Ministry of Higher Education and
Scientific Research
University of Mosul
College of Computer Science and
Mathematics
Department of Software

A Framework for Solving the Reliability Redundancy Allocation Problem Using Swarm Intelligence

**A Thesis Submitted to the Council of the College of
Computer Science and Mathematics
University of Mosul
as a Partial Fulfillment of Requirements
for the Degree of Master of Science
in
Software**

By

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2025 A.D. **1447 A.H.**

Abstract

The notion of reliability in software engineering is a key issue targeting the assurance of proper software performance. This denotes accomplishing its aimed functions regularly in a correct manner, regardless of the various ongoing conditions. Reliability in systems attempts to minimize faults, stoppages, or unanticipated failures, thereby boosting end-user satisfaction, reducing excess costs, and thus a sounder reputation for the established software and its developers.

The main feature in the process of achieving high system reliability and dependability is redundancy. Adding extra components to the system can hugely elevate its reliability. Maximizing this feature can be made through the optimization of the reliability redundancy allocation problem (RRAP). This problem is a combinatorial optimization problem, NP-Hard in complexity, that seeks to find the most desirable system component configuration in terms of overall reliability using redundancy. It is subject to constraints that might include cost, weight, and volume.

In this work, the RRAP is deeply studied and investigated to find better near-optimal solutions. Being very complex, traditional methods cannot be employed to efficiently solve the problem. Swarm intelligent algorithms are used to seek better solutions. RRAPs are treated as Reliability Block Diagrams (RBD) to deal with each component's reliability and to manage overall system configurations. Nine different RRAP instances are used in this work as RBDs.

The Framework presented in this work covers thirteen different Swarm Intelligent (SI) algorithms in an attempt to solve RRAP instances for the nine different types of RBDs in varied settings. In addition, two new hybrid algorithms, namely CSO-WOA and FPA-ABC, are developed to promote robustness and quality of solutions. The performance of all the above-mentioned algorithms is measured using statistical measures such as best fitness, mean, standard deviation, Friedman, and the LSD tests to ascertain significance. Results indicated that the swarm intelligence-based techniques, and especially the proposed hybrids, frequently perform better than the most well-known solutions in the literature and surpass a number of world-best achieved values that already appeared in the literature, setting new maximum-reliability records in seven out of nine RBD systems. The largest achieved MPI measure for individual algorithms was (99.6266546%), and for the hybrid was (99.320859%). Such contributions reveal successful results of SI-based optimization in the improvement of reliability engineering and mark new perspectives in the guidance of future research concerning RRAP and hybrid algorithms.

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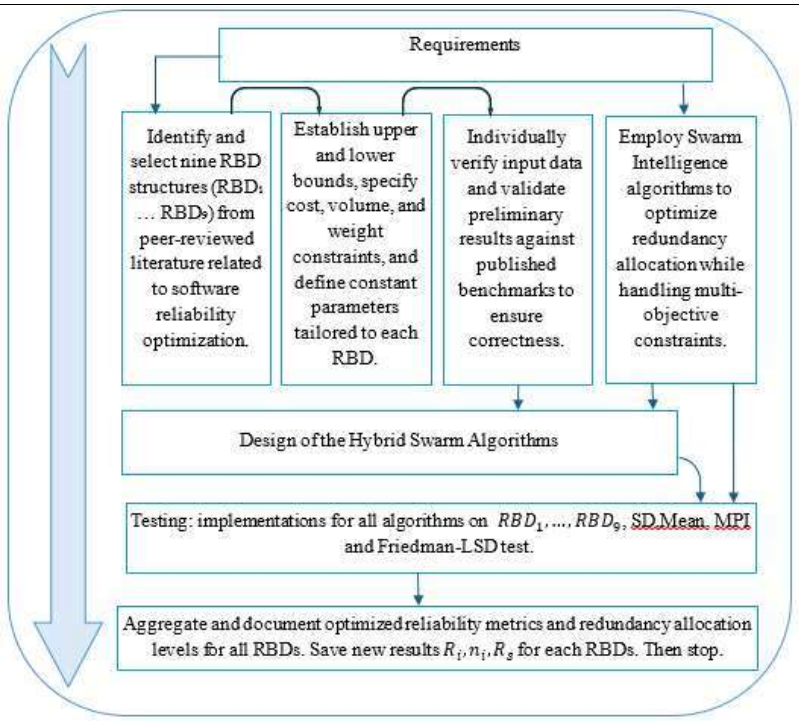
HIGHLIGHTS

- Developed a comprehensive framework applying thirteen swarm intelligence algorithms to nine RRAP RBD systems.
- Two novel hybrid algorithms (CSO–WOA and FPA–ABC) were proposed, achieving seven new global reliability records out of nine systems
- Demonstrated the effectiveness of swarm intelligence algorithms in enhancing system reliability through precise statistical analyses (best fitness, mean, standard deviation, and Friedman and LSD tests), achieving a maximum overall reliability of 99.62%

GRAPHICAL ABSTRACT



Keywords:

Software Reliability, Optimization problems, Swarm intelligence, Redundancy, Allocation Problems

ABSTRACT

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2025 M.Sc. Thesis @Univ. of Mosul, College of Computer Science and Mathematics., Software Dept. (https://www.uomosul.edu.iq/).

