CAESAR II: A SYSTEM FOR THE DESIGN AND EVALUATION OF COMMAND AND CONTROL ORGANIZATIONS

Alexander H. Levis**
C3I Center, MS 4B5
George Mason University
Fairfax, VA 22030
USA
Tel: (703) 993 1619
Fax: (703) 993 1706
alevis@gmu.edu

Didier M. Perdu
C3I Center, MS 4B5
George Mason University
Fairfax, VA 22030
USA
Tel: (703) 993 1730
Fax: (703) 993 1706
dperdu@gmu.edu

EXTENDED ABSTRACT

CAESAR II (Computer Aided Evaluation of System ARchitectures) is a suite of software tools that puts together the results of more than 10 years of research in the design, modeling and evaluation of decision making organizations. Implemented in C, ML, and C++ on a Macintosh, it realizes interfaces between COTS applications (Design/CPN™, Design/IDEF™, Microsoft Excel™, MATLAB™), COTS development tools (Visual Architect™, AppleScript™) and "in-house" applications and algorithms (Lattice Algorithm, Genetic Algorithm, Cube Tool, RULER).

There are four major stages in CAESAR II:
1) Requirements Generation,
2) Decision Making Organization (DMO) Architecture Generation,
3) Selection and Analysis of DMO Architecture
4) Performance Evaluation

Stage 1, Requirements Generation, is a heuristics process. From the definition of the mission to be performed by the organization and the operational concept that defines how the organization will perform the mission, the designer has to determine (1) the functionality (that is the decision process, the operations or methods to be used by the decision makers to perform this decision process, and the interactions among decision makers), (2) the structural constraints, (3) the performance requirements and, (4) the scenarios consistent with the operational concept that will be used in stage 4 for the derivation of performance measures.

* This research is being funded by the Office of Naval Research under Contract no. N00014-93-1-0912
** Corresponding author
The aim of the second stage is to generate a set of feasible decision making organizations that satisfy the structural constraints specified by the designer and exhibit the desired functionality. Organizations are represented as Petri Nets and the tools used in this stage rely on the mathematical properties of Petri Nets. Central to this stage are two alternative algorithms (a) the Lattice algorithm (Remy and Levis, 1988; Demaël and Levis, 1994; Zaidi and Levis, 1995) that allows to determine all admissible organizational forms satisfying these constraints, and (b) the Genetic algorithm (Zaidi and Levis, 1996) that obtains a feasible set of solutions for large organizations but the set is not exhaustive. Given a number of decision makers, the Lattice algorithm determines all the admissible organizational forms. The innovativeness of the approach is the way it addresses this combinatorial problem. Instead of characterizing every single solution, the complete solution is expressed in the form of a small set of minimally connected organizations (MINOS), a small set of maximally connected organizations (MAXOS), and the lattice structure (the partially ordered set or Hasse diagram) of all intermediate solutions. An alternate approach is the use of a Genetic Algorithm in which, starting from an initial population of decision making organizations, the population is enhanced genetically by means of mutation and crossover operations. The resulting organizations are tested against requirements and assigned a fit measure. Infeasible structures are discarded. The best organization in the final population can be used as the solution to the design problem. While not exhaustive, this second approach can be used on large problems that can not be handled by the Lattice Algorithm.

The organizations forms obtained from either approach correspond to the functional architecture. This functional architecture is then mapped to specific decision makers (human resources). Information sources and communication systems are added to the design (i.e., the physical architecture is used). Incorporation of the operational concept as a set of rules in the Petri Net completes the organizational design - the Operational Architecture is obtained.

The third stage, analyze and select DMO, leads to the reduction of the set of candidate organizations by doing a static evaluation of the Petri net representation of the Operational Architecture. Different tools can be used at this stage. S-Invariants are used to analyze the functionality by identifying key threads from sources to sinks (Valraud and Levis, 1991). Deadlocks and traps (Jin, 1994) can be identified. They correspond to parts of the organization where problems can occur. Occurrence graph analysis allows the characterization all the states reachable from an initial state and the identification of undesirable ones. Temporal properties can be analyzed without any simulation by deriving the time equation of the net. Finally, for variable structure organizations, the coordination constraint (Lu, 1992) can be checked to see whether each decision maker has the right combination of information to perform the desired function in the current mode of operations. It has to be noted that this set of tools can be used on any organization;
for example, on an existing design not necessarily generated through the first two stages of CAESAR II.

The last stage is to evaluate the performance of the organization. This is done through simulation of the Petri Net on a scenario defined in the first stage. Prior to the simulation, the parameters to be varied need to be defined and the net needs to be instrumented to collect data. To each setting of the parameters corresponds a given set of Measures of Performance attained by the organization. When varying the parameters and executing the Petri Net for each setting, the MOP space is derived. The Measures of Effectiveness are derived by comparing the MOPs to the performance requirements. They constitute the basis for the analysis for the final selection of the organization.

The paper will present an example of a Naval Tactical Command Center to illustrate the methodology.

The main contribution of this paper is a description of an approach that goes all the way from requirements definition to effectiveness assessment of decision making organizations. This methodology is constantly updated by introduction of additional modules addressing different aspects of the distributed decision making process (temporal logic issues, team adaptation, ...) and by designing graphical interfaces between the various modules that allow for interactions between the designer and CAESAR II.

REFERENCES


Lu, Zhuo (1992). *Coordination in Distributed Intelligent Systems*. MS Thesis, GMU/C3I-120-TH, Center of Excellence in Command, Control, Communications, and Intelligence, George Mason University, Fairfax, VA.


