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AGRO-ENTO BIOINFORMATION: Towards the Edge of Reality

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ABSTRACT

Information communication has advanced from the fundamental universe-bio-physics-chemistry probes to exploration of bioprocessing tangibles and intangibles. Bounded by such information advancement frames, domains of agro-forestry and entomology, and medicine, have witnessed progression through evolution, revolution, and bioinformation in their knowledge contents. Integrated Pest Management (IPM) paradigms steered the course of agro-forest and medical-industries during the 1800 and 1900 eras. IPM Concept is a synthetic framework that results from evolution, revolution, and presently bioformation in domains of agro-medico-ecological and anthropo-ecological activities. A chronological history of pest management parallels the history of industrial revolution and highlights man's attempts at dealing and living with the environment, arthropods and other pestly species. A cycle of progression from using natural controls to made-made utilities and back to enhancing of natural processes is evident as one walks through time and space of history during the development of civilization. IPM success demands usage and stringent compliance with ecological imperatives, which need to be lucidly expressed as knowledge precepts. Biological knowledge is at the forefront of this usage, especially with the new millennium becoming the Age of Biology. Consequently, bioinformation is commencing to thrive as a global entity, which revolutionizes and drives societal progress. Bioinformation, in brief, comprises biology, information algorithms, information technology, and communication protocols. Thus biology becomes a domain of information science. Attributes of bioinformation can be defined through its primers and profiles. The primers, which entrain processes, both natural and man-induced, include mechanisms such as protocols, algorithms, visualisations, and structural and visual designs. The protocols range from the molecular levels to domains of larger dimensions such as those encompassing fraternities of politics and policies, and societal applications. These protocols, algorithms, and visualisations undergo dynamic incubation processes to produce the end product, which is bioinformation. Entomology is an inherent component of this bioinformation revolution. The information communication technology linkages are exemplified through simulation, modelling, and visualization explorations.

BIOLOGY AS AN INFORMATION & COMMUNICATION DOMAIN

Biology is fast becoming an information and communication domain of knowledge. Since time immemorial, early civilizations produced intellectuals and philosophers who excelled in information and communication knowledge domains. Only a few of these people focused on biology as a knowledge domain, which provides information content then. It is only when information syntax becomes a definitive knowledge discipline known as cybernetics, that biological content e.g. biodiversity, progressively approaches a numerical matrix of information protocol.

As one ascends the complexity scale of organism, with time, the microbes are at the lowermost scale, in contrast with man occupying the upper end. The progress in information & communication can be represented by a series of simple questions, which do reflect the accretion of concerns in biological sciences. These concerns expand across the entire spectrum of knowledge, including the social and biophysical sciences.

Early in man's exploration of the universe and nature, two major questions emerged; What are you? Who are you? Fundamental and applied explorations utilize fully these probing questions. All characterizing and profiling experiments and projects are based on these lead questions. Knowing the contents of matters and particles lead researchers to the urge of unraveling the processes and mechanisms involved. Experimental and exploration results need to be communicated to others interested in the new knowledge. The primary question that prevails then is; How are you? Analytical methodology to explore process and mechanism, and communications protocol emerged. Bio-prospecting of biological materials beg the question of; Where are you? Knowledge of spatial locations enhances information content of biophysical entities. The apex of bio-communication is exemplified in today's sophisticated digital technology of wireless remote sensing of biological entities, both at size and spatial scales of micro- and macro-levels. The next progression in bioinformation delves deeper at the micro level; genetic engineering prevails which revolutionizes man's entire life and his environment. The edge of reality has begun.

The evolution and revolution of biological knowledge, with respect to agro-forestry, medicine and environment, can be best reflected by briefly tracking the principles, definition, implementation, and historical perspectives of pest management and bioinformation.

PEST MANAGEMENT

Perspectives of Integrated Pest Management (IPM) should invoke the following elements.

IPM Goal: High Yields, High Quality, Low Risk - **LEAST DISRUPTION TO ECOSYSTEMS**.

Integrated Pest Management (IPM) is a practice where pest management is one component in an **overall crop production system**. IPM is based on the principle of providing growers with the widest array of options to control pests, e.g. cultural, biological, chemical and genetic techniques. The ultimate goal of IPM is to ensure production of abundant, high quality food and fiber in an environmentally, economically, socially, and culturally sound manner. Thus monetary, ecological, and sustainable concerns are prime issues in IPM.

The concept of IPM has roots that date back to the beginning of this century, when farmers, agricultural researchers and farm suppliers began working in tandem to control agricultural pests. Early efforts focused on cultural practices, crop rotations and plant breeding for pest resistance.

