LIKE A PEARL IN THE SEA

THE PROCEEDINGS OF THE COMPUTER SCHOOL IN HUAZHONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

计算机海洋一粟

华中科技大学计算机科学与技术学院论文集

计算机科学与技术学院 编

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内 容 简 介

本书是华中科技大学(原华中理工大学)计算机科学与技术学院近年来在计算机领域所取得的研究成果的汇集。全书共收集论文29篇,重点论述了计算机存储结构、存储理论、磁盘阵列、NP-Complet问题的研究而提出的拟人、拟物方法以及在解决SAT问题、Parking问题、计算机软件及应用方面所取得的一些创造性成果。这些论文均由计算机学院的学术带头人和青年教师撰写,并已全部被《科学索引》(SCI)收录,充分展现出华中科技大学计算机科学与技术学院在计算机领域研究与应用的学术水平。

本书可供从事信息科学、计算机等领域工作的科技人员以及高等院校相关专业的师生参考。

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序　一

华中科技大学计算机科学与技术学院历经近三十年的建设，现拥有计算机系统结构国家重点学科、计算机科学与技术一级学科博士点授予权与博士后流动站，是国内计算机界中的一支朝气蓬勃的生力军。

该院的信息大容量存储与获取理论与技术、计算机科学理论（特别是NP完全问题的研究）等方面的研究成果颇丰，极富特色，引人注目。这次将其中一些具有代表性的理论成果结集出版，对促进我国计算机科学与技术的发展将发挥出其应有的作用。

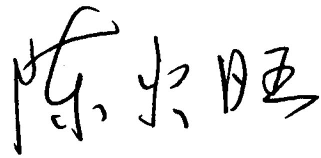
本书收录了计算机科学与技术领域内高水平的论文20多篇，全部为SCI(Science Cited Index)收录。其中有围绕著名的世界难题NP-Complet问题的研究而提出的拟人、拟物方法以及在解决SAT问题、Parking问题等方面做出的创造性的成果；有在大容量存储机理和性能评价方面所做的领先性工作；也有在计算机应用方法理论探讨和图像匹配检索等方面的突出工作。

本书选编的高水平论文有较高的学术水平和科学意义，对计算机科学与技术在若干方向上的理论研究与应用实践有其重要的指导意义和参考价值。此书出版后，相信会引起国内外IT行业的关注，将是我国计算机科学技术界百花园中的一支艳丽的花朵。

特别值得一提的是：本书作者中既有老一辈的学术带头人，又

有一批三十岁左右的年轻人，在这些青年人身上体现出来的敏捷的思维与坚实的功底是值得特别欣喜的，他们与全国一大批杰出青年一起将成为我们事业未来的希望。

中国工程院院士
国防科技大学教授



二〇〇四年六月

序　二

以计算机科学与技术为中心的信息技术革命引发了社会的大变革，人类社会发展正从工业社会阶段走向信息社会阶段，工业化进程即将完成，信息化进程已经拉开序幕，这是一个不以人的意志为转移的大趋势。信息革命、信息化将是这个时代的主旋律和主题词。

科学的发展没有终点，只有里程碑。本书收录了我院近几年来在计算机科学与技术领域内的论文，均为 SCI(Science Cited Index)收录。其中有围绕著名的世界难题 NP-Complet 问题的研究而提出的拟人、拟物方法以及在解决 SAT 问题、Parking 问题等方面做出的创造性的成果；有在大容量存储机理和性能评价方面所做的领先性工作；也有在计算机应用方法理论探讨和图像匹配检索等方面的突出工作。

这些论文均有较高的学术水平和科学意义，对计算机科学与技术在若干方向上的理论研究与应用实践有其较好的指导意义和参考价值。书中所体现出来的高显示度成果，对促进我们与国内外同行的学术交流和学科发展会有一定作用，同时为我校加大基础研究力度，加速我校国际化的步伐，也会起到积极的作用。

