New Method to Compute Optimization System Reliability by Using Parametric Approach in Visual Basic Programming

Omar A. Mohamad,
AL Iraqia University College / Dept.of Computer science.
Saad A.Abd & Rasha T. Hameed
AL Yarmouk University College
/ Dept.of Computer Technology Engineering.

Abstract:

The model design in this paper consists of two parts, the first part is a nonlinear programming formulation of the allocation problem. The second part is a cost function formulation to be used in the nonlinear programming algorithm. A new method for system reliability with linear constraints, by using the parametric approach which was used in this work. This method gives a complete and accurate analysis; also it gives a simple compute to reach optimum design of the system. This model was built by using visual basic programming.

Keywords: X_i: number of redundant (parallel) components in stage $_i$. $y_i \equiv 1+x_i$:total number of components in stage $_i$. c_i: cost of each component in stage $_i$. w_i: weight of component in stage $_i$. R_i: reliability of each component in stage $_{i.}$ C: cost constraint. W: weight constraint. R: system reliability constraint. λ :Lagrange multiplier. $\sum$: implies the sum over $_i$ from 1 to N. $\phi_i \equiv (1-R_i)/R_i$:parameter .CSCI: computer software configuration item .

طريقة جديدة لحساب أفضل معولية للنظام

بأستخدام النهج العددي في لغة الفيجول بيسك.

الخلاصة:

هذا النموذج الذي صمم بهذا البحث يتكون من جزئين ، الجزء الاول هو صياغة البرمجة الغير خطية لمشكلة التخصيص . الجزء الثاني هو صياغة دالة التكاليف لاستخدامها في خوارزمية البرمجة الغيرخطية. يعرض هذا البحث طريقة جديدة لتحسين موثوقية النظام مع القيود الخطية وبأستخدام النهج العددي. هذه الطريقة تعطي تحليل كامل ودقيق بالاضافة الى سهولة الحساب للوصول الى تصميم امثل للنظام. هذا النموذج تم بنائه بأستخدام لغة الفيجول بيسك .

1. Introduction:

To increase the overall reliability of series system, redundancies are introduced at each stage. But at the same time the system may be subjected to some linear constraints. The problem is to find the number of redundant components at each stage to get the optimum design within the constraints. Many authors have solved the N-stage redundancy problem [1].Reliability maximization with linear constraints was solved by Bellman and Dreyfus using dynamic programming. Kettele developed an algorithm which utilizes dynamic programming for reliability maximization subject to a single cost constraint [1, 2].

The purpose of this paper is to present a computationally simple new procedure for reliability optimization using the parametric approach .It is used in conjunction with nonlinear programming for optimization of system reliability or cost. Using the properties of convexity, algorithm to generate sequences of undominated modes are derived. Finally reliability optimization with multiple linear constraints is treated. Example is given to solve this problem.[2]

2. Reliability:

The characteristic of an item expressed by the probability that it will perform required function under stated conditions for a stated period of time [3, 4].

2.1 Reliability Function; R(t):

The probability that the system (component) does not fail in the time interval (o,t], can be expressed as follows [5] :

$$R(t) = p_r(T>t) \quad \text{for} \quad t>o$$

Where p_r is the probability and T is a random variable for failure time of the component.

2.2 Unreliability, Q(t):

The probability that the system fails within the time interval (o,t], and can be expressed as follows [5]:

$$Q(t) = p_r (T \leq t)$$

Therefore

$$R(t) + Q(t) = 1$$

3. Reliability Allocation

Reliability Allocation deals with the setting of reliability goals for individual subsystems such a specified reliability goal is met and the hardware and software subsystem goals are well-balanced among themselves. Well-balanced usually refers to approximate relative equality of development time, difficulty, risk, or to the minimization of overall development cost. [5,6]

3.1 System Reliability Allocation.

Reliability allocations for hardware/software systems can be started as soon as the system reliability models have created. The initial values allocated to the system itself should either be the specified values for the various reliability metrics for the system, or a set of reliability values which are marginally more difficult to achieve than the specified values. Reliability values that are slightly more aggressive than the required values are sometimes allocated to the system to allow for later system functionality growth and to allow those parts of the system which cannot achieve their allocated values to be given some additional reliability margin later in the design process.[7]

The apportionment of reliability values between the various subsystems and elements can be made on the basis of complexity, criticality, estimated achievable reliability, or any other factors considered appropriate by the analyst making the allocation. The procedures provided for allocation of software failure rates can be applied to both hardware and system elements provided the user recognizes that these elements typically operate concurrently. System-level allocations are successively decomposed using the reliability model(s) until an appropriate set of reliability measures has apportioned to each hardware and hardware/software component of the system.