Many growers have adopted IPM programs on a voluntary basis. To these growers, the rewards are obvious: Improved safety, environmental protection and economic returns. If, however, policies mandate the adoption of IPM, understanding what it is and how programs will be measured becomes critical. Specifically, IPM criteria should not be formula driven, must be broad in its interpretation and must take into account differences among commodities as well as the geographies in which they are grown. To be successful, any criteria used to judge the effectiveness of a given IPM program must be practical (science based), agronomically sound (allow for variation within and among crops), economically viable (cost effective), and have achievable and measurable objectives.

IPM is intended to provide growers with the widest array of environmentally sound, safe and economical pest management tools, including, when appropriate, synthetic tools. Because of the potential risk of crop failure from pest damage, many growers are unwilling to initiate an IPM program that doesn't allow for the use of specific chemical alternatives when pest pressures exceed manageable threshold levels. Progressive growers, researchers, and farm suppliers have long recognized the value in the judicious use of synthetic inputs as part of an overall farm management program.

There are many reasons why IPM programs are designed to decrease reliance on any one pest management practice or technique, including the use of pesticides. One objective of IPM is to minimize or eliminate pest resistance through the judicious use of pesticides in combination with other pest management techniques.

Undoubtedly technological advances will provide the keys to sustaining successful IPM programs.

Examples of scientific and/or technological breakthroughs which enhance the ability of growers to adopt and sustain IPM programs include the advent of narrow spectrum, minimal risk pesticides, improved plant genetics and breeding techniques, and the development of transgenic plants that optimize pathogens to control pests. **The continued success of IPM programs will depend on sound research and development, applied outreach of demonstrated IPM techniques, environmentally sound agronomic decisions, effective agricultural policies and positive economic outcomes for the grower**.

In spite of the well-documented successes attributed to IPM, barriers exist that impede its development. **These barriers fall into the general categories of research and development (R&D), policy, and grower education**.

IPM: DEFINITIONS & INTERPRETATIONS

In spite of the many definitions, there is common ground with respect to the principles, the tools and the goals of IPM.

Principles of IPM

- A systems approach to managing crop pests.
- Devises strategies to prevent economic pest damage.
- Relies on a balance of techniques to manage pests.

Tools of IPM

- Biological (protect/enhance/release natural enemies).
- Cultural practices (crop rotation, cultivation, irrigation, pest monitoring).
- Chemical (pesticides, insect growth regulators, pheromones).
- Genetic (sterile release, resistant varieties, transgenic plants).

Goals of IPM

- To ensure production of high quality food and fiber in a sustainable, environmentally sensitive and economical manner.
- To minimize the risks to human health and to the environment.

What IPM Is

IPM is "the intelligent selection and use of pest control actions that will ensure favorable economic, ecological and societal consequences." (R. L. Rabb, NCSU, 1972. (Association of Applied Insect Ecologists))

IPM is a pest population management system that anticipates and prevents pests from reaching damaging levels by using all suitable techniques such as: natural enemies, cultural management, and the judicious use of pesticides. (Farm and Forest INSIGHTS.)

IPM is a systems approach based on science and proven crop production and resource conservation practices. It uses all suitable techniques, such as natural enemies, pest resistant plants, culture management, and pesticides in a total crop production system to anticipate and prevent pests from reaching damaging levels. (Bruhn et al., Consumer Response to Information on Integrated Pest Management. Journal of Food Safety (1992) 12: 315-326.)

IPM is a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health and environmental risks. (National Coalition for Integrated Pest Management, January 1994.)

IPM is a complex set of behavior, decision-making procedures, methods, technology and values organized to provide efficient alternative methods of pest control. (J. Apple and R. Smith [eds] 1976. Integrated Pest Management. Plenum Press. New York.)

IPM is a thinking farmer's philosophy for pest management. A thoughtful, comprehensive approach to the challenge of farming, it calls on many different disciplines, seeking links and relationships among them rather than seeking to establish a separate science. It is an environmentally based pest control strategy offered as part of an overall crop production system. IPM provides a diverse array of practices that can be used together to fight crop pests in an economically and environmentally efficient manner. (Kenneth Farrell, Vice President, Agriculture and Natural Resources, University of California.)

"Integrated pest management," means a coordinated decision-making and action process that uses the most appropriate pest control methods and strategy in an environmentally and economically sound manner to meet agency pest management objectives. (From Oregon Statute, as used in ORS 634.650 to 634.670.)

What IPM Is Not

IPM is not new
In one form or another it has been around since the advent of agriculture. Scientifically based programs specifically focused in this area, however, are only a few decades old.

IPM is not implemented overnight
The development of an IPM program may take years of research and involve participants such as university and Extension researchers, production agriculture, pest control advisors, industry scientists and, most importantly, farmers.