华中科技大学教授

计算机科学与技术学院院长

二〇〇四年六月

前　　言

本书精选了我院张江陵、黄文奇等20几位老师的学术论文(包括与李未院士合写的一篇),并汇集成册出版。这些论文均被SCI(Science Cited Index)收录。书中较集中地反映了近几年来我院在计算机系统结构、计算机科学与理论以及计算机应用方面所取得的一些研究成果。此次结集出版,一方面是我院研究工作一个侧面的小结与回顾,但更为重要的一方面是以期更有利于与海内外同仁们进行较有深度的交流与切磋,共同为计算机科学与技术事业的发展做出贡献。

本书的编辑出版得到作者们的鼎力相助,王炎坤教授为本书的出版精心策划,李久红同志为本书的组稿、论文收集和编辑做了大量工作,同时也得到我院全体师生的支持,在此一并表示感谢。

本书的出版得到科学出版社的鼎力支持,特别是鞠丽娜编辑为本书的出版付出了大量心血,在此表示感谢。

华中科技大学计算机科学与技术学院

二〇〇四年六月

目　录

Two Personification Strategies for Solving Circles Packing Problem*

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Abstract Two personification strategies are presented, which yield a highly efficient and practical algorithm for solving one of the NP hard problems-circles packing problem on the basis of the quasi-physical algorithm. A very clever polynomial time complexity degree approximate algorithm for solving this problem has been reported by Dorit S. Hochbaum and Wolfgang Maass in J. ACM. Their algorithm is extremely thorough-going and of great theoretical significance. But, just as they pointed out, their algorithm is feasible only in conception and even for examples frequently encountered in everyday life and of small scale, it is the case more often than not that up to

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a million years would be needed to perform calculations with this algorithm. It is suggested toward the end of their paper that a heuristic algorithm of higher practical effectiveness should be sought out. A direct response to their suggestion is intented to provide.
Keywords Packing problem NP hard Heuristic algorithm Personification method Quasi-physical method

Solving NP hard problems is the bottleneck task for computer science and techniques of this century and the beginning of the forthcoming one. Investigations from the 1970s to now, however, show that for NP hard problems, there simply does not exist an algorithm that is both complete and rigorous and not too slow[1,2]. That is to say, thoroughly axiomatic and formalistic mathematical methods will not be of much use here.

Thus people turn to nature for wisdom, hoping to obtain an approximate algorithm for solving NP hard problems that is not absolutely complete but is of high speed, high reliability, and high efficiency. Its working path is to find natural phenomena equivalent to the original mathematical problem in the physical world and then observe the evolution of the motion of matter in it so as to be inspired to obtain a formalistic algorithm for solving the mathematical problem. Such a working path can be called the quasi-physical approach.

As the evolution of a physical state proceeds naturally in such a manner that the time integral of its Lagrange function is made to reach the minimum[3], this process results in making the quasi-physical algorithm an optimization in mathematics. However, if an optimization problem is to be solved mathematically, there is often the possibility of going to a local minimum. As for how to jump out of the trap of local minimum and let the calculation head for a region of better prospects, the quasi-physical approach is incapable of doing anything. But human beings have accumulated rich social experience through thousands of years of common life. It is sometimes possible to think out a good strategy for jumping out of a trap with the help of these experiences[4,5]. We can call the way of formalizing humanity's social experience into an algorithm to solve certain extremely difficult problems in mathematics the personification approach.

The efficiency of the quasi-physical personification algorithm is usually higher than that of the biogenetic algorithm, the neural net method, and annealing method[6], the reason being that it has found a very appropriate physical world for a specific problem instead of relying on a unique and invariable, and hence often not quite appropriate physical system as with the genetic, neural net, and annealing methods. In addition, the personification approach consists in learning from experience, however, people have much higher wisdom than those individual neurons and crystals of protein in the genetic, neural net works and annealing world. Of course, the crux here lies in the art and means on the eve of appropriate mathematical formalization that are not easy to obtain but require painstaking effort for a long period of time. Such a requirement for hard work in the course of obtaining an algorithm can be said to be a drawback of the personification quasi-physical approach.

