INTO THE FUTURE WITH KNOWLEDGE FROM OUR PAST

A Sourcebook for

- **Archaeometallurgy**
- **Aviation**
- **Computer Science**
- **Optical Character Recognition**
- **Statecraft**
- **Vedic Mathematics**

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"Among the nations, during the course of centuries and throughout the passage of time, India was known as the mine of wisdom and the fountainhead of justice and good government and the Indians were credited with excellent intellects, exalted ideas, universal maxims, rare inventions and wonderful talents …."

- Sayid Al Andalusi

"India suffers today, in the estimation of the world, more through the world's ignorance of the achievements of the heroes of Indian history than through the absence or insignificance of such achievement."

- Vincent Smith

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PREFACE

Why is it necessary to go back into the past? Why is it important to re-discover what knowledge has been lost in the history of time? How could that knowledge be useful or relevant to us of the modern, advanced space age? For that matter, why should we study history or the science of evolution? History is full of stories of achievement and science is replete with stories of discoveries, with humankind being inspired to seek greater heights by the accomplishments of their forbears. A nation that has no record of its history forgets its heroes and loses its inspiration. Sir Isaac Newton, by his own admission, stood "on the shoulders of giants" to achieve all that he did. We in India too had "giants" whose discoveries we could have built upon. But, "Somewhere along the forgotten road of history, calamity – or deliberate destruction – lost to man the secrets he had amassed" (Desmond Doig in The Statesman, January 1956). It is necessary for us to re-discover these secrets so that we may truly understand the greatness of the nation we belong to and reclaim the potential of the vast intellectual capital that now lies dormant. It is important for us to rediscover, through this "knowledge from the past" our self-effacing heroes of yore so that in their singular achievements we may find our inspiration.

The VTT Scholar award was conceived to involve young people in this very significant task of re-discovering our history and re-constructing our past. An ideal VTT Scholar would try to discover more about our past than we know already. They would use the available information about India's heritage of knowledge in science, mathematics, arts and crafts,

1) to examine the possibility of newer applications for our ancient knowledge – for example, how far can a felicity with Vedic Mathematics help in a competitive entrance exam to institutions of higher education? Or
2) find hitherto unrecognized nuances in existing literature – for example, the Ramayana talks of snow in Panchavati, which today is near Nasik which is rarely even ´cold´ nowadays. Does this have any geological significance?

These 'discoveries' need not necessarily eulogize; a critical, scientific appraisal would be appreciated.

The VTT Scholar would receive a scholarship of Rs.300/- per month for one year during which they are expected to do some research on the relevance of ancient Indian knowledge (particularly in Sanskrit) to the present day. The research should exhibit some original thinking and spirit of inquiry. It cannot be merely reproduced from existing literature. At the end of the year, the VTT Scholar will be invited to present his/ her findings under the auspices of Sri Tirunarayana Trust.

October 2005 **Sri Tirunarayana Trust**

A BRIEF SKETCH OF OUR SPEAKERS[1]

Dr. T V SUBRAMANIAN

- Fellow in Management from the Indian Institute of Management, Ahmedabad.
- Honorary Fellow of the Indian Institute of Materials Management.
- Renowned management consultant and academician.
- Has executed more than 50 major consulting assignments and conducted more than 500 management development programmes in the areas of Strategic Management, Supply Chain Management, Operations Management and Information Technology Strategies.
- Deeply interested in the Sastras, Philosophy, Sanskrit and Tamil literature and spoken Sanskrit.

Dr. B. NARSING RAO

- B Tech in Chemical Engineering from IIT Madras, M Tech in Industrial Engineering from NITIE Bombay, PhD in Industrial Engineering from The University of Iowa, USA.
- Director of Technology at Interwoven, a company that specializes in software for enterprise content management.
- Provides technical direction to the company and directs the development of complex software systems.
- Has been senior executive at IBM Global Services, India; Professor at IIM Bangalore; positions in California State University and AT&T Bell Laboratories.
- Interest in Vedic chanting and Sanskrit.
- Regularly chants and teaches the chanting of the Rig Veda and the Krishna Yajur Veda. Studying Vyakarana Sastra in depth, fascinated by the contribution to linguistics made by ancient Sanskrit Grammarians.

Dr. H. K. ANASUYA DEVI

- Fellow of the National Institute of Advanced Studies.
- PhD in computational linguistics from the Indian Institute of Science and Masters in Sanskrit.
- Has been involved in research in Computational Linguistics and Artificial Intelligence, Natural Language Processing, Remote Sensing Applications and Expert Systems.
- Research interests include Human-Computer Interaction, Soft Computing, Pattern Recognition, Signal Processing, Remote Sensing Applications, Archaeology and Epigraphy.
- Has developed charts of the varieties of the Brahmi letters in Asokan Edicts from 3rd Century BC to 1st Century AD which is an important step in building an optical character recognition system for Brahmi Scripts.

1The speakers presented papers at the annual 'Into the Future with Knowledge from Our Past' series. This Sourcebook contains highly simplified versions of most of their papers.

Wg. Cdr. M P RAO

- Retired Aeronautical Engineering Officer of the Indian Air Force, with 25 years' experience in the maintenance of various aircrafts.
- Research in Aviation Science in ancient Indian literature since 1998.
- Extensive survey of literature beginning with Maharshi Bharadwaja's ´Vaimanika Prakaranam´ and enlarging the scope to include other aspects of aviation cited in the Puranas, Vedic Literature and History. Rare books, reports and other publications have been unearthed in the research.
- In a project assigned by the Ministry of Defence, Government of India, a report called 'Vaimanika Sastra – Rediscovered' was brought out.

Dr. SHARADA SRINIVASAN

- Phd. in Archaeometallurgy from University College London, MA in Art History from School of Oriental and African Studies, London and B.Tech from IIT, Powai.
- Associate Fellow, National Institute of Advanced Studies.
- Scholar in metals heritage, archaeometallurgy, scientific applications in art history, archaeology, conservation, crafts and performing arts documentation.
- Co-author of the book 'India's Legendary Wootz Steel', supported by Tata Steel.

Dr. P. K. SRIVATHSA

- Graduate in Civil Engineering, Post graduate in Management, Doctorate in Homeopathy, EXCEL trainer from JCI, Florida, USA.
- Management and Software Consultant, Trainer and Visiting Professor to Colleges of Management.
- Musicologist, Performing artiste on Veena and practising Homeopath.
- Extensive research in Management, Mathematics, Medicine and Music.

Mr. I V SRINIVAS KOWNDINYA

- VTT Scholar, 2004-05 and student of B.Sc, Sarada Vilas College, Mysore.

Mr. P N ADITYA

- VTT Scholar, 2004-05 and student of PUC, MES Pre University College, Bangalore.

ECONOMIC, MANAGEMENT AND ADMINISTRATIVE PRINCIPLES IN KAUTILYA'S *ARTHASASTRA* THAT ARE RELEVANT IN THE PRESENT DAY

T V Subramanian[1]

Why should we read a book, four thousand years old, to learn about economics, management and administration? Does it talk about subjects like J2EE or .net or portfolio management? If not, how is it useful in the present day context? The answer is: J2EE,.net etc. could become irrelevant in the next decade, because technology changes, and newer tools replace the older ones. Autocoder, for instance, was a computer programming language that was prevalent in the 1970s, but is obsolete today.

Arthasastra, on the other hand, does not talk about things that change. The principles and policies it contains are for all time to come, and they are for universal application as well. The very title suggests this, for the book deals with the acquisition and judicious management of wealth or *artha*, about which Kautilya says:

> *The subsistence of mankind is termed* artha *(wealth); the earth, which contains mankind, is also termed* artha*; that science which deals with the means of acquiring and maintaining artha is the* Arthasastra - *the Science of Polity.*

An Overview of *Arthasastra's* Contents

The book, written in simple Sanskrit, is a handbook on governance for the state that desires to be well-organised. In India, *Arthasastra* was included in the syllabus for students of Political Science till a few decades ago. The book has been translated into German and Russian and the book has now generated interest in Japan as well. Three American Universities, including Harvard's School of Public Administration, have done research in *Arthasastra*. Several dissertations on the subject have been submitted at the Delhi Institute of Public Administration and the Satya Sai Institute, India.

Arthasastra makes observations and provides guidelines for the efficient and effective operation of 35 departments such as Treasury, Trade, Foreign Affairs, Defence, Agriculture, Forestry, Mining, Law and Justice and even Weights and Measures, Textiles, Animal Husbandry, Ports, Reservoirs and Precious Metals.