IPM is not organic farming
Organic farming is a philosophical approach to crop production that relies on no synthetic inputs for either pest control or plant nutrition. Organic farmers are prevented from using some of the low-risk techniques and technologies available to growers practicing IPM, simply because they are synthetic.

IPM is not a formula to eliminate or reduce pesticide use
Well developed, science-based IPM programs have consistently resulted in reduced pesticide use, as they employ a wider array of pest management techniques. IPM programs, by design, result in safer, more judicious use of pesticides.

IPM is not a rigid program of management techniques
IPM is a balance of all suitable techniques, providing the grower with options to manage pests within a given crop production system.

IPM programs are not universal
Depending upon the pest complex and the geography, programs may differ dramatically for the same crop in different geographies.

ACTIONS AFFECTING IPM ADOPTION

Positive Actions To
Promote IPM

- Develop policies that will foster cooperation between regulators and growers.
- Involve the regulated community, i. e., growers, crop advisors and farm suppliers, when developing policies that promote IPM.
- Recognize that although reduced reliance on pesticides is often an outcome of IPM programs, pesticides are an important tool in many successful IPM programs. Excluding pesticides from IPM programs by definition will reduce the acceptability of IPM as an effective agronomic tool.
- Develop policies that don't impede advances in minimal risk, effective pest management technologies.
- Consider geographical, seasonal, climatic, biological and cropping differences when developing IPM programs.
- Adopt evaluation criteria that are practical (science based), realistic (allow for variation within and among crops), economically viable and have measurable and achievable objectives.
- Promote IPM research, development and demonstration programs at the university and Cooperative Extension level.
- Recognize that Integrated Pest Management (IPM) is a mature concept, which improves the environmental and economic consequences of pest management through better use of information and technology

ACTIONS THAT CAN IMPEDE IPM SUCCESS

- Failing to recognize that acceptance of IPM by growers is driven by economics.
- Establishing a nationwide "formula" for what constitutes adoption of IPM.
- Discounting the significant contributions, that advances in technology, including the advent of narrow range, minimal risk pesticides, will continue to make to IPM.
- Viewing IPM as a mechanism to simply reduce pesticide use or equating IPM with organic farming. IPM will only advance with understanding of agricultural systems and the intelligent use of existing and new technology.

Necessary Elements of a Successful IPM Policy

Practical: IPM programs must be based on sound science. This process involves the coupling of solid field biology research with workable delivery systems. For IPM to succeed, a grower has to be able to apply sound scientific principles to his agronomic decisions.

Realistic: IPM programs must be broad enough to allow for variation from area to area and from time to time throughout the growing season. IPM policy elements must allow for enough flexibility and options to accommodate differences due to geography, temperature, climate and other variables that exist within any given commodity. Rigid, specific formulas will not provide the necessary flexibility.

Economical: The bottom line is that in order for IPM programs to be successful, they must work economically for the grower. Rigid, formula driven IPM programs will likely result in increased grower costs, i. e., exposure to economic loss, because growers may not have the flexibility to adapt to pest problems that are specific to a particular crop or region.

Achievable: IPM programs must include realistic, measurable objectives. Measurements must be based on sound science rather than philosophy. Criteria that are too narrowly focused may invite manipulation rather than interpretation needed for meaningful change.

Retrospectives

EVOLUTION

Ecological and Social Methodologies

The beginning of agriculture around 8000 B.C. marks an evolutionary stage in man's utilization of natural resources for living purposes. Early records from China indicate sericulture was part of the primeval agro-system around 4700 B.C. Cultural control (e.g. burning), natural chemicals (e.g. sulphur, plant materials, mercury, arsenic, oil sprays), and biological control to a limited extent, had been practiced in various parts of the world, especially in civilizations centred around the Middle East, well before the era of the Roman Empire and Christianity. The Sumerians were already using sulphur compounds to control insects and mites, around 2500 BC. The first well-recorded history of biological control occurred in China in 300 AD. Predatory ants, *Oecophylla smaragdina*, colonies were set up in citrus orchards, with trees interlinked using bamboo bridges, to suppress populations of pestly caterpillar and beetle. Around 400 AD, the application of white arsenic to the roots of transplanted rice to protect against insect pests, had already been recommended. Similar biological and natural-chemical modes of managing populations of various types of pest continue to dominate the agro-systems well into the 1700 A.D. During the period extending 1000 through 1300 AD, date growers in the Arabian Peninsula seasonally and augmentally transported cultures of predatory ants, from nearby mountains to control phytophagous pestly-ants on the date palms. Simultaneously, mechanical methods of weed elimination e.g. hoeing, crop rotation and cultivation, had been practiced then. During the 1400 to 1500 AD era, Europe had eclipsed into the Dark Middle Ages. Pest ravages were often associated with ecclesiastical omens and dogmas. Nevertheless, the subsequent birth of Islam gradually replaced unknown mystical causes of pestilent arthropod outbreaks with knowledge-based eclectic research-empirical-based foundation. Europe began to radiate with knowledge and the quest for scientific exploration and discovery began. This was then the Age of Renaissance.