1. The Problem[1,7]

Suppose an empty round box (container) (Fig. 1) and several different round cakes are known. We shall ask if these cakes can be packed into the empty box without over-lapping one another. This problem is stated more formally as follows:

For an arbitrarily given positive integer M and arbitrarily given $M+1$ positive real numbers $R_0, R_1, \cdots, R_M$, do there exist $2M$ real numbers $x_1, y_1, \cdots, x_M, y_M$ such that for an arbitrary positive integer i in $\{1, 2, \cdots, M\}$, we have

$$\sqrt{x_i^2 + y_i^2} \leqslant R_0 - R_i, \tag{1}$$

and for two arbitrary different positive integers i, j, we have

$$\sqrt{(x_i - x_j)^2 + (y_i - y_i)^2} \geqslant R_i + R_j. \tag{2}$$

If there exist such real numbers, then please give a specific set of the real numbers that meet these requirements.

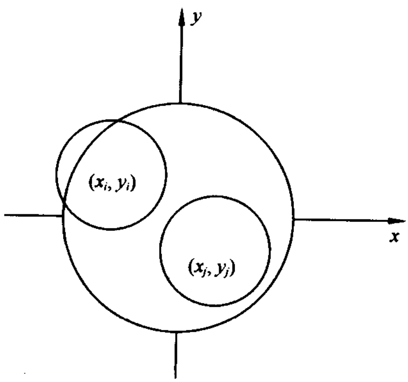

Fig. 1

2. The Quasi-physical and Personification Lines of Thought

2.1 The Quasi-physical Line of Thought[7~10]

We shall consider the problem in 2-D Euclidean space. Imagine all the M cakes as smooth elastic solids and the container as the remaining infinite part after a cake of radius R_0 is hollowed out of the whole 2-D infinite elastic solid.

Imagine that the M cakes are squeezed into the container. As each object has the tendency to restore its shape and size, there occurs the interaction of extrusion elastic forces between the solids. Driven by such extrusion elastic forces, a series of movements will result. It is possible that the result of the motion is the establishment of a solution to the problem, each object in an appropriate position with respect to another, with no two solids embedded into each other.

If we can simulate the series of motion via a certain mathematical method, then we shall have in effect found an algorithm for solving the circles packing problem.

2.2 The Quasi-physical Algorithm

Take the origin of 2-D Cartesian coordinate system at the central point of the container (see Fig. 1). Denote the coordinates of the center of the ith ($i=1,2,\cdots,M$) cake by x_i, y_i. Then the embedding depth between the ith cake and the plate is:

$$d_{0i} = \begin{cases} \sqrt{x_i^2 + y_i^2} + R_i - R_0, & \text{if } \sqrt{x_i^2 + y_i^2} + R_i > R_0, \\ 0, & \text{otherwise.} \end{cases} \quad (3)$$

The embedding depth between the ith and jth different cakes is

$$d_{ij} = \begin{cases} R_i + R_j - \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}, \\ 0, \end{cases}$$

$$\text{if } \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} < R_i + R_j, \tag{4}$$

otherwise.

Obviously, d_{ij} and d_{0j} are constantly non-negative, $d_{ij} > 0$ signifies that the ith and jth objects embed each other and $d_{0i} > 0$ the 0th and ith objects embed each other. $d_{ij} = 0$ signifies that the ith and jth objects do not embed each other while $d_{0i} = 0$ signifies that the 0th and ith objects do not embed each other. According to elasticity mechanism, the extrusion elastic potential energy between two smooth elastic objects is proportional to the square of the depth of their mutual embedment. Hence $d_{\lambda\mu}^2$ can be used to characterize the extrusion elastic potential energy between the λ th and μ th objects:

$$u_{\lambda\mu} = d_{\lambda\mu}^2, \ \lambda, \mu = 0, 1, 2, \cdots, M, \ \lambda \neq \mu. \tag{5}$$

It can be considered that the extrusion elastic potential energy U_i possessed by the ith cake is

$$U_i = \sum_{\lambda=0, \lambda\neq i}^{M} u_{\lambda i}, \quad i = 1, 2, \cdots, M. \tag{6}$$