وزارة التعليم العالي والبحث العلمي
جامعة الموصل
كلية علوم الحاسوب والرياضيات
قسم البرمجيات

إطار عمل لحل مسألة تخصيص الموثوقية والتكرار باستخدام ذكاء السرب

رسالة مقدمة
الى مجلس كلية علوم الحاسوب والرياضيات في جامعة الموصل
كجزء من متطلبات نيل شهادة ماجستير علوم في
البرمجيات

من قبل
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١٤٤٧ هـ ٢٠٢٥ م

الملخص

يُعد مفهوم الموثوقية في هندسة البرمجيات مسألةً أساسيةً تهدف إلى ضمان الأداء السليم للبرمجيات. ويعني ذلك إنجاز وظائفها المستهدفة بانتظام وبطريقة صحيحة، بغض النظر عن الظروف الجارية المختلفة. تسعى الموثوقية في الأنظمة إلى تقليل الأعطال أو التوقفات أو الأعطال غير المتوقعة، مما يعزز رضا المستخدم النهائي، ويقلل التكاليف الزائدة، وبالتالي يعزز سمعة البرمجيات الراسخة ومطوريها.

الميزة الرئيسية في عملية تحقيق موثوقية واعتمادية عالية للنظام هي التكرار. يمكن أن تؤدي إضافة مكونات إضافية إلى النظام إلى زيادة وثوقيته بشكل كبير. ويمكن تعظيم هذه الميزة من خلال تحسين مشكلة تخصيص التكرار للموثوقية (RRAP) . هذه المشكلة هي مشكلة تحسين تركيبي، ذات تعقيد NP-Hard ، تسعى إلى إيجاد أفضل تكوين لمكونات النظام من حيث الموثوقية الكلية باستخدام التكرار. وهي تخضع لقيود قد تشمل التكلفة والوزن والحجم.

في هذا العمل، تمت دراسة RRAP بعمق وبحثها لإيجاد حلول أفضل شبه مثالية. نظرًا لتعقيدها الشديد، لا يمكن استخدام الطرق التقليدية لحل المشكلة بكفاءة. تُستخدم خوارزميات الذكاء السربي للبحث عن حلول أفضل. تُعامل RRAPs كمخططات كتلة الموثوقية (RBD) للتعامل مع موثوقية كل مكون وإدارة تكوينات النظام الشاملة. تُستخدم تسع حالات مختلفة من RRAP في هذا العمل كمخططات كتلة الموثوقية. يغطي الإطار المقدم في هذا العمل ثلاث عشرة خوارزمية ذكية سربية (SI) مختلفة في محاولة لحل حالات RRAP لتسعة أنواع مختلفة من RBDs في بيئات متنوعة. بالإضافة إلى ذلك، تم تطوير خوارزميتين هجينتين جديدتين، وهما CSO-WOA وFPA-ABC، لتعزيز متانة وجودة الحلول. يتم قياس أداء جميع الخوارزميات المذكورة أعلاه باستخدام مقاييس إحصائية مثل أفضل ملاءمة، والمتوسط، والانحراف المعياري، وفريدمان، واختبارات LSD للتأكد من الدلالة. أشارت النتائج إلى أن تقنيات ذكاء السرب، وخاصةً الهجينة المقترحة، غالبًا ما تُحقق أداءً أفضل من أشهر الحلول في الأدبيات، وتتجاوز عددًا من أفضل القيم المُحققة عالميًا التي ظهرت سابقًا في الأدبيات، مُسجلةً بذلك أرقامًا قياسية جديدة للموثوقية القصوى في سبعة من أصل تسعة أنظمة RBD. بلغ أعلى مقياس مُحقق لمؤشر MPI للخوارزميات المنفردة (٩٩.٦٢٦٦٥٤٦٪)، وللهجينة (٩٩.٣٢٠٨٥٩٪). تكشف هذه المساهمات عن نتائج ناجحة للتحسين القائم على SI في تحسين هندسة الموثوقية، وتَفتح آفاقًا جديدة في توجيه الأبحاث المستقبلية المتعلقة بـ RRAP والخوارزميات الهجينة.