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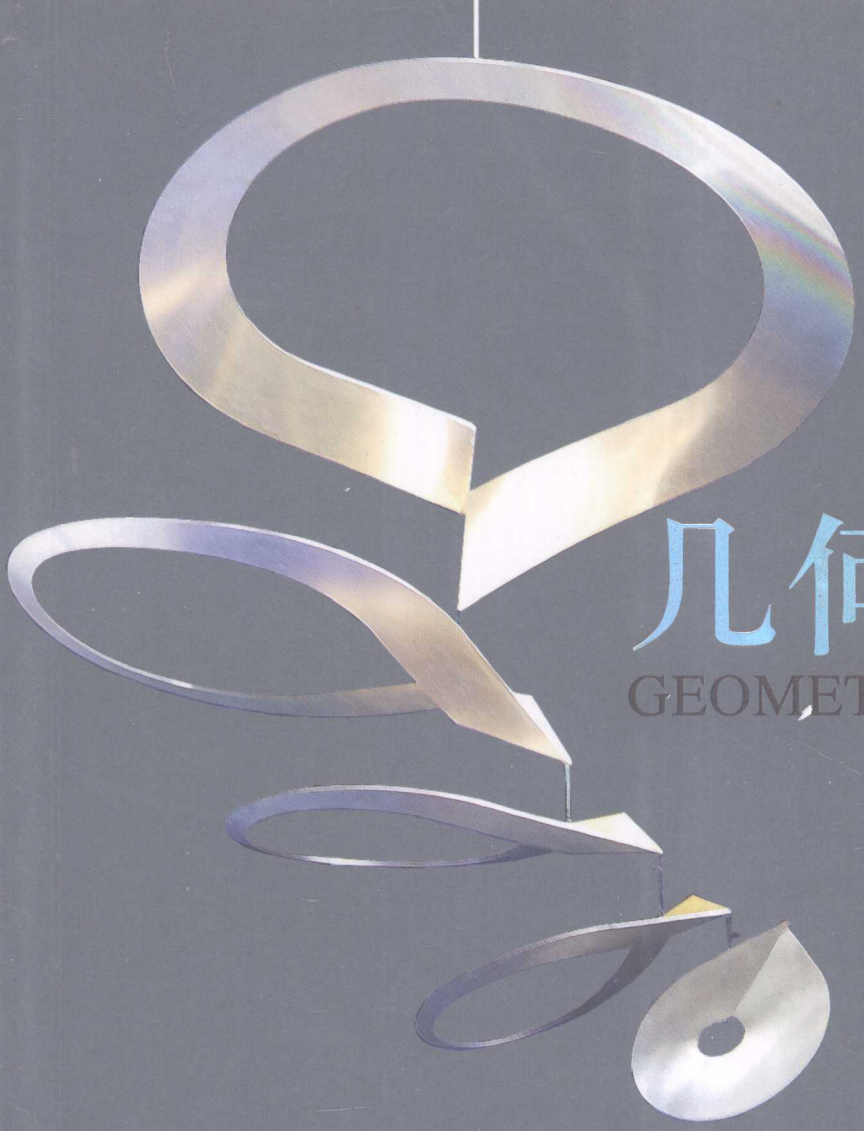

几何动艺
GEOMETRIC MOBILES

艺术灵感 + 科学分析
Artistic Inspiration + Scientific Analysis

郭慕孙 著
Mooson Kwauk

科学出版社
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序

工业革命初期，有些艺术家对机械结构和运动感兴趣，将之纳入他们的作品，自称结构派（constructivism）。实际上，结构和运动不限于机械；广义化后，这一艺术发展到今日的动态艺术（kinetic art）。结构可用一切可能的材料造就，原动力也不限于机械，而可直接用流水或风力。为了采用工程技术开发的“构思—设计—制作”的习用方法，作者将结构限于便于定量描述的几何造型，对动力采用环境中的自然气流，并在此指导思想下，制作了数以百计的作品，称为“几何动艺（geometric mobiles）”（俗称“魔摆”）。