3.2 Hardware Reliability Allocation.

The allocation of reliability values to lower-tiered hardware elements is a continuation of the allocation process has begun at the system level. The system level hardware reliability models are used to successively apportion the required reliability measures among the various individual pieces of hardware and from the hardware equipment level to the various internal elements. For existing hardware items, the reliability allocations used should be based on the reliability performance of previously produced equipment. Reliability allocations to internal elements of existing hardware are not typically performed. Hardware equipment level allocations are further allocated to various internal elements within the equipment.[8,9]

3.3 Software Reliability Allocation.

The first step in the allocation process is to describe the system configuration (system reliability model). Next, trial component reliability allocations are selected, using best engineering judgment. Computer system reliability for this set of component reliability values. The result Compare against the goal. Adjust component reliability values to move system reliability toward the goal, and component reliability values toward better balance. The process repeat until the desired goal and good balance are achieved [10].

The allocation of a system requirement to software elements makes sense only at the software system or CSCI level. Once software CSCIs have allocated reliability requirements, a different approach is needed to allocate the software CSCI requirements to lower levels. The allocation of system requirements to hardware and software elements can be illustrated through a simple example.

4. Maximization of Reliability for A Given cost constraint :

The parametric equation for a system having N stages in series and each stage having parallel redundancy is, in the high reliability region [4]:

$$\phi_s \equiv \sum \emptyset^{yi} \qquad \dots (1)$$

The problem is to minimize ϕ_s (i.e to maximize system reliability R) subject to minimize to the linear constraint $\sum c_i y_i \leq C$. The optimality conditions are obtained from the Lagrangian [3,4,11].

$$L = \sum \emptyset^{yi} + \lambda\, [\sum c_i\, y_i - C] \quad \dots (2)$$

The conditions for an optimum are :

$$\frac{\partial L}{\partial yi} = \ln\phi_i \,.\, \emptyset^{yi} + \lambda c_i \qquad \dots (3)$$

$$\sum c_i y_i = C \qquad \dots (4)$$

From (3)

$$Y_i = a_i \ln \lambda + b_i \qquad \dots (5)$$

Where

$$a_i \equiv \frac{1}{ln\phi_i}$$

$$b_i \equiv \frac{lnK_i}{ln\phi_i}$$

$$K_i \equiv \frac{-c_i}{ln\phi_i}$$

From (4) and (5),

$$\lambda = e^s$$

Where

$$s \equiv \frac{C - \sum c_i\, b_i}{\sum c_i a_i} \qquad \dots (6)$$

Once λ is obtained, y_i can be obtained using (5); y_i , obtained by treating it as continuous variable , is approximated to the nearest integer to get a near-optimum design.

In the above derivation, we have made a simplifying assumption in L; the most general Lagrangian for the problem is:

$$L = \sum \phi_i^{(1+x_i)} + \lambda\, [c_i(1 + x_i) + \alpha^2 - C] + \sum \beta_i(-x_i + \mu_i^2) \dots (7)$$

The Kuhn-Tuker conditions for an optimum are

$$(\ln\phi_i)\phi_i^{(1+x_i)} + \lambda c_i - \beta_i = 0 \qquad \ldots(8)$$

$$\lambda[\sum c_i(1 + x_i) - C] = 0 \qquad \ldots(9)$$

$$\beta_i x_i = 0 \qquad \ldots(10)$$

$$\beta_i \geq 0, \lambda \geq 0 \;. \qquad \ldots(11)$$

In writing (3), we assumed that $\beta_i = 0$ for all i in (8); i.e. we initially assume that x_i does not exactly equal to zero in (10). But this does not mean that at least one redundancy will be presented at each stage , for after solving for x_i if some of them are function near to zero, they can be rounded off to zero. At this point it prudents to ask whether this method can be used to generate a sequence of undominated modes.

Let $\bar{n} \equiv (n_1, n_2, \ldots, n_i, \ldots, n_N)$ be a policy in which n_i is the number of components in stage i ; $c_i(n_i)$ represents the cost of stage i ,and $R(\bar{n})$ is the system reliability for this allocation . Let there be some other policy $\bar{m} \equiv (m_1, m_2, \ldots m_i, \ldots m_N)$that yields better system reliability . Allocation $\bar{n}$ is said to be undominated if "$R(\bar{m}) > R(\bar{n})$ implies $c_i(m_i) > c_i(n_i)$ for some i [11]. Tow methods have discussed by Messinger and Shooman to generate an incomplete sequence of undominated method [8]. But the drawback in their methods is that the region interest(starting allocation) is not nown ;usually the algorithm is started with zero redundant components in all stages . This is where the method suggested here is very useful since it gives a good starting value (upper, because the continuous solution of an integer problem results in an upper bound) and a few searches in one direction will result in optimum or near –optimum design [11].A sequence of undominated modes can be generated by finding the smallest integer n_i which satisfies the inequality

$$\frac{\phi_i^{n_i}}{(1+\phi_i)^{(1+n_i)}} < \lambda\, c_i \qquad \ldots(12)$$

(12) follows directly from the convexity of ϕ. The proof is given [6].A flow chart for the algorithm is given in fig.(1)