The potential energy of the whole system is

$$U = \sum_{i=1}^{M} U_i \tag{7}$$

It can be seen from (3) to (7) that the potential energy U of the whole system is a known function of the coordinates $x_1, y_1, \cdots, x_M, y_M$ of all the cakes:

$$U = U(x_1, y_1, \cdots, x_M, y_M). \tag{8}$$

Obviously, we know that 1) $U(x_1, y_1, \cdots, x_M, y_M)$ is defined as non-negative on the whole $(-\infty, +\infty)^{2M}$; 2) if $U(x_1, y_1, \cdots, x_M, y_M) > 0$, then $(x_1, y_2, \cdots, x_M, y_M)$ is not a solution for the circles packing problem whereas if $U(x_1, y_1, \cdots, x_M, y_M)=0$, then $(x_1, y_1, \cdots, x_M, y_M)$ is a solution for the circles packing problem. Therefore, the circles packing problem has been converted, into an optimization problem for the known function (8), that is, the minimum $(x_1^*, y_1^*, \cdots, x_M^*, y_M^*)$ of the function should be found. If $U(x_1^*, y_1^*, \cdots, x_M^*, y_M^*)=0$, then $(x_1^*, y_1^*, \cdots, x_M^*, y_M^*)$ is a solution for the problem whereas if $U(x_1^*, y_1^*, \cdots, x_M^*, y_M^*)>0$, then the problem does not have a solution.

For this optimization problem, we have a ready-made algorithm for its solution, the gradient method, or the steepest descent method. It should be pointed out that, in the course of solution using the gradient method, $(x_1, y_1, \cdots, x_M, y_M)$ will be steadily evolving. This process of evolution is in complete conformity with the pattern of motion of the smooth elastic cakes squeezed in the container.

2.3 The Origin of the Personification Strategy

It is often possible for the quasi-physical algorithm to get stuck in the course of execution when the problem is rather difficult, that is, the calculation falls into the trap of local minimum. We are now at the local minimum of the potential energy function U:

$$P_{LM} = (x_1, y_1, \cdots, x_M, y_M)_{\text{local minimum}}$$

As the gradient is zero, we do not know how to proceed with the gradient method: But now the potential energy is still greater than zero and for this reason we cannot say that the problem cannot be solved as it is quite possible that the function U is zero at its global minimum P_{GM} (Fig. 2).

To extricate oneself from this predicament, it is the practice of the purely quasi-physical algorithm to randomly choose the

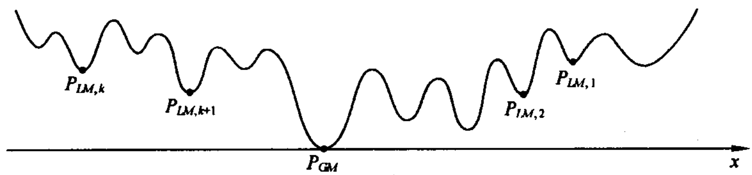

Fig. 2

initial value $(x_1, y_1, \cdots, x_M, y_M)$ for another round of quasi-physical calculation. Although such calculation is characterized by eventual convergency in principle, its efficiency is low as seen from actual calculation. Now the promising approach is to put forward a good strategy for jumping out of the trap by taking the calculating point out of the trap of local minimum and place it in a position with better prospects. Then new quasi-physical calculation can be carried out.

This strategy of "jumping out of the trap" can be obtained by observing and learning from the social phenomena of man and is therefore called the personification strategy.

In a boisterous and closely crowded bus, those that are squeezed the most always manage to shift to a better position, while those that are better off often make part of their room for others.

Regard the M cakes squeezed in the container and the plate that holds the M cakes as the carriage of the bus. Then the observation of the ride in a bus will inspire us to obtain the following strategy.

In a stuck situation, the cakes that are squeezed the most can be picked out and randomly placed in a certain spot in the plate. Sometimes the best-off cake can be picked out and randomly placed in a certain spot of the plate. Picking out the worst