The treatise contains laws for the orderly management / resolution of various facets of civilian life such as contracts, property inheritance, property sale and purchase, marriage disputes and public nuisance as well as for widow's rights and consumer protection, which are modern concepts.

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[1] Dr T V Subramanian is a management consultant and academician. This article is based on the presentation made by him on August 7, 2005 at Bangalore under the annual 'Into the Future with Knowledge from Our Past' series and his compilation of the work, based on R Shamashastry's translation of Arthasastra published by the Government Press, 1915.

Though some of his recommendations are preposterous, particularly those pertaining to harem maintenance and secret means to overcome enemies, more than 80% of his suggestions and observations are valid and very true to this day. Many of his recommendations pertaining to women show a progressive and understanding approach that one does not find even today. For instance, consider the following rules.

- On the death of her husband, a woman, desirous to lead a pious life, shall at once receive not only her endowment and jewellery (*sthapyabharanam*), but also the balance of *sulka(*शुल्क*)*due to her. If both of these two things are not actually in her possession, though nominally given to her, she shall at once receive both of them together with interest (on their value).
- A woman, hating her husband, cannot dissolve her marriage with him against his will. Nor can a man dissolve his marriage with his wife against her will. But from mutual enmity, divorce may be obtained (*parasparam dveshanmokshah*). If a man, apprehending danger from his wife desires divorce (*mokshamichhet*), he shall return to her whatever she was given (on the occasion of her marriage). If a woman, under the apprehension of danger from her husband, desires divorce, she shall forfeit her claim to her property.

A Strategic Approach to Statecraft

Let us now consider some of the observations made by Kautilya on management, administration and economic policy making that are relevant today and will be so for all time to come:

MANAGEMENT:

- There cannot be a country without people and there cannot be a kingdom without a country. A king without well-satisfied subjects is like a barren cow. An echo of these words may be found in Peter Drucker's famous statement that if there are no followers, there is no leader.
- The numbers of those who are scrupulously honest and those who are ingenious con artists are very few (*athi svalpa* - अति स्वल्प). Punishment (*dandaneeti* - दन्डनीति) is superfluous in their cases, but necessary to control the vast majority who are afraid of the law but will indulge in malpractices if there is a possibility. But punishment must be proportional to the crime, the consequence and the capacity of the offender.

ADMINISTRATION:

- प्रजा सुखे सुखम् राज्ञ प्रजानाम् च हितम् हितम् ।

  न आत्मप्रियम् हितम् राज्ञ प्रजानाम् तु प्रियम् हितम्॥ (1.13.34)

  "*prajA sukhE sukham rAjnya prajAnAm cha hitam hitam.*
  na Atmapriyam hitam rAjnya prajAnAm tu priyam hitam."(1.13.34)

  Meaning: In the happiness of his subjects lies a king's happiness; in their welfare his welfare. He shall **not** consider as good only that which pleases him but treat as beneficial to him whatever pleases the subjects.
- It is the primary role of a king or state to maintain the well-being of the subjects; this requires wealth and its judicious management.

- For the sustained *yoga kshema* - योगक्षेम (overall welfare) of the subjects, the king should be both a *raksha* - रक्षा (protector) and a *paalana* - पालन (administrator)

ECONOMIC PLANNING:

- The Treasury Manager is supreme, next only to the king and his ministers, for wealth alone enables creation of wealth. A king with a depleted treasury eats into the vitality of the country.
- The root of wealth is economic activity. Inactivity brings material distress. The state should run diverse economic activities prudently, efficiently and profitably. Without active policies and implementation, current prosperity as well as future gains are destroyed.
- Treasury must contain an emergency source for times of calamity. A special calamity tax must also be imposed at such times, with the ministers being charged first.
- Monopolies must be taxed additionally till competition emerges
- **Observations on revenue collection:** Just as a bee extracts honey from flowers, just as fruits are plucked only when fully ripe, just as one doesn't milk a sick cow so too one must collect taxes without hurting the subjects, only when the taxes are due and the old, the sick, those who have done service to the society and the vedic scholars who do not pursue a profession for pecuniary benefit must be exempted.

Lessons For The Present Day

- All policies should be citizen-centric and welfare-focused.
- Emphasise on efficiency and profitability of all economic activities.
- Law enforcement is as important as law enactment.
- Growth and expansion is necessary for the very survival of a country.
- Country's long-term interest should be the primary factor in all foreign policy dealings.
- A formal, well-designed organizational structure and systems and processes are essential for the smooth functioning of the state.

PĀṆINI AND COMPUTER SCIENCE

B Narsing Rao[1]

INTRODUCTION

Indian linguistics around 1000 BCE[2] was far more advanced than Western linguistics of the twentieth century. In fact, India has had a long, unbroken linguistic tradition which is several thousands of years old. Some of the most important personalities in this tradition are:

- Grammarians before *Pāṇini*, such as *Āpiśali*, *Gārgya*, and *Śākalya*
- *Pāṇini* (~ 500 BCE) who systematised Sanskrit grammar
- *Kātyāyana* (~ 300 BCE), who clarified certain ambiguities in *Pāṇini's* grammar
- *Patañjali* (~ 150 BCE), who wrote an important and exhaustive commentary on *Pāṇini's* grammar
- *Bhartruhari* (~ 500 CE), who wrote the *Vākyapadīya* - a work dealing with the philosophy of grammar.

In this article we highlight some important contributions made by the great grammarian Pāṇini and discuss how concepts developed by him are relevant to modern computer science.

Study of Language

Correct knowledge and use of language was considered to be of paramount importance in ancient India. Language was considered to be not only the basis of all knowledge but also, in a subtle way, of human existence itself. Not surprisingly, the major Indian language of those days was named *Samskruta*, which literally means "refined". The intense desire to systematically study language also led to the discovery of tools to do this with. In this case, the tools were two more disciplines – Mathematics and Logic.

The rigorous approach to the study of language comprised the following logical steps:

1. Formation of *Varnas (*वर्ण*)* based on sounds. *Varnas* are the basic building blocks that make up a language. Thus *varnas* in the Sanskrit language are mainly all the vowels (a to au - अ to औ) and all the consonants (ka to ha - क to ह),
2. Formation of words (*pada* - पद*)* from sounds (*varnas* - वर्ण*)*,

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[1]Dr Narasing Rao B is Director, Technology, Interwoven Software. This article is based on his paper and the presentation made by him on August 21, 2005 at Bangalore under the annual ´Into the Future with Knowledge from Our Past´ series..

[2]BCE is a modern, internationally accepted nomenclature for BC; it means: Before the Common Era.

3. Formation of sentences (*vākya* - वाक्य) from words,
4. The use of sentences to convey meaning, and ultimately,
5. Understanding the nature of the meaning that language seeks to convey.

Who was Panini?

Panini was a native of Shalātura, near Takshashila (Taxila), now in the North West Frontier Province of Pakistan. Here, we are mainly concerned with his work of grammar called *Ashtadhyayi (*अष्टाध्यायी*)*, which literally means ´That which comprises eight chapters´. In the eight chapters of *Ashtadhyayi*, each of which has four *pādas* - पाद (quarters), Panini has listed roughly four thousand rules (*sūtras* - सूत्र) pertaining to Sanksrit grammar. 2500 years after these rules were framed, Sanskrit continues to be governed by these very same rules! The western philosopher George Cardona has described the *Ashtadhyayi* as ¨One of the greatest monuments to human intelligence¨. Not that if Cardona had not said so Panini´s contribution would have become less valuable, but we have a tendency in our country to recognise greatness in our midst only if it is given the seal of approval by a foreigner.

Panini´s *Ashtadhyayi*

Ashtadhyayi is significant for the following reasons:

- It represents the first and only attempt by any human being to define completely the grammar of a natural language.
- It uses the novel idea that the grammar of a language can be defined using a set of rules.
- It uses a meta-language (Sanskrit with special vocabulary), to describe another language (Sanskrit itself, in this case).
- It uses many sophisticated concepts similar to the ones invented by a computer scientist called Backus, further refined by Naur. These concepts are being used in computer science roughly since the last 50 years. Modern computer programming languages can be defined using what is called the Backus Naur Form (BNF). *Panini's* grammar is very similar to BNF. This has so astonished researchers that it has been suggested that Backus Naur Form be renamed to honour Panini as Panini-Backus-Naur-Form!

Paninian Concepts and Computers

Panini uses several concepts that are now widely prevalent in mathematics and computer science. These concepts include sets, functions, tags, lexical scope, inheritance and meta-rules (rules about rules).

