5	0	0	1	H	overflow/imbalance	↓	↓	↓	AND/OR	↑
6	0	0	1	M	imbalance	○	○	↓	-	○
7	0	0	1	L	underflow/imbalance	↑	↑	○	AND/OR	↓
8	0	0	0	H	overflow	↓	↓	↓	AND/OR	↑
9	0	0	0	M	optimum flow	○	○	○	-	○
10	0	0	0	L	underflow	↑	↑	↑	AND/OR	↓

CLASS 2 RULES — Qualitative Rules For Junctions



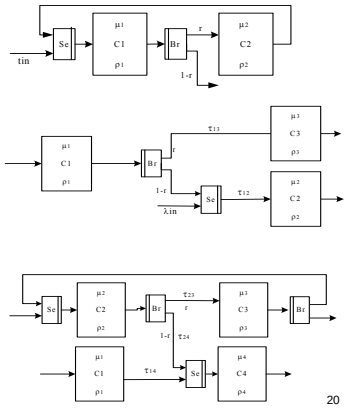
CLASS 3 RULES

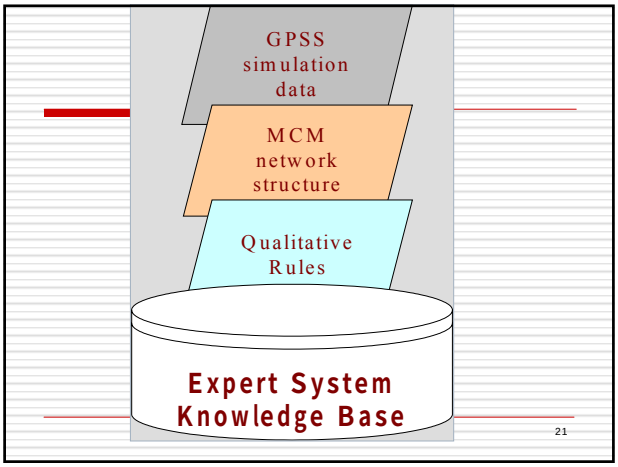
Qualitative Rules for contexts with their sub-structures (1)



CLASS 3 RULES

Qualitative Rules for contexts with their sub-structures (2)

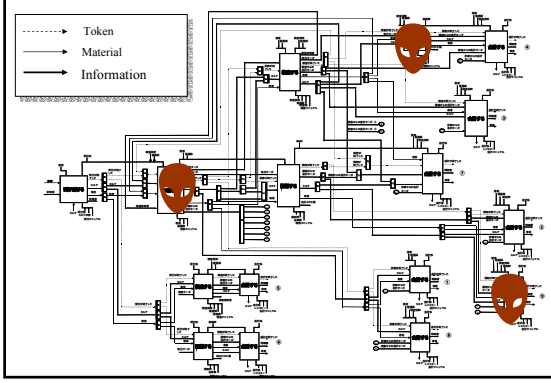




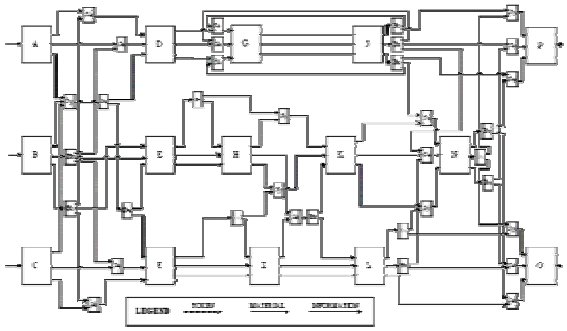
Guiding Principles

- Feasibility Condition
  - Expert System looks for the feasible conditions in the upstream to affect a change in the required parameter
- Advisability Condition
  - Expert System foresees the effect of the changes made in the upstream, on the downstream.

MCM of a general clinic



Collaborative Engineering performance improvement benchmark



Results

Bottleneck chosen by user for resolving : Context N
Performance evaluation of context N
ρ = 0.719; (TMI)q = 1.576;
Tq = 0.000, Mq = 13.266, Iq = 1.814

ES to user : Here is the improvement plan.
"Decrease the M flow to contexts D & E.
Increase the M & I flow to contexts F.
Decrease the I flow from context J to N
Decrease the M flow from context L to N "

Improved performance : Characteristics of context N after improvement
ρ = 0.589 (0.3 < ρ < 0.7) ; (TMI)q = 0.313 (< 1.0)
Tq = 0.000; Mq = 0.714; Iq = 0.671 (Tq,Mq,Iq < 1.0)
Characteristics of context J after improvement
ρ = 0.594 (0.3 < ρ < 0.7)

Conclusion

- We defined Collaborative system
- We traced the fundamental stages in system development
- Modeling

Performance Evaluation

Performance Improvement

We used Qualitative Reasoning in the art of performance improvement

Future Work

- **Insufficiency of the present improvement technique**

Expert system does not instruct the user how much to increase or decrease the given parameter

This can be compensated by the application of the principles of fuzzy logic