Nevertheless, even during the agricultural revolution in Europe, around 1750 through 1880 A.D., natural controls and usage of naturally-derived substances remained the pest management norms throughout this era in human civilization. The Renaissance witnessed a proliferation of entomological writings, which included insect descriptions and discoveries. The descriptions were largely based after Linnaeus . In 1732 farmers began to grow crops using intensive row systems to facilitate weed removal. Some students of agricultural history consider the agricultural revolution in Europe commenced during the period between 1750 and 1880. This was when crop protection became more extensive, and international trade promoted the discovery of the botanical insecticides pyrethrum and derris.

During the early 1800's, many writings emerged on pest control; these were centred largely on cultural control, biological control, varietal control, and physical and chemical controls. In 1840 the Potato Blight (*Phytophthora infestans*) outbreak in Ireland, England and Belgium, thus leading to widespread famine. This was probably the first big wakeup call for good pest management strategy and practice to be planned, strategized and implemented. In terms of societal movement, waves of exodus of human migration marked the beginning of massive emigration from Europe to colonized lands and continents. It was during this period too that large numbers of predatory carabid beetles *Calasoma sycophanta*, were collected and liberated, to suppress populations of leaf feeding larvae of the gypsy moth. By the mid 1800's intensive agriculture and big pest problems began to emerge, especially in the New World i.e. the Americas. The period extending from 1848 to 1878 saw the introduction of *Viteus vitifoliae* from Americas, which nearly put an end to the French wine industry. The release of the natural enemy *Tyroglyphus phylloxerae* to France from North America in 1873 provided adequate levels of control. During 1870-1890, the Grape Phylloxera (*Viteus vitifoliae*) and powdery mildew were successfully controlled in French vineyards, by the introduction of Bordeaux mixture and Paris-Green, and the use of resistant rootstalks and grafting. The year 1880 heralded the first commercial spraying machine. The revolution in pest control operation had just entered the phase of incipient dawn.

REVOLUTION

Pest Control Application

The chemical pesticide revolution was preceded by an also stunning revolution is biological control, especially in agriculture. In the 1860s, phytophagous insects were first employed to control weeds. Perhaps the first and most outstanding success of biological control was the introduction of the ladybird beetles (vedalia beetle), *Vedalia* (=Rodolia) *cardinalis*, from Australia into California in 1888 to control the cottony- cushion scale insect, *Icerya purchasi* Maskell, on citrus. Breeding programmes were also initiated in 1899 to develop varieties of cotton, cowpeas, and water melon resistant to the fungal *pathogen Fusarium* wilt. In 1901, the first successful biological control of weeds (*Lantana* spp.) was achieved in Hawaii. This period coincided with the Agricultural Revolution Era in Europe (~1750 -1900). In fact the revolution expanded to many parts of the world, including the U.S.A., Australia, and parts of Asia, Africa, and South America. This was also the age of rapid land exploitation, exploration, and colonization, by the Europeans, and their descendents. Subsequently, during a later period, 1920-1930, more than 30 cases of natural enemy establishment were recorded throughout the world.

The 1890s period witnessed the widespread use of lead arsenate for insect control. In the field of medical entomology, 1893 marked the recognition of arthropods as vectors of human diseases. Subsequently, in 1915, the successful control of mosquitoes vectoring malaria and yellow fever parasites, led to the completion of construction of the Panama Canal, after its abandonment in the late 1800s. The year 1930 marked the introduction of synthetic organic compounds for control of plant pathogens. The era of rapid revolution in widespread use of synthetic chemicals for pest control was just about to begin.

Subsequent chronological events are outlined below:

1939	**Recognition of insecticide properties of DDT**
1940	**W.G.Templeman observed the amazing selectivity of the herbicidal activity of ·- naphthalacetic acid. The subsequent development of this compound led to 2,4-D in 1944 and MCPA which revolutionized weed control in cereals. Use of milky disease to control the Japanese beetle as the first successful use of an entomopathogen.**
1940	**THE CHEMICAL SPRAY REVOLUTION.**
1942	First successful plant breeding programme for insect resistance in crop plants through release of wheat resistant to the Hessian fly. Rediscovery of the insecticidal properties of benzene hex chloride and in particular its gamma isomer ("-BHC) shared with DDT the credit for the dawn of a new era of insect control in agriculture, horticulture, stored products, timber preservation and public health.
1944	First hormone based herbicide - 2,4-D available
1946	First report of insect resistance to DDT in houseflies in Sweden.
1950's-60's	Widespread development of resistance to DDT and other pesticides
1950's	First applications of systems analysis to crop pest control
1959	Introduction of concepts of economic thresholds, economic levels and integrated control by V.M. Stern, R.F. Smith, R. van den Bosch and K.S. Hagen
1960	First insect sex pheromone isolated, identified and synthesis in the gypsy moth
1962	**Publication of "Silent Spring" by Rachel Carson; led to world reawakening of ecological backlashes following intensive and extensive applications of wide spectrum chemicals in the environment.**
1963	K.E.F. Watt introduced systems science to pest management
1965	Release of carbamate insecticide pirimicarb and pirimiphos ethyl, and the systemic fungicide dimethirimol for control of mildew on cucurbits
1966	Release of the systemic fungicide ethirimol for control of mildew on cereals
1967	**Introduction of the term INTEGRATED PEST MANAGEMENT** by R.F. Smith and R. van den Bosch. L.R. Clark, P.W. Geier, R.D.Hughes and R.F. Morris introduced the relevance of ecology to IPM through the concept of "Life Systems". Release of pirimiphos methyl

1969	US National Academy of Sciences formalized the term Integrated Pest Management
1970's	Widespread banning of DDT
1972	Release of *Bacillus thuringiensis* insecticide based on isolate HD-1 for control of lepidopterous pests
1973-1975	Development and release of the synthetic pyrethroid insecticides permethrin and cypermethrin
1985	First resistance reported to Bacillus thuringiensis in the flour moth Plodia interpunctella. India and **Malaysia declared IPM the official Ministerial Policy**.
1986	**Germany** makes IPM official policy through the Plant Protection Act. **Indonesia; Presidential Decree makes IPM official policy**. **Philippines** - IPM implicit in Presidential declaration.
1986	**OECD declares containment procedures for genetically engineered products.**
1987	IPM implicit in Parliamentary decisions in Denmark and Sweden.
1988	Major IPM successes in rice systems in Indonesia.
1989	First resistance reported to genetically engineered *Pseudomonas fluorescents* containing the delta endotoxin of *Bacillus thuringiensis*.
1989	**The USA National Research Council proposed the concept of Ecologically Based Pest Management (EBPM).**
1990	**Publication of Shaping** *Genes: Ethics, Law and Science of Using New Genetic Technology in Medicine and Agriculture,* D.R.J. Macer (Eubios Ethics Institute, 1990).
1991	IPM implicit in multiyear plan for crop protection introduced by Cabinet decision in the Netherlands.
1992	**United Nations Conference on Environment and Development. Attended by the World's Heads of State; introduction of Agenda 21 (focussing on Sustainable Development & Environment), Rio de Janeiro.**
1993	More than 504 insect species are known to be resistant to at least one formulation of insecticide and at least 17 species of insect species are resistant to all major classes of insecticide. 150 fungi and other plant pathogens are resistant and several plant pathogens are resistant to almost all systemic-fungicides used against them. Five kinds of rats are known to be resistant to the chemicals that are used against them. Resistance to herbicides has been documented in over 100 weed biotypes and 84 species (Cate and Hinkle 1994).

1994	Biodiversity studies mushroomed in many countries.
1994-2000	Genetic Engineering researches & products emerged on an unprecedented scale Crops Animals Animal products Microbes HUMAN GENOME PROJECT
1996	**Genetically engineered soybeans by MONSANTO.**
1997	**Genetic Engineering on Potatoes to increase starch content.**
2000-	**AGE OF BIOINFORMATION**

Prior to the age of bioinformation, the revolution era witnessed development of huge repositories of data on insect (arthropod) biology, ecology, behaviour, physiology, and population management. Numerical and functional description and prediction of population dynamics and responses invoke technologies of simulation and modeling. Crop-based integrated-team researches were the norm. Examples of some of these researches on cotton, rice, and polycrop (chilli-brinjal-leucaena) ecosystems are listed at the URL of Hassan (2001).