In this article we shall see how the concepts of sets, rule classification, meta rules, *asiddha(*असिद्ध*)* and *kāraka(*कारक*)* have been used by Panini.

Sets:

Varnas, as we just learnt, are the letters of the Sanskrit alphabet. They are organized in specified sequences, that are quite different from their alphabetic sequence, in 14 *sutras* in the *Ashtadhyayi.* These *sutra* sets and their subsets are known as *pratyāhāras(*प्रत्याहार*).* The creativity, conciseness, span and scope of these 14 *sutras* have led people to believe that these must have been obtained by the grace of Lord Mahesvara himself and are, hence, called the *´mAhesvarāṇi sūtrāni´* (माहेश्वराणि सूत्रानि).

Each of these *sutras* contain a varying number of *varnas*. They begin with a vowel or consonant and end with a special demarcation sound. There are, thus, 14 demarcation sounds for the 14 *sutras*. Sets, or *pratyaharas,* are made by identifying just two sounds – one *varna* from any of the 14 *sutras* and one following demarcation sound. This indicates the string of *varnas* that is contained between the *varna* and the demarcation sound.

For example,

Set {Vowels in the Sanskrit language} = *Pratyahara* {ach-अच्}.

The meaning of this *pratyahara* will become clear if you consider carefully the first four *sutras* in the *Maahesvarani Sutrani*, which go like this:

अ इ उ ण् (Sutra 1) – contains vowels *a, i, u* (demarcation sound = *N*)

ऋ लृक् (Sutra 2) – contains vowels *r lr* (demarcation sound = *k*)

ए ओङ् (Sutra 3) – contains vowels *E, O* (demarcation sound = *ng*)

ऐ औच् (Sutra 4) – contains vowels *ai, au* (demarcation sound = *ch*)

In the *pratyahara* or Set {*ach*}, *varna ´a´* indicates the first vowel *´a´* in *Sutra* 1 and *´ch´* the demarcation sound in *Sutra* 4. Since the *sutras* in between contain all the vowels (*svaras*), simply saying *{ach}* would tell a student of Sanskrit that what is being referred to is: Set {All the vowels in the Sanskrit language}. Consider how much more concise this is than making a set containing all vowels as we would, normally: Set (All the vowels in the Sanskrit language) = *{a, i, u, r, 1r, E, ai, O, au}* as against just *{ach}*

Panini has used *pratyaharas* extensively in *Ashtadhyayi* when formulating grammar rules. Simple *pratyaharas* obtained from the *Maaheshvarani Sutrani* are used ingeniously in the *Ashtadhyayi sutras* to indicate sets of *varnas* instead of listing all the *varnas* required.

Classification of sutras:

The rules defined by *Panini* can generally be classified as:

1) Definitions - which define grammatical terms
2) Clarifiers - they clarify anomalies in the *sutras*

3) Directives - which are instructions to perform some action

4) Declarations - of various terms having a given scope or applicability

5) Sutras which specify the conditions for a certain *sutra* to be applied

6) Sutras which control the application of a group of *sutras*

The third type of *sutras*, that is directives, is what is now normally understood by the term *rule* in computers. It has the following familiar structure:

IF (some set of conditions is true)
THEN (perform a given set of actions).

A simple rule is one in which there is one action which is performed when the given condition is satisfied. An example of this is:

IF {it is raining}
THEN {carry an umbrella}

A complex rule is one in which there can be many conditions and actions. An example of a complex rule is:

IF {it is raining} AND {it is windy}
THEN {carry an umbrella} AND {wear a raincoat};

An example of a directive in *Ashtadhyayi* is discussed below.

The rule Chapter 6, Part I, *Sutra* 77 in *Ashtadhyayi* reads**:** इकोयणचि (to be read as *ikOyaNachi)*
The *pratyahara,* or string set *´ik´*(इक्) in *´ikO´* stands for the four *varnas ´i u r lr´*(इ उ ऋ ऌ), in that order, contained in the first two *sutras* of the *Maaheshvara Sutras* (mentioned above).

Similarly, the *pratyahara ´yaN*'(यण्) represents the four *varnas ´ya va ra la´*(य व र ल), in that order, which are contained in 5th and 6th *sutras.* (Notice that the order *´ ya va ra la´* is different from the alphabetic sequence of *´ya ra la va´*, signifying the special purpose of this sequencing, which is to derive or construct appropriate sets)

The *pratyahara ´ach´*(अच्) in *´achi´*, as discussed under sets (details in sub-section on ´Sets´ above), represents all the vowels.

The rule *ikOyaNachi*, therefore, when deciphered states that:

´IF a word ending with any of the four *varnas ´i u r lr´* is followed by another word beginning with any vowel *{ach},*

THEN replace the last *varna* of the first word with that of the four *varnas ´ya va ra la´* respectively.

Example*: iti* + ***u****ktam = ity+uktam=ityuktam (*इति + उक्तम = इत्युक्तम्)

(Since the last vowel (इ)*'i'* in the word *' iti'* is followed by the vowel *'u'* (उ) in *'uktam'*, *'i'* (इ) is replaced by *'ya'* (य)and iti-uktam becomes ityuktam.

Meta rules:

A situation may arise wherein for a given set of conditions more than one rule may become applicable at the same time and these may specify conflicting actions. In such a situation we need rules about rules or rules that govern application of rules. Such rules are called meta-rules. These specify which of the multiple rules is applicable in this conflicting situation.

For example, in Sanskrit, मुनि + इन्द्रः = मुनीन्द्रः muni+indraH=mun**I**ndraH

You will notice that in this case the rule *´ikOyaNachi´* discussed above has not been applied though the vowel *'i'* in '*muni*' is followed by a word beginning with another vowel, in this case, *'i'* in '*indra'*. The reason for this is, the formation of the word *munIndra* has been governed by a rule that appears in Chapter 6, Part I, Rule 101. One of the meta rules in *Ashtadhyayi* states that a rule which comes later in the *Ashtadhyayi* overrides a rule that has come earlier. Hence in this situation the rule 6-1-101 has been applied and not the earlier *ikOyaNachi*, which is rule 6-1- 77.

Asiddha:

´Asiddha´ is a unique concept introduced in Paninian *Sutras*. Applying this concept, Panini has divided his *Ashtadhyayi* into two parts. The demarcation point is indicated by the rule *´*पूर्वत्रासिद्धम्*´* (Chapter 8, part 2, *sutra* 1). This rule states that an action performed by a rule which is after the rule 8-2-1 is not ¨visible¨ to those rules which come prior to rule 8-2-1.

Thus,

IF {a rule (say rule A) which appears in *Ashtadhyayi* after rule 8-2-1 has been applied and the words transformed accordingly}

AND {as a result of this transformation, another rule (say rule B) becomes applicable, but rule B comes chronologically before rule A in *Ashtadhyayi*},

THEN rule B does not consider that rule A has been applied. As far as rule B is concerned, no transformation has occurred (*asiddha*) to the words, though in fact rule A has been applied. As a result of this, the transformed words are not considered a candidate for application of rule B.

Consider the following example:

Let us say, we have the two words*: tasmai+Etat (*तस्मै + एतत्) In the combination of these two words the conditions are such that the rule 6-1-78 gets activated.

Step 1: These words get transformed into तस्माय् + एतत् *(tasmAy+Etat),* as per rule 6-1-78

Step 2: The moment the above transformation happens, new conditions make another rule (8-3-19) applicable. The word form then gets changed to *tasmA+Etat* (तस्मा + एतत्) (dropping the last letter *´y´* in the first word)

Step 3: This new transformation has resulted in a condition that should normally activate another rule 6-1-88 and change *tasmA Etat* further to ´*tasmaitat*´.

But in this case, governed by the meta rule 8-2-1 (*PurvatrAsiddham*), rule 6-1-88 does not perceive the result of action performed by rule 8-3-19. It is as though the condition required for its activation has not happened. As such this rule does not get activated and no further transformation happens. The words remain as they were at the end of step 2 (*tasmA etat*). Thus, transformation caused by rule 8-3-19 is ensured.

Such structures can beneficially be adopted in computer science to concisely and precisely handle exception conditions.