作者终生从事化工研究和开发，始终手脑并用、工程结合科学；从负责科研岗位退下时，看到这块手脑并用、艺术结合科学的领域，开始了探索，对制作的每一件作品保留详细记录，三五年中已汇总成书，遂将第9稿以讲义形式复印，此讲义加上家中的不少作品，引起了亲友的注意，有人提出正式出版，启发青少年的智力开发和动手能力。于是将原来的英文稿加上了中文，用双语由化学工业出版社于1998年出版。原书10章：制约条件、物理、设计、制作、棒/丝、三角形、矩形、圆、棒/板、两/三面体。本书在原书基础上加入了以立体组件为主的4章：折叠法、多面体组件、扁条组件、下方支承的几何动艺；同时改进并增加了原著中的照片，再次出版。

几何动艺的“构思—设计—制作”基于作者提出的5条“制约条件”，即制作几何动艺的“游戏规则”，与象棋、围棋、棒球相似。三位一体的“构思—设计—制作”中的重点是定量的设计，包括造型和平衡，往往以数学习题方式出现，简单的几分钟可获解，提供造型、组件联结和平衡的数据，难者可供几天的思考。

原著的序“献给中国的青年”的动机是诚意和热心，目的是通过具有吸引力的活动培养青年手脑并用、专业结合科学的心态，只有正确的心态才能引导其走向创新，而这种心态的建立主要依靠实践，即手脑并用。但是具有吸引力的课外活动无可避免地会背离由应试教育通向的成功的道路。而本书的读者必须懂得代数、几何、三角和解析几何，这正是即将考大学的青年。

作者十分感谢科学出版社将本书作为科学和艺术相交叉的著作出版，也感谢唐清博士和王仁伟博士，对本人多方联络和在展出、组织出版的热心帮助。

2008年1月

PREFACE

At the early stage of the Industrial Revolution, certain artists noted with interest the structure and motion of mechanical parts of machines which were incorporated into their works, forming the trend of *constructivism.* Of course, structure and motion could be produced otherwise, and this trend soon developed into the present-day *kinetic art.* Structures differ with the materials adopted and motion could originate from flowing water and wind. To implement the usual sequence of R&D, *concept-design-making*, the present author adopted geometrically definable structures to facilitate computation and limited motion to that produced by natural air current, creating hundreds of works, under the title of *geometric mobiles.*

Having gone through a career of R&D in chemical engineering, the author was happy to come across, when retiring from R&D directorship, this hands-on/science-*cum*-art domain, and started making geometric mobiles, accumulating in 3-5 years sheaves of notes, which he progressively organized into a text. The 9th draft of the text was printed in mimeograph form, which, together with the ceiling-full of his works at home, greatly impressed visitors, some of whom suggested publication. The 11th draft was eventually published by Chemical Industry Press in 1998 with a bilingual text, consisting of 10 chapters: proposed constraints, physics, design, construction, rod/wire, triangles, rectangles, circles, rod/plate, dihedrals/trihedrals. The present edition adds 4 chapters on three-dimensional mobile members: *folds*, *polyhedrons*, *flat strips* and *bottom-supported mobiles*, and improves all photographs in the prior edition.

The syllogism, *concept-design-making*, is based on the 5 *constraints* proposed by the author which serves as the rule-of-the-game in similar manner as for chess and base ball. The crux of the syllogism lies in quantitative design involving form and equilibrium, and it generally takes the form of mathematical problems, which could be solved in a matter of minutes or may call for days of thinking.

The author dedicated in all sincerity the prior edition to the youth of China, in the hope of cultivating, outside regular curriculum, the hands-on/science-*cum*-profession attitude, which is the very basis for all innovation, and could be acquired only through practice and participation. However, extracurricular activities would deviate from the examination-dominated road to success, and the young people who understand algebra, geometry, trigonometry, and analytical geometry are readying themselves for the most difficult step toward college education and cannot afford missing.

The author wishes to express his gratitude to Science Press for publishing the present manuscript as an interdisciplinary work involving science and art, and to Dr. Tang Qing and Dr. Wang Ren Wei for their unstinting support and assistance.