Prospective

BIOINFORMATION

Primers and Profiles

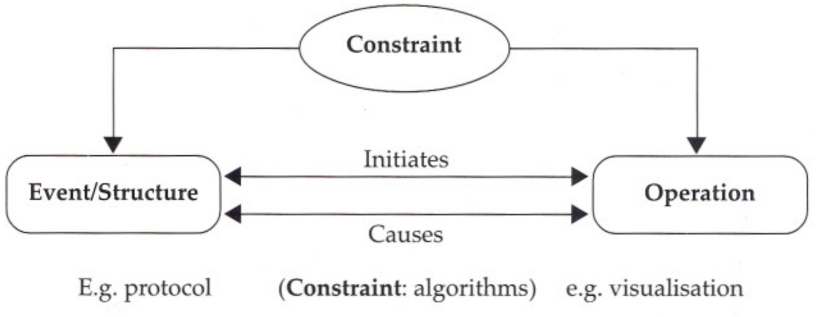
INTRODUCTION

The new second millennium heralds the age of information technology coupled with the bloom of biology. In general, the major underlying factors which will largely contribute towards progress of a nation can be synonymised as GESEL; governance, education, sustainability, ecology, and living humanity. The drivers of these factors can be summarised as the synonym SIEMEN: Science & technology, Information Communication technology, Educational processes and technology, Manpower expertise, Ecological-Economics dynamics, and Novelty enhancers. Hence, information is acknowledged as a major driver of societal progress and development. In Malaysia, the development of information technology (IT) or information and communication technology (ICT) has been moulded by initiatives of the National Information Technology Agenda (NITA). NITA emphasised the need to incorporate IT or ICT in every domain of knowledge and societal function. However NITA failed to formulate definitively the multiplier and exponential effects of ICT on strategy and business, as impacting on the K-economy (Nordin Othman personal communication 2002). The new second millennium also sees the dawn of an era of renaissance in biology. Biological knowledge and its downstream applications permeate into the life spheres of man, animals, plants, and the environment at large. Subsequent to the industrial revolution, the 19th and 20th century witnessed accelerating pace of human progress based on rapid developments in physical sciences, engineering, and transportation. The 21st century and the new millennium then promise to be the age of information & communication, and biological domains.

There is an essential need for biological knowledge to be transformed digitally into information matrices, to enable digital processing and transformation for various purposes. These biological information then undergo digital incubation invoking operation of mechanisms and tools, at various levels of protocols, along varied paths of algorithms, and employing differing methods of visualisation. The incubation profiles are in turn controlled by the design architectures, as determined by characterising modules such as Format, Storage, Transmission, Models, and Languages and Codes (e.g. Synchronised Multimedia Integration Language - SMIL, and Multipurpose Internet Mail Extensions - MIME, respectively). The design mould is then further modified by attributes which shape, characterise, and determine the attractiveness, interactivity, choreography, and user-friendliness of the designed visual package.

The Conceptual Modelling Approach (CMA) can be generalised as an activity which aims to capture the user requirements as correctly as possible, by mapping the requirement for one level of abstraction to another, to an implemented system (Flynn 1987). Three relevant concepts are involved; Structure (objects/associations/activities), Constraints (rules/constraints), and Process (dynamic behaviour e.g. updates) (Jamaludin 1988). From these concepts, three models are derived; the Entity Model which models Structure, the Rule Model which models Constraints, and the Function Model which models Processes. Activities of the CMA can be elaborated into a number of stages, each with its own sub branches or functional hierarchy. The structure and constraint components comprise a Data model, whereas the process constitutes the Process Model. A Process Model can be viewed as consisting of event and operation components. The constraint subsequently links the event and operation.

Figure 1 : Major elements of the Conceptual Modelling Approach (Jamaludin 1988).



In this paper, the profiling attributes (characterising attributes, defining entities, distinguishing features) and primers/priming processes (underlying processes, drivers i.e. driving mechanisms, operators i.e. operational tools) are analysed and aligned to the CMA methodology and components. The Structure of the Entity Model can be represented by event entities such as teaching and research, while the Constraints be represented by entities such as design architecture attributes, and the Processes be represented by activities which contribute to building the bioinformation block.

ATTRIBUTES OF BIOINFORMATION

Fundamentally, bioinformation is a biological knowledge entity, which may be explicit and/or tacit. It occupies coordinates, which can be defined through its axes, including sensory-perception, response-evocation, spatial dimension, temporal entity, knowledge worth, economic value, societal gain, interactive dynamics, and its action/animation potential. Undoubtedly, learning of bioinformation through the Internet technology can be greatly enhanced by maximising usage of the action/animation capability (Eddy 1997). In terms of downstream application, there are many components, which can form core subjects for research foci and/or key modules for teaching and learning explorations. In Fig. 1, these components are hierarchically diagrammed as protocols and algorithms.

The bioinformation product is an entity, which is shaped by processes of both natural and man-made. Natural processes include those evolutionary mechanisms, which structure biodiversity profiles and ecological heterogeneity. In contrast, the man-made processes are responsible for most of the bioengineering domains, which include mechanisms responsible for genetic modification of organisms. During the bioinformation-incubation gestation period, all the biological knowledge data are transformed into digital entities. These digital entities then undergo further processing to become visualization modes and/or products. It is these products, which are then moulded and designed into various delivery packages, for downstream usage, including for educational and applied commercial entreprises (for digital and societal needs).