Kārakas:

Kāraka is a simple technique that Panini uses to make clear the meaning of the nouns in a sentence with respect to their relation with each other and to the verb, by simply adding specific, pre-set syllables to the basic noun form. These determining syllables are known as case-endings or *vibhakti pratyayas*. There are 7 *vibhaktis* that each noun can end in, depending on the ´case´ or the relationship of the noun to other words in the sentence. These few syllables added at the end of a subject or an object can change the meaning of a sentence entirely. For example, consider the following sentences:

1. रामः बालकम् **ग्रामात्** याति - Ramaha baalakam **graamaat** yaati.
2. रामः बालकम् **ग्रामम्** याति - Ramaha baalakam **graamam** yaati

   Their meanings are:

   1. Rama **brings** the boy **from** the village.
   2. Rama **takes** the boy **to** the village.

Did you notice that in English, four different words are required to make the required changes, whereas in Sanskrit just changing the *vibhakti* of one word conveys the difference in meaning?

Panini's contribution can be used effectively in:

- Natural Language Processing (NLP) using computers
- Artificial Intelligence (AI) while developing rule based expert systems.
- Search engines such as Google to make concept specific searches possible rather than searches based on mere word strings as it is now.

Programming is a part of it but Computer Science has to do, basically, with developing algorithms or problem solving methods. Browsing the web has become a necessity in this information age. There is a constant search for newer and better ways of connecting customers to the information they are seeking. Panini's *Ashtadhyayi* – the *'karaka'* theory, in particular - can provide the inspiration for developing cutting edge information retrieval algorithms that will result in novel, effective approaches to navigating the Internet and getting less broad, more qualified information. Representation of relationships is, probably, the major contribution of Panini.

AUTOMATED RECOGNITION OF ANCIENT INDIAN SCRIPTS

H K Anasuya Devi[1]

1. What are Scripts?

By scripts we mean ´writing systems´, which are different from ´language systems´. Language systems express human thinking. Writing systems record these thoughts for communication, preservation and propagation. Different writing systems or scripts have been used, over several millennia, to express thoughts in specific language systems that have suited human genius at that period in time. For example, the epic, *Ramayana*, which is composed in Sanskrit language, has been transcribed over a period of time in several scripts including Kannada - the script in which most of us in Karnataka have read this epic - and many other Indian and even non-Indian scripts. In the former case, that is, script being Sanskrit, the Language system and the Writing System are the same and in the latter cases they are different. Similarly, we find that several of the Asokan edicts or proclamations of Emperor Asoka (3rd Century B.C) are written in *Brahmi* script, but the language employed to express the message contained in them is *Prakrut*.

When we look at ancient scripts, or writing systems, we find them evolving or changing over time - over the centuries they have been in existence. What has caused such changes? Writing systems as well as language systems have changed due to environmental influences on them such as changes in societal values, in social norms, in polity, due to historical influences, influences of other languages in vogue at that time and even economic influences. We also find that because of these influences some of the scripts that were in existence a few thousand years ago, or even a few hundred years ago, are now extinct. If they are not completely extinct, only very few know how to read or write using that script.

Scripts and languages continue to exist, or become extinct, depending on:

- the vastness of the literature that is available in it, which could be of the genre Science, Philosophy, Religion, Arts, Prose, Poetry, Drama, Administrative proclamations, Judicial pronouncements, and such others,
- the economic benefit and social recognition that would ensue on knowing a language,
- cohesiveness of a social, or linguistic group, and
- the necessity of it in order to communicate trans-nationally for the purpose of trade, commerce, education, research and social interchange.

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Languages and scripts also transform over a period of time by including in themselves elements from other languages or scripts.

2. An Overview of the Work Involved in Studying Ancient Indian Scripts

Consider for a moment that we are now engaged in reading several artifacts, or objects, which could be rock edicts, paper scrolls, palm leaf manuscripts or even books belonging to different time periods, all written in a specific script, say Brahmi. How can we understand them all correctly, unless we are also aware of the changes that Brahmi might have undergone during this time period? If we do not take suitable note of script and language evolution, while reading these artifacts we will surely encounter unfamiliar symbols, alphabets and numbers, resulting in incorrect reading and leading to incorrect understanding of the artifact. This observation leads us to an important step – the awareness of the need to build a set of symbols, a corpus of symbols or a table of symbols that have been used to express a letter, a number, an idea or a concept. Every time we encounter an unfamiliar or slightly variant symbol in our reading, we can then consult our corpus of symbols and determine what that symbol could mean or represent.

2.a. Building a corpus of symbols

How do we build a corpus of symbols? This requires, initially, knowledgeable persons in that specific language, script and preferably in the subject matter dealt with. These persons will have to read the artifacts or any material available in that script and help us to build a corpus of notations and what they stand for. If such notations are available because of previous efforts by others in the past or at present, these should also be included because only then will we be able to get a rich set of notations containing different styles and patterns of the same symbol or letter, or number, including their meanings. Fortunately, for Brahmi, with which we at NIAS - the National Institute of Advanced Studies - are concerned, a corpus of notations is available due to past efforts by scholars – Epigraphists, Archaeologists, Linguists, Indologists and Anthropologists. We have improved upon this corpus by studying other artifacts and taking relevant information from them.

2.b. Building a dictionary

In addition to the notations or corpus of symbols, it is necessary to build a vocabulary - a dictionary containing various meanings for the words used in the language. Let us say that we now know the words and their meaning. What is the utility of building such a dictionary? Let us once again consider the artifacts. We are all aware that many of these are in the medium that have decayed due to passage of time. Edicts on rocks have decayed due to rain, sunshine and ignorant vandalism. Works on palm leaf manuscripts have decayed for want of proper care and preservation methods. This, as you can imagine, has resulted in the fading, distortion and even erasion of many symbols, letters and numbers. Our first process, therefore, would be to clean the text by removing what is called ¨noise¨ that is layers of unwanted material while retaining the script, so as to get a clean image. Now, after doing all these when we get to read a word that is partially obscured, we can then make an informed guess about the proper or suitable word, with the help of the dictionary constructed above. Therefore,

dictionaries or corpus of words are useful in tackling the problem of decay.

2.c. Interpreting sentences

As all of us know, this in itself is not sufficient. We should understand sentences and only then will we be able to supply the missing word based on the context and the subject matter, or domain being discussed in the book or artifact. For this, we should have the ability to interpret sentences both for the correctness of its structure (syntactic analysis based on the rules of grammar) and the correctness of meaning (semantic analysis, based on domain knowledge). This again is a complex matter, particularly so when we are talking not about a single artifact, but about hundreds of them, thousands of them.

3. Using Computers to Study Ancient Indian Scripts

We have so far encountered a few of the many layers of complexity:

- of identifying symbols,
- variations and transformations in symbols,
- building a dictionary of words,
- cleaning the image by elimination of noise,
- substituting missing letters and words and
- finally arriving at a text which is faithful to that found in the artifact.

As we are faced with multi-level complexity, automation or using computer systems that are appropriate to the task and building software solutions that encompass all the tasks, briefly discussed above, seems to be the only approach to the process of reading ancient Indian manuscripts. Automated processes, refined through many cycles of trial and error, not only yield desired result, which in this case is reading an ancient artifact correctly, but also become powerful tools when tackling similar problems with different dimensions, for example reading old Sanskrit, Kannada or Tamil scripts.

At NIAS, we have developed in this context various image processing techniques, successive levels of filtering, techniques for segmentation of sentences and words, techniques for syntactic and semantic analyses, Artificial Intelligence based expert systems, verification and validation processes, continuous learning process through reading of several artifacts and building of vocabulary and symbols etc..., details of which I am not in a position to share with you at this stage, as we are now in the process of safeguarding our Intellectual Property Rights (IPR).

As I have said before, the Asokan edicts were written in Brahmi whereas the proclamations themselves were in Prakrut. Since the script of the Asokan edicts was Brahmi, one can surmise that *Prakrut* did not have a script of its own and also that the common man knew how to read and write Brahmi. Be that as it may, it is a fact that much of ancient Indian thought has been expressed in Sanskrit and Sanskrit has had great influence on other Indian languages both past and present and even on some non-Indian languages. What is important here is to note that if we now succeed in reading and

interpreting a book or any written material in an ancient language such as Brahmi that has been quite extinct, the process and the methodology developed in doing so could well be employed to understand written material in other ancient languages. The process and methodology, thus, could be applied to books in Sanskrit and this will help many scientists to correctly interpret our ancient books and infer the scientific content they may contain.

In conclusion, automating the reading of ancient Indian scripts involves multiple complex tasks pertaining to script, language, decay and multiplicity of medium, elimination of noise in images, and sense making, transcending varied computational and linguistic technologies. Such an effort would bring past to the present enabling holistic learning in our quest for a better future.