献给中国的青少年
（原版代序）

我一生从事化工研究，现年逾七旬，对过去能做的工作，已感心有余而力不足。近年来我逐步转向力所能及之事：除了写书改稿，我开始做“几何动艺”。对我的动艺，我仍然采用多年来所熟悉的方法：构思—设计—制作。我的作品数早已过百。许多朋友欣赏这些风动作品，其中不少人认为何不将这套颇能启发智力的方法传授给青少年。

“几何动艺”的构思要求立体的思维、运动的设想以及一定程度的美感。设计要求运用简单的力学分析，主要运用几何、三角、代数等中等数学进行数学模拟，定量地指导自己如何动手。制作的物质要求不高：一般的手工工具和易得的材料。但另一方面，制作要求精确的手艺、耐心细心和不断地去想办法。

“启发智力”对我是一种启发。多年来，我深感我国的青年科技工作者创造能力不强。这与我们的教育有关：许多老师向学生传播知识，而很少启发他们如何适应社会、经济、资源去用自己的头脑想办法，改造自然、创造工艺、方法或制品。我不能说，“几何动艺”能给青年带来多大能力，但只要一旦他们能被自己的创作所吸引，他们将不断给自己创造练习“构思—设计—制作”的机会，形成这种习惯。

“几何动艺”对我从自娱开始，今后可能成为帮助青少年成长的一种社会活动。我很感谢观赏我作品的朋友们的启发，特别是边东子同志。他帮助我组织有关活动，寻找制动艺的材料，并取音译义，将我英文原著命为“魔摆”，由化学工业出版社得以出版。

作者的写作、讲解和展出

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讲解和展出 LECTURES & EXHIBITS

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清华大学美术学院雕塑系演讲，“几何动艺”，2001-11-12

“科技日”演讲，北京世纪坛，“几何动艺”，2003-6

中国科学院文献情报中心展出和演讲，“几何动艺”，本人作品 11 件，北京，2004-9

清华大学建筑系演讲，“几何动艺”，2006-6-11

艺术与科学国际作品展出，清华大学美术学院，2006-11-11，本人作品“心心和谐”和“三人行”

艺术与科学国际学术研讨会，“几何动艺”，清华大学美术学院，2006-11-11

上海国际科学与艺术展，2007-5-10，本人作品“双”获科学与艺术优秀作品奖

作者简历

1920　出生于湖北汉阳，留英工程师郭承恩的三子，郭承恩当时于汉冶萍钢铁厂负责钢铁生产

1943　毕业于上海沪江大学化学系

1947　美国普林斯顿大学化工硕士，在论文研究中首次观察到液/固和气/固流态化的差异，分别命名为“散式”和“聚式”流态化

1946～1947，1952～1956　纽约碳氢研究公司，开发煤气化、空气分离、气体净化及铁矿气体还原工艺；获三种美国专利

1948～1952　美国可口可乐公司，于新德里建造印度的第一个可口可乐工厂；负责纽约总部实验室；获1950年美国汽水同业会的彻斯德曼奖（碳化分析）

1956至今　中国科学院化工冶金研究所研究员、所长（1978～1986）、名誉所长（1986至今）。研究中国氧化铁矿的流态化焙烧（富集，分离有色金属，制金属铁粉）；流态化浸取和洗涤（提取有色和稀有金属）；提出“广义流态化”及其有关概念。近年著作：《理想

Autobiographical Notes of Author

1920　born Hanyang, Hubei Province, China; third son of British trained engineer, Z. U. Kwauk, who produced iron and steel at Hanyeping Ltd., the only ferrous metals maker in those days

1943　B. S., chemistry, University of Shanghai

1947　M. S, chemical engineering, Princeton University; noted in dissertation research the distinct behavior of fluidization of solid particles with a liquid and with a gas, for which the designations, “particulate” and “aggregative” were proposed respectively

1946－1947, 1952－1956　Hydrocarbon Research Inc., New York: process development in coal gasification, air separation, gas purification, gaseous reduction of iron ores; 3 U. S. patents

1948－1952　Coca-Cola Export Corporation: built first bottling plant (New Dehli) in India; headed laboratory in New York; received Chesterman Award in 1950 of American Bottlers of Carbonated Beverages for analysis of carbonation

1956－date　Institute of Chemical Metallurgy, Academia Sinica: professor, director 1978－1986, emeritus director since 1986. Research: fluidized roasting of oxidic Chinese iron ores for upgrading, for separation of nonferrous metals and for powdered iron; fluidized leaching and washing of ores for winning nonferrous or rare metals; proposed “generalized fluidization”, and other basic concepts. Latest books: *Idealized and Bubbleless Fluid-*