The characterising profiles of the visualization products are determined, to a large extent, by their architectural designs. Ideally, these designs incorporate optimal measures of characteristics such as Interactivity, user response-enability, embedded hot-linked hierarchies, animation-manipulability, audio-video functionality, simulative-capability, modelling-capacity, predictive-usability, and navigational-functionality. These characteristics are then enveloped and driven by their design parameters, of which the primary ones are format, storage, transmission, and models.

BIOINFORMATION PROFILES

Since bioinformation is a biological knowledge entity, which is based on biological phenomena, it has spatial and temporal coordinates, with prescribed storage identity, format architecture, and security attributes.

The spatial coordinates include:

Sensory perception	-	how the senses perceive the biodiversity information.
Response-evocation	-	how the biodiversity information initiates user-responses.
Space	-	the space axis in a multi-axes continuum.
Value	-	the perceived worth of the biodiversity information.
Interactive-ness	-	the level of flexibility in users' participation, when responding actively to the biodiversity information.
Action/animation	-	the level of flexibility in users' manipulation in creating action-oriented response to the biodiversity information.

Temporal coordinates refer to the time axis in a multi-axes continuum.

Storage identity, format architecture, and security attributes are configurations set up by the author/editor.

BIOINFORMATION PRIMERS

The primers, which entrain processes, both natural and man-induced, include mechanisms such as protocols, algorithms, visualisations, and structural and visual designs. These are all listed in Fig. 2. These primers act as the main engine complex, which drives the entire temporal-based incubation process. The dynamic incubation activity is influenced primarily by the design architecture characteristics, and attributes.

Processes

The processes, which comprise the sources of bioinformation (Fig. 2), can be categorised into two major groupings: the man-made part and natural components. The man-made processes comprised steps involved in the execution of biological-based assignments e.g. bioengineering. The natural processes are those which act on the environment at large, species, populations, and individuals. Both processes are as outlined below:

Man-made:

Formulate & brainstorm
Allocate assignments
Experiment, analyse, and interpret
Meet & review
Design and develop graphics & interfaces
Design and develop shared documents & reports
Monitor job progress
Communicate continually to improvise
Present & demonstrate to elicit response
Repeat cycle if deemed necessary

Natural:

Genetic
Systematic

Adaptive
Physiological
Ecological
Environmental
Cross-scale super-processes

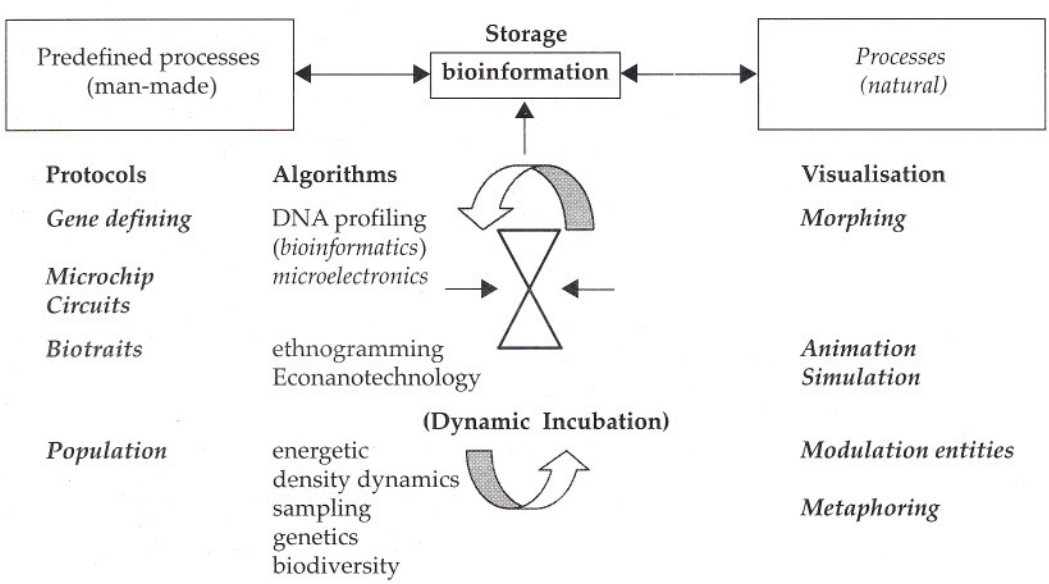
Algorithms

Algorithm for the design architecture (Fig. 2) describes characteristics of presentation or visualisation, especially pertaining to the Internet. These are outlined below:

User-seductive
User-participation
Non-cluttered
Metaphoric
Introductory panel
Index panel
Main page panel
Detailed info panels
Self-test panels
User-friendly
Interactivity
Hierarchical
Linked to resources
Real Time & Non-Real Time

Figure 2 : Frame chart of BioInformation Primers

Processes



Species
biogeography
evolution
patch dynamics
cross-scale interactions
biophysics
biophysical chemistry

Community
energetic
sustainability
ecology

Politics & policies - **(societal application)**
genetically modifying organism (GMO)
bioengineering
bioprocessing
ethical pressuring
ecclestical pooling
globalising
prospecting
pirating
risk assessing
stock piling
greening

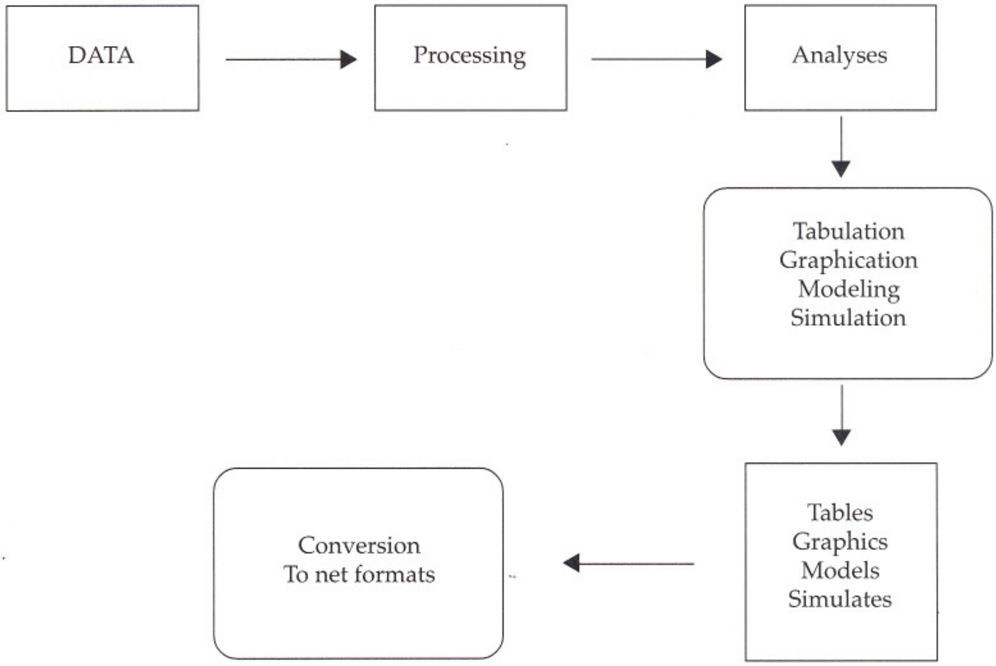
Digital application
bioware engineering
biogroupware
bioautomation

Format
Storage
Transmission
Models
Language
(E.g. SMIL, MIME)

Attributes
User-seductive
User participation
Non-cluttered
Metaphoric
Introductory panel
Index panel
Main page panel
Detailed info panels
Self-test panels
User-friendly
Interactivity
Hierarchical
Linked to resources
Real Time & Non-Real Time

The algorithm for the Internet input comprises steps involved during the entire procedure commencing with the bioinformation data through conversion to the Web format. This is visualised in Fig. 3 below:

Figure 3 : Algorithm for Net input



TEACHING & RESEARCH FUTURES

Teaching and research on bioinformation, including agro- & entomology-based contents, should utilise web-based (Internet) and localised (Intranet) technologies. The information values in the documented bioinformation modules can be enhanced by concomitant usage of Internet resources. Undoubtedly, web-based learning through teaching and research interactive and user-participative modules enhances activated academic exploration. Once bioinformation can be organised into digitised systems, which can solve application problems, applied biological knowledge emerges; and knowledge itself is power for societal progress and life enrichment. Hence enlightened and advanced digital teaching and research should invoke techniques and technologies which include video-streaming, digital-audio enhancement, artificial intelligence, expert systems, 3 D-animated modelling, real-time process simulation-modelling, instantaneous remote sensing, micro- and nano-technology visualisation, and bio-ecological rate-process user-based simulation. These techniques and technologies are already in existent today, albeit the high cost implicated to employ them, Nevertheless, a nation, such as Malaysia, which proclaims to be a future leader in digital education should be willing to invest in digital technology, notwithstanding the known costs involved. It is envisaged that there are three major challenges in digital education, which need urgent address now: multimedia intensive application, wider Internet-based domain, and wireless accessibility. Undoubtedly, apart from technological input, a repository with increasing convergence of knowledge resources is an essential requisite.

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