AVIATION SCIENCE IN ANCIENT INDIA

M P Rao[1]

Introduction

If you undertake a study of aviation science in ancient India, you would come across many treatises of pre-historic and medieval periods that talk about the subject. References are made to air borne machines, moving under their own power, from place to place, island to island and from one *loka* to another. In Sanskrit, *'vi'* means 'bird' and *'mana'* means 'like'; *vimana*, therefore, apparently denotes a craft flying like a bird under it's own volition. It appears that ancient Indians too, like their modern western counterparts, conceived flying craft inspired by birds. The present exposition is, essentially, based on the study of and research on Bharadwaja's *Vaimanika Prakaranam.*

Vaimanika Prakaranam – an Overview

Vaimanika Prakaranam is a part of *Yantra Sarvasva* (An Encyclopaedia of Machines), authored by Rishi Bharadwaja. Tradition has it that his life spanned both the *Treta* and *Dwapara Yugas*. His book, hence, is at least more than 2500 years old. In addition, in the introductory passages of *Vaimanika Prakaranam*, the sage himself explains that what was being presented was but knowledge culled out from the *Vedas.* The *Vedas*, as you all know, are much older!

- In the 10th century AD, Bodhananda wrote *vrittis*, or commentaries, explaining the contents of *Vaimanika Prakaranam*.
- After a hibernation of almost nine hundred years, some time between 1895 and 1918 AD, Pandit Anekal Subbaraya Shastri resurrected the *Vaimanika Prakaranam* along with other *Bhautika Shastras* (Physical Sciences).
- The transcripts, in Sanskrit, were sent to Oriental Research Libraries in Pune and Baroda.
- The Hindi version, called *Brihad Vimana Shastra*, was published by Dayananda Bhavan, Delhi in 1959.
- English translation of the *Vaimanika Prakaranam* was done by G R Josyar of Mysore and published as *Vaimanika Shastra* in 1973.

It is revealing that principles propounded by other well known *rishis* and preceptors such as Atri, Shaunaka, Lallacharya, Galava, Agastya and Visvambhara are also cited in the *Vaimanika Prakaranam*. Further, the principles so quoted draw references from certain topic-specific works such as *Anshu Bodhini, Valmiki Ganita, Yana Bindu, Loha Kalpa, Kriya Sara, Rahasya Lahiri*, and over 40 such works. It appears that these reference works constituted a body of core research knowledge that applied sciences like *Vaimanika Shastra* could draw upon.

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[1]Wg. Cdr. M P Rao retired from the Indian Air Force. This article is based on his paper on the subject and his presentation at Bangalore on September 4, 2005 under the annual ´Into the Future with Knowledge from Our Past´ series.

Contents of *Vaimanika Prakaranam*

In about 600 aphorisms (crisp, short *sutras* / rules), Bharadwaja has dwelt on a number of topics pertaining to flying machines, of which this paper presents an overview of a few:

The pilot

There are various terms used to refer to the pilot. He is called *'rahasyagnodhikari'*, that is a master custodian of flying craft and its systems; an *'akashayodha'*, meaning a warrior in the sky, affirming that air combat was a part of warfare; and *'saubhika'*, meaning 'juggler'.

Techniques of offence and defence on board *vimanas*

Thirty two techniques termed *'rahasyas'* or 'secrets' have been discussed. These techniques, coupled with references to the high skill levels in performing spectacular manoeuvers, - a basic qualitative requirement of the pilot - confirm that the aircraft being talked about in the *Vaimanika Prakaranam* includes combat craft for war applications. Many of these features are comparable to, and even closely resemble systems seen in modern military aircraft. This should be a matter of interest to connoisseurs of military aviation science. The following table illustrates some of these concepts.

TABLE I: Concepts in *Vaimanika Prakaranam* and Comparative Modern Aviation Techniques

	Concepts In *Vaimanika Prakaranam*	Equivalent Contemporary Aviation Techniques
1.	***Adrishya*** – Make *vimana* invisible by producing a smoke cocoon around it.	Detection avoidance and deception tactics.
2.	***Sarpagamana*** – Achieve zig-zag motion while flying to make chasing and targeting difficult.	
3.	***Antaraala*** – Forewarning of danger zones in flying routes and atmosphere.	Safe flying and advance warning techniques
4	***Vistrita*** – Expanding wings to protect overheating of some parts.	
5	***Sankocha*** – While at high speeds, constricting the profile by folding	
6	***Paroksha*** – Harnessing atmospheric energy for directing against enemy.	Strategic/ tactical strike rolls, psychological warfare tactics, biological warfare tactics.
7	***Stamblaha*** – Discharging *apasmara* – a poisonous smoke on the enemy to incapacitate them.	
8	***Parashamba grahaka*** – Intercept audio communication among enemy *vimanas*	Communication interception, aerial photo reconnaissance, photo intelligence.
9	***Roopakarshana*** – Taking pictures of activities inside enemy vimana	
10	***Kriyagrahana*** – Getting pictures of activities below the flight path of the aircraft.	

Diet and clothing for the aviator

Vaimanika Prakaranam has exclusive chapters dealing with food for the pilot and occupational clothing. Season-specific food is prescribed for the pilot's physical fitness and nutrition and season-specific clothing to ward off the ill effects of radiation. It is also prescribed that the pilot consume food 5 times in a day, twice after dark. Interestingly, modern aviation also makes it mandatory for pilots to desist from flying on an empty stomach.

Foods for normal times as well as packaged or ready-to-eat foods, as well as food prepared from grasses, herbs and roots for times of drought are mentioned with references from texts such as *Ashana Kalpa* and *Lalla Karika*. Sages like Atri and Galava discuss the manufacture of fabrics from cotton, wool, silk as well as leather, hair and moss.

The atmosphere

Vaimanika Prakaranam stresses that it is vital for pilots to have a thorough knowledge of the atmosphere. The route through bands of atmosphere up to 1500 km, denoted as *'avartas'*, have been discussed. The point of interest to modern science is that the characteristics and bandwidth of the *avartas* correspond well with what we know about atmospheric bands such as troposphere, stratosphere etc. The findings from the *Vaimanika Prakaranam* in this regard are tabulated below:

Troposphere	Rekha patha	High air density	Shaktyavarta
Stratosphere	Mandal patha	Clear Air Turbulence	Vatavarta
Mesosphere	Kendra patha	Extreme Cold	Shaityavarta
Thermosphere	Sakti patha	Extreme Heat	Gharshanavarta
Van-Allen Belt	Kaksha patha	Radiation hazards	Kiranavarta

Function based parts of the *vimana* and application specific *yantras*

Bharadwaja discusses special parts and features of the aircraft, meant for specific functions. The locations specified for these parts or fixtures seem to have been aptly chosen. Thirty one such parts are enumerated in the chapter dealing with parts of the aircraft. However, the most sophisticated and exciting part of the book is the chapter on contrivances, called *Yantradhikaranam.* This chapter, which constitutes almost half of the treatise, describes the various devices and explains how they must be arranged to provide the desired effect. This chapter has been the focus of a lot of research by modern scientists. Correct interpretation of key words in the aphorisms *(sutras)* relating to *yantras* have helped the researchers arrive at logical interpretations about the intended functional roles of these devices. However, a deeper study of the chapter and experimentation based on the findings is required.

TABLE 3: Contrivances and their Potential Uses		
	Yantra	**Interpretations**
1	Visvakriya Darshana Darpana Yantra	A telescopic camera arrangement to take pictures of activities below the craft. (Even constructional drawings have been made by researchers)
2	Parivesha Kriya Yantra	An auto guidance device to keep the *vimana* in a desired flight path
3	Prana Kundalini Yantra	Throttle control to regulate the speed of propulsion power plant.
4	Dikpradakshna Yantra	Direction finder to get warning of direction of approach of enemy *vimana.*
5	Pushpani Yantra	To produce cabin comfort on the lines of present day cabins.
6	Shabdakarshana Yantra	Device to forewarn about the presence of birds and quadrupeds in the vicinity to help pilots take a deviation.
7	Guha Garbha Yantra	Using *vimana* as an aerial platform, detecting presence of explosives hidden underground.

CORE METALS AND ALLOYS

The treatise prescribes three core metals - *somaka, saundalika* and *maurthvika* - and their alloys for construction of *vimanas.* The basic requirements of these materials are lightness, strength and heat absorption / resistance. The prescribed properties of these metals indicate that they are in consonance with structural materials used in modern aeronautics.

Even geological aspects relating to formation of ores, the specified layers of the earth from where they are to be obtained, causative factors governing the ore formation such as temperature, centrifugal force of earth, and pressure inside earth's crust have been considered by Bharadwaja. While modern geologists too consider these aspects when prospecting for ores, *Vaimanika Prakaranam* also discusses additional factors such as intra-planetary forces of attraction in specified ratios and the gravitational force of the centre of universe while talking about the availability and nature of the metal ores.