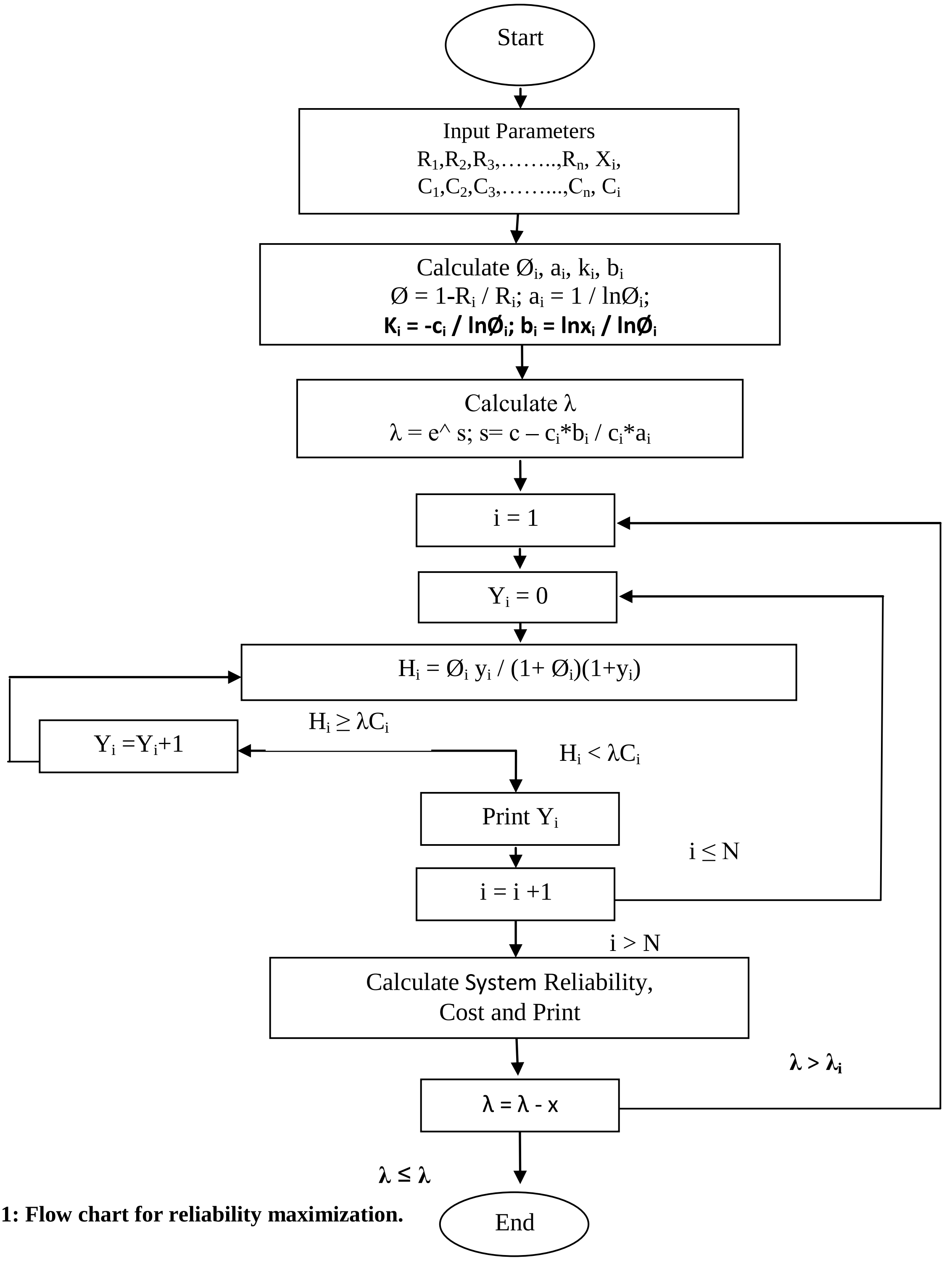

Fig.1: Flow chart for reliability maximization.

The program that solves this problem was written by using visual basic programming. At first must choose parameters as shown in fig.2.