和无气泡流态化》(1992)，科学出版社和 Ellis Horwood，《快速流态化》(1994)，Academic Press。获奖：两次全国自然科学二等奖(1982 和 1990)；国际流态化成就奖(1989，加拿大)。1980 年当选为中国科学院院士；访问教授(1986～1987 美国弗吉尼亚工业大学，1989 年美国俄亥俄州立大学)；1984 年英国拉夫保罗 Davis-Swindin 讲师；1989 年英国伦敦 Danckwerts 讲师；1997 年当选为瑞士工程科学院外籍院士

ization, 1992, Science Press and Ellis Horwood, "*Fast Fluidization*," 1994, Academic Press. Awards: twice, National Natural Science Award, second class, 1982 and 1990; International Fluidization Award, 1989, Canada. Elected 1980 Member, Chinese Academiy of Sciences; visiting professor (1986 – 1987 Virginia Polytechnic Institute and State University, 1989 Ohio State University) 1984 Davis – Swindin lecturer, Loughborough; 1989 Danckwerts lecturer, London; elected 1997 Corresponding Member, Swiss Academy of Engineering Science

1950 结婚，爱人桂慧君为美国波士顿大学社会工作硕士；长子伟明，美国 SCI 公司；女儿瑞明，美国特拉华谷金融服务公司；次子向明，美国 Solstice 公司

1950 married to Huichun Kwei, M. S., social work, Boston University; son, Weimin, software analyst, SCI Corp., Huntsville, Alabama; daughter, Reimin, programmer/analyst, Delaware Valley Financial Service, Berwyn, Pennsylvania; son, Xianmin, engineer, Solstice Software, Claymont, Delaware

目　录

Contents

我是怎样开始制作“几何动艺”的

在我幼年时，父亲教我做风筝。他是个工程师，对风筝的制作有自己的想法，而不循传统。他的风筝有的能飞，有的却上不了天。这远在空气动力学建立之前。当时的业余爱好者也很少用科学方法认真研究他们的作品。

从此，我对风动玩具和设备有了兴趣。风筝在中国曾用于军事，当作侦察和投射的工具。另一个具有中国特色的风动玩具是走马灯，用点燃蜡烛的热气进行驱动。走马灯可用绘图或小件模型装饰，使其运转更生动迷人。

中国南方农村田野中常可看到风车，用于输水、碾米、磨面。这和欧洲一些国家相同。可是这些风动工具大都代代相传，对其进行研究的人并不太多。外来的游客往往见之好奇，但当地的居民早习以为常。

中国人习惯于对现象的抽象。中国的文字就始于象形，从代表形态逐步发展至代表概念。我从幼年成长，逐步对刻图章感兴趣，当然采用的都

HOW DID I BECOME INTERESTED IN MAKING MOBILES

As a young boy I was taught by my father how to make kites. He was an engineer, and as all engineers do, he had his own ideas of making kites, apart from accepted practice. Some of the kites would fly, and some would not. This predated aerodynamics as an established discipline in engineering, and the then hobbyist rarely went to the extreme of giving serious studies to what he was doing.

I have since become interested in wind-driven toys and devices. Kites were used in China for military purposes as well, such as releasing lethal missiles from high vantage points onto the enemy or reconnaisance by hoisting observers up in the sky. A toy which is made even to this date is the hot-air driven circus lantern, with acrobats painted on a paper cylinder illuminated from the inside by a lit candle, which also rotates the cylinder by propelling a paper windmill located at the top. Sometimes the acrobats are replaced by figurines of spear-bearing cavaliers attached to the windmill, thus imparting even more realistic animation.

Windmills are sometimes used in the Chinese countryside for power, just as they are in Europe or other parts of the world. But all these, toys and devices used in productive activities, have been handed down from generation to generation with the barest attention to innovation or even improvement. To the casual observer they may seem novel, but for those who have lived with them, they are mere morsels of an old institution, established and somewhat mundane.