Elaborate metallurgical processes such as extraction, purification, melting and mixing three core metals and making 16 types of alloys are discussed. Metallurgical processes explain the use of varieties of crucibles, furnaces and bellows of various shapes. These supporting tools themselves reflect on the existence of a high order of material practice.

PROPERTY – SPECIFIC MATERIALS

Many unique and property specific materials are specified for constructing *yantras.* These include metallic and non-metallic materials as well as acids (*drava*), glues (*lepa*) and mirrors (*darpana*). These materials are made of various ingredients, sometimes numbering up to 20, and are of organic and inorganic nature. They include parts from animals and birds, botanical plants and substances derived from oceanic organisms.

In the last decade, this aspect of *Vaimanika Prakaranam* has attracted many modern scientists who have developed materials in their labs as per formulae given in *Vaimanika Shastra* (the English translation of *Vaimanika Prakaranam*) and related works such as *Anshu Bodhini.* Given a fair chance to the research activists, a new family of materials and a parallel generation of material technology could evolve. Bio-metallurgy is a new branch of modern science and research in this branch of science should giving a fillip to olden metallurgical practices

VARIETIES OF *VIMANAS*

Twenty five types of aircraft are listed, of which four of them in the *Kritaka* category are discussed in some detail. Diagrams of these aircraft are given and provide a rough idea, though they need to be reviewed. These *vimanas* are called *Shakuna, Sundara, Rukma* and *Tripura*. Their constructional details such as alloys used in their construction, structural parts, propulsion system, on board accessories, electrical and solar energy harnessing, flying control arrangements are explained. Propulsion energy systems derive energy from engine-driven propellers, internal combustion, jet propulsion, mercury and solar energy.

- *Shakuna*, apparently, is one of the early conceptions under the *Kritaka vimana* category.
- The significant feature of *Sundara vimana* is its jet propulsion system that uses a mixture of three oils.
- The *Rukma vimana* has the appearance of a beautiful hovercraft, being golden in colour; it uses solar energy.
- *Tripura vimana* is a unique three-in-one concept, as it is designed to operate under water, on land and in space; it has a three-tier construction, one for each flying application, and is propelled by solar power.

Other Aspects of Science Contained in Aviation Science of Ancient India

- Principles elucidated in *Vaimanika Prakaranam* refer to several core texts, hinting at a broad based research.
- While discussing formation of metallic ores in the earth's crust, the causative factors considered are: force of earth's rotation, temperature and humidity inside the earth, gravitational force of earth, gravitational influence of other planets, stars and even the centre of the universe.
- Material science includes substances of metallic, non-metallic, organic, inorganic, botanical and herbal and oceanic origins.

- Materials are classified on the basis of their source into categories such as: artificial or synthetic, soil origin, aquatic origin, mineral origin, vegetation origin, vermin based, animal origin, hair origin and egg born.
- Mercury has been mentioned as a potent source of energy in a number of applications.
- Mirrors have been used for harnessing, radiating and controlling energy.
- Units of measurements have been defined indicating the existence of a standard system:

TABLE 4: Units of measurement in Vaimanika Prakaranam

Measurement	Unit Of Measurement
Length	Vitasthi, Angula, Danda, Krosha
Weight	Mushthi, Linka, Pala
Temperature	Kakshya
Speed	Prenkhana, Linka
Time	Ghatika
Volume	Drona

- Description of special clothing for pilots indicates that knowledge of fabric technology extended to the use of silk, cotton, wool, hair, moss and leather.
- Energy has been harnessed from unique sources such as the atmosphere, clouds and air currents besides solar radiation.
- Stipulations of close melting temperatures cited in material production hint at precision in pyrometry.
- Knowledge of high potency explosives and their detection methods indicate a different kind of warfare, akin to recent centuries.

CULTURAL AND ARTISTIC SIGNIFICANCE OF INDIA´S METALS HERITAGE[1]

"From the smallest insignificant piece of construction material to delicate works of art, all these objects show the incredible amount of labour and the fascinating knowledge of our ancestors."[2]

Archaeometallurgy is the study of this "fascinating knowledge" of metals that our ancestors had. This science helps us find answers to questions such as:

- How were metals produced in the past and what was the technology involved?
- Where were the mines and how were they operated ?
- What kinds of objects and artefacts were manufactured ?
- Which were the societies or cultures involved and what was the environmental and economic impact on them?

CHRONOLOGY OF INDIAN METALLURGICAL HERITAGE[3]

Use of **Copper** : 4000 BC
Making of **Bronze** alloy by smelting copper and tin ore together: 3500 BC
Iron metallurgy: 1000 BC
Zinc metallurgy, making of brass alloy by mixing pure zinc and pure copper: 100BC

Gold And Silver

Early gold and silver ornaments from the Indian subcontinent are found from Indus Valley sites such as Mohenjo-daro (3000 BC). These are on display in the National Museum, New Delhi. In the first millenium BC, the Aravalli region of India was among the few major silver producing sites and the Maski region of Karnataka had some of the deepest gold mines.

Bronze

Some of the most beautiful and well executed bronze castings in the world are the icons of the Chola period and are from the Thanjavur area of south India (10th c. AD). But, what is probably more fascinating is the bronze ´dancing girl´ statue from Mohenjo-daro.

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[1]Compiled from a talk by Dr Sharada Srinivasan, Associate Fellow, National Institute of Advanced Studies, Bangalore on September 11, 2005 under the annual 'Into the future with knowledge from our past' series and other sources available in the public domain.
[2]University of Fribourg, Switzerland.
[3]Prof. Rajesh Kochhar, CSIR brochure, New Delhi, February 2003.

The Dancing Girl from Mohenjo-daro

A large number of copper and bronze objects were produced in Harappa and Mohenjo-daro. They also made a number of tools - razors, chisels, arrowheads and fishhooks – which are among the best in the Ancient World. But probably the best known find from this ancient civilization is the statue of the ´Dancing Girl´.

It was the first sculpture in dancing gesture discovered in the Indian subcontinent and is among the earliest bronze castings in the world. But its most interesting aspect is that in casting it the Harappan metallurgists used an advanced technique known as the lost-wax process (Described in the next section). Though the figure's height is only 10.8 cm. it tells us a lot about the metal technology that was developed in the Indus Valley Civilization, also called the Harappan Culture, which flourished during 2500-2000 B.C.

Bronze making is a technology involving alloying copper with tin, lead or arsenic. In the bronzes of Mohenjo-daro, the presence of tin is 4.5 to 13 per cent. This indicates an amazing level of understanding of metallurgy as good quality bronze, we know today, is obtained by alloying copper with 8 to 11 per cent tin.

What is the lost wax process?

´Lost Wax´ is a process of casting bronze and is used for making both solid and hollow objects. Ancient south Indian bronzes are mostly solid (*ghana*) cast whereas north Indian bronzes are mostly hollow (*sushira*) cast. To cast a small solid statue, such as the dancing girl, it was first modelled in wax. The wax model was then covered with a layer of fine clay followed by a thick outer coating of coarse clay. The mould was first allowed to dry and then heated so that the wax could melt and run out. Molten metal was then poured into the hollow of the hard mould thus prepared. After cooling, the mould had to be broken open to get the object cast.

To cast a hollow bronze statue, first a clay core was made and allowed to dry. This clay core was covered with wax, the thickness of which depended on the intended thickness of the metal object being designed. This was once again covered with a thick outer layer of clay. The rest of the process was as mentioned above, for solid casting. To prevent the shifting of the inner clay core, it was attached with thin rods to the outer wax mould. Interestingly, cow dung was used as fuel for the furnace as it was known to provide uniform heating!

The metal mirrors of Aranmula

The few traditional bronze smith households in Aranmula, Kerala, are the 'custodians' of the metallurgical secret of the Aranmula *kannadi*, the world-famous metal mirrors. Making this mirror is a long process, and no more than one mirror can be made in a day. The age-old lost wax technique is used to make these mirrors too. Some undisclosed metals are alloyed with bronze, copper and a high level of tin, which are melted on a furnace fitted with a manual blower and poured into typical clay

moulds. The moulded metal disc is mounted on a wooden plank and polished using a jute cloth dipped in well-ground burnt clay powder and castor oil. The polishing process can go on for two to three days. The mirror is then mounted on bronze frames with exquisite carvings. The smallest Aranmula mirror of one-and-a-half inches could cost about Rs.950.