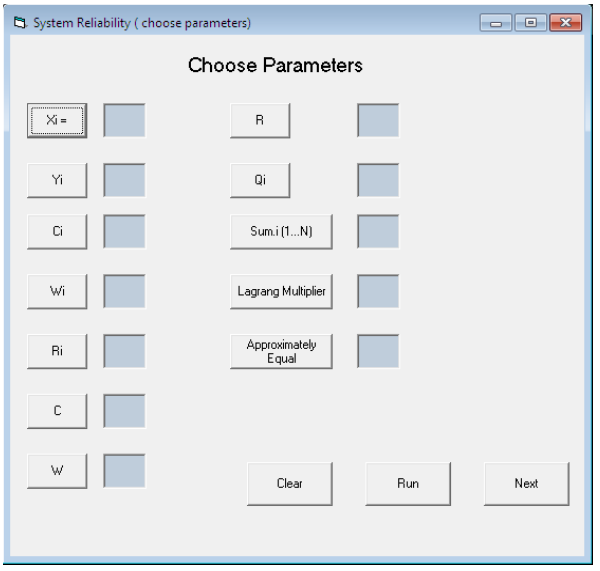

Fig.2: The Choose Parameters windows.

After choosing parameters, using the proposed algorithm to find the maximize reliability of the 4- stages system as shown in fig.3.

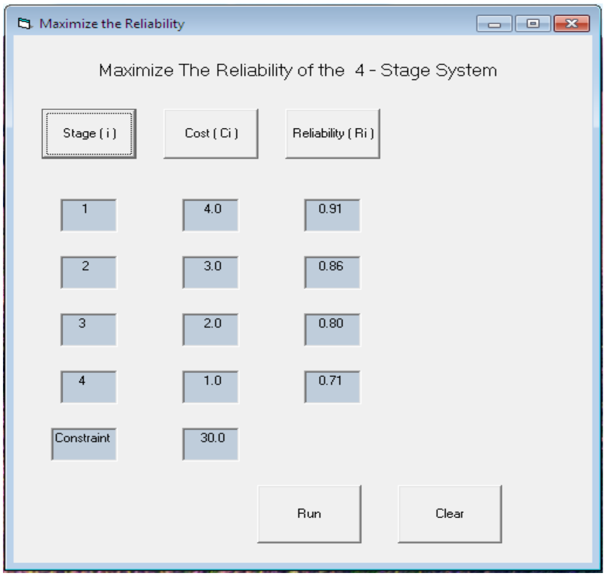

Fig.3: Maximize the reliability of the 4- stages system.

The proposed algorithm can be used in N stages such as 1, 2, 3, 4,……, N stages. As shown in fig.4

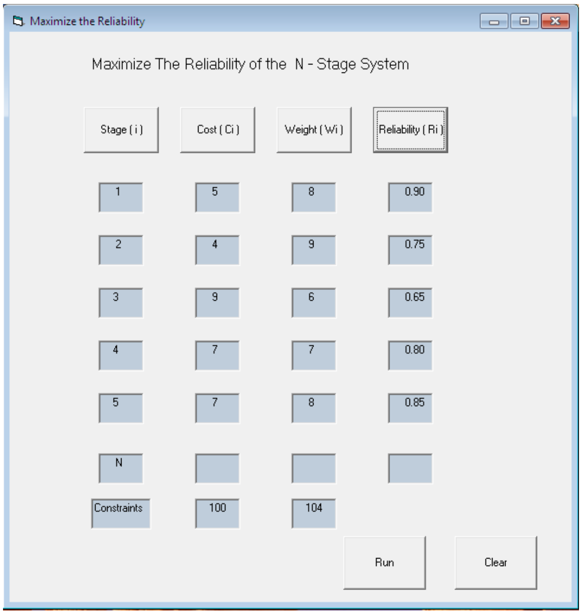

Fig.4: Maximize the reliability of the N- stages system.

In the 4- stages system reliability using the value of λ is 0.00495. The undominated solutions generated by the proposed algorithm are shown in fig.3. In the flow chart, X is the decrement in λ and λ is the final value. A decrement of 0.001 is used here .The solution is (2, 3, 4, 5) and the maximum reliability is 0.911, as shown in table (1).

Table (1)

Y_1	Y_2	Y_3	Y_4	C	R	λ
2	3	3	5	4.0	0.911	0.00495
2	3	3	5	3.0	0.86	0.00395
2	3	4	5	2.0	0.80	0.00295

Conclusion:

This paper work presents a computationally simple procedure for reliability optimization with any number of linear constraints. The theory is extended to generate an incomplete sequence of undominated modes, the final result of which is the exact integer solution. In the case of multiple constraints, the problem is reduced to that of solving a set equation, the number of unknowns begin equal to the number of constraints; with the solved values, sequences of undominated modes are generated.

The nonlinear programming part of the model can also be used for other cost functions. The advantage of the model is that it can be applied to any system with high complexities. The program in visual basic is effective for small and large systems. As long as the system is reliability equation can be derived analytically, using the path tracing method for solving the reliability allocation problem.

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