The Chinese also possess the inclination to pursue the abstract. For example, the Chinese characters have their origin in ideograms which are pictorial representations of objects, motion, or even ideas. So, as I grew up, I became interested in engraving seals using archaic Chinese script, and later, in designing and

是篆字。后来，又常用英文字母为朋友设计人名首母的母标，为学术会议设计会标。

making monograms for friends and logos for conferences and books.

我年轻时旅居美国期间既注意到几何动艺，偶尔我也做些动艺，但从未认真地去设计和制作。特别是我成年后将绝大部分精力投于科研工作，没有时间搞业余爱好。现在我已退休，能支配一些自己的时间了，于是又拣起年轻时的爱好。

Mobiles, in their modern sense, caught my attention when I lived in the United States in my younger years. Sporadically I made weak attempts at designing and making mobiles, but my efforts proved to be rather futile, especially in my later years, when as director of research, I felt myself almost constantly on call during all my waking hours. Now that I am retired from active duties, I begin to have the luxury of leisure and have taken up mobile-making as a continuation of what I relinquished in my younger years.

1986 年从负责岗位退下以后，我开始有系统地制作几何动艺。在初始的两年中，我制作了二十多个几何动艺的模型，并对如何形成概念、如何设计、如何进行数学模拟及制作，提出了一套制约条件。同其他研究工作一样，我对制作几何动艺保存了不少文字记录，于是到 1989 年我已写成了本书的初稿。1993 年，我在内部出版了我的第 10 稿。1998 年由化学工业出版社出版了第 11 稿。本书为第 12 稿，包含了对文字和制图方面的不少改进，增加了设计内容，并提出了如何平衡和串联动艺的新方法。

Since my retirement as director of research in late 1986, I started a somewhat systematic effort at making mobiles. In about two years I had accumulated about two dozen prototypes of my own design, and had formulated a set of rules, or "constraints", for conceptualization, design, mathematical modeling and construction. From the ample notes that I kept for what I had made, I wrote, in early 1989, the first draft of this book, and in 1993, I printed 100 copies of my 10th draft. The 11th draft was published by Chemical Industry Press in 1998, and the present 12th draft contains improvements in text and figures, additional examples of design, as well as new ideas on balancing and stringup of mobile members.

对我来说，几何动艺的魅力在于抽象的形状、不可测的运动以及设计者对形状和运动的全局控制能力。特别是数学模型更可使设计者定量地掌握他所构想的形状和运动。

As I see it, the attraction of mobiles lies in their abstraction in shape, irregularity in motion and yet a deterministic approach in design. Whenever mathematical formulation is possible, mobiles represent the objective realization of a designer's endeavour at creating shape and motion in harmony with given sets of constraints.

我不具什么艺术背景，且生长在中国，对西方的动艺大师，如 Alexander Calder 和 George Rickey，仅在近年去美国访问时才见到一些他们的作品。

Coming from a nonartist background, and, perhaps, from a different culture, I came to know the names of the accomplished masters in mobile-making very late in my life, and began to admire the creative genius of Alexander Calder and George Rickey only during my very recent visits in the United States.

制约条件

我对动艺的设计和制作，自定了一些制约条件，以突出其形状和运动的构思：

（1）形状必须在几何上可述。

（2）材料限于棒、丝形或板、片形，除了磨平抛光外，不加表面修饰或上色。

（3）“七巧板”似的裁切下料，尽可能不浪费材料，组件能拼回原状。

（4）动艺部件的平衡需循数学模拟，强调设计的科学性和普适性。

（5）室内陈列，要求观看者的呼吸和身体运动足以启动作品，不考虑能否承受狂风的工程措施。

PROPOSED CONSTRAINTS

In developing the mobiles described in this book, certain self-imposed rules have been observed to accentuate the concept of shape and motion in space:

（1）shapes of mobile members to be geometrically definable.

（2）materials limited to rod/wire and plate/sheet with no extraneous ornamentation except high-quality surface finish.

（3）jigsaw layout of mobile members to minimize waste of materials and to further highlight the uniqueness of geometrically definable members.

（4）balancing of mobile members to be modeled mathematically which is facilitated by the use of geometrically definable members, thus adding another dimension to the aesthetics of mobile-making, namely, intellectual fulfilment.

（5）all mobiles driven by normal air current indoors-preferably by body movement or breathing of an observer standing nearby-and none to be engineered to withstand gale or hurricane outdoors.