Iron & Steel

The forging of wrought iron seems to have reached its zenith in India in the first millennium AD. An enduring example of this expertise is the Iron Pillar at New Delhi, which you must have heard of. The most remarkable feature of this pillar, and a lesser known iron pillar at Kochadri in Karnataka, is the absence of corrosion in over 2500 years, a fact which is supposed to be due to the high purity of the wrought iron and the phosphorus content, among other factors. By the 12th c. AD, Indian construction engineers were using iron girders and beams on a scale unknown in any other part of the world, particularly in the building of temples. The Puri temple contains 239 iron beams and one of the beams in Konarak is 35 feet long. That the iron used remains free of rust despite the temples' proximity to the sea is further testimony to the advanced knowledge of developing corrosion resistant iron.

Wootz steel

Besides iron, India is also believed to be home to some of the earliest reported finds of high-carbon steels in the world . The steel is called ´wootz´ in western references, derived from the Kannada ´ukku´ and the Tamil ´ekku´, meaning crucible steel. This high carbon, wootz steel from ancient India has a characteristic wavy pattern, with alternating light and dark shades due to the large quantities of carbon added to the iron. The southern peninsula was the hub of steel making and there are admiring references to *´Seres´* (Cheras) iron and *´Teling´* (Telengana) swords in world literature dating from the 1st century BC such as *Periplus of the Erythrean Sea*, a personal first-hand account of trade with India by an anonymous Graeco-Egyptian sailor of the 1st century AD and sources from the Mediterranean, including from the time of Alexander (3rd century BC).

By the late 1600s shipments running into tens of thousands of wootz ingots were exported from the Coromandel coast to Persia. This indicates that the production of wootz steel was almost on an industrial scale in what was still an activity predating the Industrial Revolution in Europe. It may interest you to know that the famous Damascus Sword and Prophet Mohammed´s 'Teling' sword were manufactured using wootz steel.

Zinc

India was the only country in the ancient and the medieval world to produce pure zinc metal and alloys of zinc, particularly brass. The earliest artifact in the world (2200 – 1500 BC) containing an appreciable amount of zinc was found in Lothal, Gujarat. In April 1980, the Hindustan Zinc Limited (HZL) sponsored a three-year research project on recovery of zinc from the ancient slags which was successfully conducted at the Indian Institute of Technology (IIT) Kanpur. In 1982, HZL conducted archaeological investigations in Zawar, Rajasthan, in collaboration with the British Museum Research

Laboratory and the Department of Archaeology, M.S.University of Baroda. Zawar, about 30 km south-west from Udaipur, is where the ancient zinc mines (earliest so far is 430 BC) are found.

Brass

Fusion of zinc with copper increases the strength, hardness and toughness of the latter. When this alloy, brass, is composed of 10-18% zinc, it has a pleasing golden yellow colour. It can also take very high polish and glitter like gold. It is this property of brass that has caused it to be a popular material for covering temple roofs, fabricating vessels, etc.

Bidriware

Bidriware, the sleek and smooth dark coloured metalwork with intricate eye-catching designs in silver, brass or gold on its glossy surface, is famous all over the world. This metalwork as well as the technique to produce it are found in India alone. Bidri is an alloy which contains 76% to 98% zinc, 2 to 10 % copper, up to 8 %. lead, 1 to 5% tin and a trace of iron.

A FEW SANSKRIT LITERARY REFERENCES TO METALS & METALLURGY

Madanapala – Nighantu (1374 AD) refers to *Yasam vangasadrsam* (zinc – tin like) :

Manasollasa: A 12th century text attributed to King Bhulokamalla Somesvara of the Western Chalukya dynasty of Kalyani.

Silparatna: a 16th century work attributed to Srikumara who wrote it at the instance of King Devanarayana of Ambalapuzha in Central Kerala.

Manasara: This text still serves as a practical guide for the *sthapatis* of Swamimalai in Tamil Nadu. A few select verses in this text deal with the lost wax process, called *Maduchchitta vidhanam*.

Rasaratnasamuccaya: Describes the arrangement of the downward distillation retort with the condensing unit underneath for extraction of zinc.

Vedic Mathematics – An Alternative and Creative Approach to Problem Solving

P K Srivathsa[1]

What is Vedic Mathematics? Of what use is this Ancient Indian Mathematics when Modern Mathematics and Computer Science are so advanced? Such is the skepticism with which we regard our traditional knowledge. However, Universities such as in Zurich, have departments dedicated to Vedic Mathematics. In some others, VM (Vedic Mathematics) or Ancient Indian Mathematics (AIM) has been used to teach even Digital Signal Processing since 1992. The London School of Economics, and the Universities of Birmingham, Philadelphia, Oslo, Munchen, Sydney and Heidelberg have all introduced VM in their curriculum.

The *Vedas* are, primarily, religious texts that are not intended as textbooks of Science or Mathematics. Mathematical concepts, methods and techniques embedded in the Vedic and Upanishadic literature have to be culled out from the rest of the text. It was only due to the untiring zeal of HH Bharati Krishna Tirtha that the world came to know of Vedic Mathematics. He had reconstructed 16 mathematical formulae from the *Atharva Veda* after they were 'revealed' to him during his intense *tapas* (meditation) in the forests of Sringeri. However, the subtlety of the expression makes the verses and aphorisms appear like coded literature. So, in simple Sanskrit, HH Bharati Krishna Tirtha wrote 16 books on Mathematics, one explaining each formula. A 1952 recording on spool tape is available, in which HH Bharati Krishna Tirtha talks about these books with Albert Einstein. However, most of these books are lost to India as the manuscripts were, allegedly, smuggled out of the country in the Swamiji's own lifetime. When His Holiness came to know of the loss, in 1957, he started re-writing the books from memory. However, due to his failing health he could only complete one volume. This is the only original work on Vedic Mathematics that is available to us today.

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[1]Dr P K Srivathsa is a Management and Software Consultant. This article is based on his papers and the presentation made by him at Bangalore on August 28, 2005 under the annual 'Into the Future with Knowledge from Our Past' series. HH Sri Bharati Krishna Tirtha Swami's book, mentioned below, has also been referred to.

[2]Source: Vedic Mathematics, Jagadguru Swami Bharati Krishna Tirthaji Maharaja, edited by Dr V S Agrawala, published by Motilal Banarasidas, 1987 (First edition, 1965).

About His Holiness Jagadguru Shankaracharya Sri Bharati Krishna Tirtha[2]

HH Bharati Krishna Tirtha (1884-1960) became the Shankaracharya of Govardhan Math, Puri in 1925. He was born and brought up in the then Madras Presidency. In his *purvashrama* (life before becoming a *sanyasi*), he was called Venkatraman. By the age of 20, he had acquired Masters degrees in eight subjects (including Mathematics) from the American College of Sciences, Rochester, New York's Bombay Centre, securing the highest honours in all of them, which perhaps is an all time world record of academic brilliance. He participated in the National Education Movement under Sri Gopal Krishna Gokhale and also worked as a Professor and a Principal. However, he gave up everything to study Sanskrit and Philosophy under Sri Satchidanada Shivanubhava Nrisimha Bharati Swami at Sringeri. After eight years of rigorous study and meditation in the Sringeri Sharada Math, he took *sanyas*.

Application of Vedic Mathematics – Some Examples

The scope of Vedic Mathematics spans all branches of basic Modern Mathematics – Arithmetic, Algebra, Geometry, Trigonometry, Calculus (integral and differential), Biquadratics, solving of Polynomials, Astronomy, Graph Theory and even some numerical methods used in computers! They can be used to square numbers, generate 3 digit multiplication tables with knowledge of only up to table 5, find the HCF of two algebraic expressions, divide polynomials and solve magic squares among a host of other possibilities. "Anonymous ancients have, in 16 sutras and 120 words, laid down simple formulae for all the world's mathematical problems" (Desmond Doig in the *Statesman*, India, January 10, 1956).

We will discuss just a few of the concepts in VM and explain them with sample problems solved using the methods suggested by the *sutras.* The problems discussed here are very elementary. However, VM, as already mentioned, can be used to solve even the most complex problems.

I 'एकाधिकेन पूर्वेण' (ekAdhikEna pUrvENa)

This *sutra* which simply means 'by one more than the previous one' has a number of applications. Let us consider an example relating to squaring of numbers ending in 5:

Squaring of numbers ending in 5:

Example 1) Solve: 195 x 195

Step 1: Multiply the last digits = 5x5 = 25 (this is common while squaring all numbers ending in 5)

Step 2: The 'previous one', that is the number previous to 5 in the given problem is 19.

Step 3: One more than the 'previous one' = 20.

Step 4: It is interpreted that the *sutra* also tells us to multiply the 'previous one' that is 19, by 'one more than the previous one that is 20.

Step 5: Following from step 4, 19 x 20 = 380.

Therefore, 19 x 19 = 38025.

Example 2) Solve: 125 x 125

125 x 125 = 12 x 13 followed by the digits 2 and 5 in the tens and units places so that the answer ends in 25.

Therefore, 125 x 125 = 15625.

II.'एक न्यूनेन पूर्वेण' (ekanyunEna pUrvENa)

Multiplication where multiplier consists only of 9s

Example 3) Solve: 111 x 999

Step 1: Subtract (*nyunena*) one from the '*purva*', or the 'previous one', which in this case simply means the multiplicand.

Therefore, 111 – 1 = 110

Step 2: Subtract result of step 1 from the multiplier, that is 999.

Therefore, 999 – 110 = 889

Ans: 111 x 999 = 110 / 889 = 110889.

Example 4) 97,65,431 x 99,99,99

Step 1: 9765431 – 1 = 9765430

Step 2: 9999999 – 9765430 = 0234569

Ans: 9765431 x 9999999 = 97654300234569

This VM process is so much less cumbersome; with small modifications, this method is also applicable when the multiplier consists of 9s but the multiplicand consists of lesser or more number of digits than the multiplier.

III 'विन्कुलम्' (vinculum) – THE CONCEPT OF COMPLEMENTARY NUMBERS

The objective here is to convert all numerals greater than 5 to less than 5 in order to facilitate speedy calculation and reduce carry over. Vinculum method is based on the fact that 19 is the same as (20-1), 80 is the same as (100-20), 6945 is the same as (10000-3055) and so on. Given here is a sample problem for solving division involving numbers with multiple digits.

Example 5: Divide 121234 by 8998

Step 1: 8998 = 10,000 – 1002 (1002 is called ´deficiency´)

So, write problem as indicated in step 2 below. Draw a line after as many digits from the right of the dividend as there are in the divisor. In this case, there are four digits in 8998, so draw the line after

4,3,2,1 (in the dividend 12 1 2 3 4) counting four digits from right. The digits to the left of this line in the answer will constitute the quotient and to the right, the remainder.

Step 2: 8998 **)** 12 | 1234
1002 |

where 1002 is the deficiency.

Step 3: Bring down the first digit from the left of the dividend into the answer and then multiply the deficiency by this number. Start writing the products under the subsequent figure in the dividend.

8998) 12 | 1 234
1002 1 | 002
1

Step 4: Bring down the second digit of the quotient by adding the digits of the second column and multiply the deficiency by this number; start writing the products under the subsequent figure in the dividend.

8998 **)** 12 | 1234
1002 1 | 002
| 3006
13 4*

Ans: q = 13; r = 4* The remainder can be worked out accurately to any number of decimal places by continuing with the procedure.

IV. निखिलम् (nikhilam)

निखिलं नवतश्चरमं दशतः *(nikhilam navatascaramam dasataha)* says this *sutra*, meaning "All from 9 and the last from 10." As do all other *sutrams*, this too has vast and varied applications. We will consider its application in multiplication of large numbers.

Example 6: Solve 1016 x 1006

Step 1: Add or subtract the given numbers from a power of 10, which can be a suitable base. Therefore 1016 = 1000 + 016; 1006 = 1000 + 006

Step 2: The problem is written as:
1016 + 016
1006 + 006

Step 3: Multiply the numbers representing the surplus and cross add one of the original numbers with the surplus of the other number.

Thus, you will multiply 16 by 6 and add 1006 and 16 or 1016 and 6.

Enter the product of the surpluses on the right hand side and the sum of the cross addition on the left hand side. All the figures together constitute the product.

1016 + 016
1006 + 006
1022 / 096 Therefore, the answer is 1016 x 1006 = 1022096

If neither the multiplicand nor the multiplier is sufficiently near a convenient power of 10, you can take a multiple or sub-multiple of a suitable base as the working base to perform the necessary operations as in the following example.

Example 7: Solve 41 x 41

Step 1: Take 50 as working base.
Step 2: Represent problem as:

41 – 9
41 – 9

Step 3: Perform the calculations as indicated in Example 6. That is, multiply right hand side digits (9x9 in this case) and cross add one original number with the surplus of the other (in this case, 41 + (-)9)

41 – 9
41 – 9
32 / 81

Step 4: Proportionately divide the left hand side number in the same ratio that the original base has to the working base. As 50, the working base in this case = half the original base of 100, divide 32 by 2.

32 = 16. Answer = 1681.
2

IV. SOLVING MAGIC SQUARES

There are special couplets for magic squares of various sizes. Here, we will present the *sutram* to help you solve magic squares of size 3 x 3.

The *sutram* to be applied in this case is:
indra vAyu yamascaiva nivrutO madhyamastathA
IsAnasca kubErasca agni vArunamEvaca.
इन्द्र वायु यमश्चैव निवृतो मध्यमस्तथा
ईशानश्च कुबेरश्च अग्नि वरुणमेवच.

The places or houses allotted to each deity is fixed and is as shown below. *Madhyama*, of course, means the central house.

Isan	indra	agni
kubEra		yama
vAyu	varuna	nivrti

If you memorize the *sutra* and remember the places / houses allotted to each of these deities, you can solve the magic square in a jiffy, given a single number.

Example 8:

You are given the following problem and asked to fill in the rest of the numbers. The totals of all columns and rows must be equal, of course, this being a magic square.

		10

By reciting the *sutra*, given above, we would know that the number after *Nivrti* belongs to *Madhyama* and thereafter to, in order, *Isan, Kubera, Agni* and *Varuna*. Thus you have

12 Isan		**14** agni
13 kubEra	**11** madh-yama	
	15 varuna	**10** nivrti

The remaining spaces can also be filled up by recalling the *sutra* and entering the numbers in descending order from the house of *Nivrti*. Thus you have 9 in *Yama's* house, 8 in *Vayu's* house and 7 in *Indra's* house.

12	7 indra	14
13	11	9 yama
8 vAyu	15	10

The magic square is complete, with totals of all columns and rows being 33.

Conclusion

The problems presented here are in the nature of an introduction to VM. The scope of the subject, however, extends right from fundamental Mathematics to the highest levels. They score over conventional methods in terms of novelty, elegance and computational time required. Reports confirm that the entire syllabus of present institutions of higher education can be covered in 50% to 60% of the time, using VM. Candidates attending competitive exams have found that they are able to answer the mathematics paper in 60% to 70% of the time, with 100% accuracy using VM. The future of Vedic Mathematics is very bright as more than 20 universities, worldwide, have introduced VM in their curriculum and the number of international conferences on the subject is also increasing. In India too, many individuals and organizations are engaged in serious R&D on the subject.

QUIZ FORMAT

I. Preliminary written round, mainly objective in nature, on November 6, 2005 (Sunday) at the National Pre-University College, Basavanagudi, Bangalore 560 004 at 10:30 am. **(Open Book Evaluation)**

II. Final oral round for about eight students selected from the preliminary round, on November 13, 2005 (Sunday) at the National Pre-University College, Basavanagudi, Bangalore 560 004 at 4:30 pm.

Sri Tirunarayana Trust is a public charitable trust conceived to honour the memory of Tiruvaimozhi Acharya Purusha, Professor V. T. Tirunarayana Iyengar (1903-1995). VTT, as Tirunarayana Iyengar was popularly known, was a Professor of Sanskrit at the University of Mysore, a renowned scholar of the Srinvaishnava school of thought, and an acclaimed expert in Indian Philosophy. Much of his life was spent in sharing his vast knowledge in these fields with the many eager students of all ages who sought him out.

To foster a love and understanding of the subjects that were so close to VTT's heart and to ensure that the knowledge of the ages are nurtured for posterity, Sri Tirunarayana Trust has been organizing lectures and cultural programmes by renowned scholars and reputed artistes, almost every Sunday evening since January 2000. These programmes come under specific series such as *Enjoying Sanskrit Kavya, Getting to Know Our Ancient Texts, Science and Sanskrit,* and *Music of the Azhwars and Acharyas.* Two classical music festivals, *Kartikotsava* and *Udaya Taare* are also held, every year.

As VTT had become synonymous with knowledge and learning, Sri Tirunarayana Trust felt that it was only right that it contribute, in some small measure, to the furtherance of the cause of education in India. A corpus fund is being created for this purpose.

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