# The Specificity Property for the Exchange-Interaction

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***Abstract***

*The proposed work deals with highly complex, multi-dimensional systems/processes that cannot be described using low-level details. This is due to the complexity and uncertainty inherent in their nature of functionality, behaviour, interaction, hierarchy and geometry. To keep pace with such complexity and uncertainty, abstract modelling would be useful in predicting the level and nature of the exchange-interaction between processes and the consequent occurrence of events, thus devising rational strategies for tradeoffs. A set of principle analytical expressions are constructed to analyse and assess the performance or outcome of diverse processes (e.g. environment, economics, technology or globalization).*

*Keywords: multi-dimensional systems, exchange-interactions, specifity property*

## 1. Introduction

There is a considerable need for assessing and controlling many of the complex processes that take place in the real world. The process referred to herein may represent a physical system or a conceptual entity e.g. a set of events executed in a certain order to satisfy certain objectives, which may be medical, environmental and security driven. The assertion and execution of events may be governed by a set of variables, internal and external to the process (via the cause-effect relationship). The complexity of assessing or predicting the exchange-interaction of processes and the consequent occurrence of events should not be understated. This is due to the fact that the physical and temporal properties of a complex process (the words process and system are used interchangeably in the paper) may vary overtime. Furthermore, the uncertainty in the events that might arise and the complexity of high global interdependencies between n processes (n: integer, $n \geq 2$) make it difficult to determine which of the many process variables are important. Depending on the nature of tasks and the environment within which a system may function, quantifying and accurately characterising a large number of variables that may affect system performance may prove to be prohibitive.

Furthermore, present applications in the fields of medicine, economics, the environment, biochemistry, security and defence may require systems (or processes) not only to perform a desired function satisfactorily, but they should also be able to mitigate the effect of undesirable operational properties, caused by internal or/and external disturbances. That is, systems should be capable of anticipating future behavior [1][2] and adapting themselves to counteract abnormal events. Systems satisfying such objectives require some form of control to adjust their specified operation. In such control, information can be received and manipulated to produce control information in accordance with the sequence of the information received. The quality of the received information is key for the success of any form of control mechanism being instigated.

When systems are functionally, structurally and/or geometrically dependent on each other, specificity is essential and has a vital role in the exchange-interaction and the consequent functional events. The specificity could be thought of as a set of properties that processes should acquire for effective interaction activity. Some analytical modelling approaches have treated processes as one-dimensional entities of independent, uncorrelated properties. This may be analytically convenient, but, in certain cases, it may not be structurally and functionally realistic. The proposed work, which makes use of the model developed in [3] considers both processes of multi-dimensional events and the specificity aspect of the interaction between processes, and whether specificity is sufficient to maintain successful exchange-interaction

This paper is structured as follows: Section 2 introduces process-domains and analytical modelling expressions. A sample of applications for the proposed model is presented in Section 3. Conclusions are given in Section 4.

## 2. Modelling Expressions

The block diagram of Fig.1 shows two domains representing two distinct processes, $P_X$ and $P_Y$. The shaded area represents the interaction between $P_X$ and $P_Y$. As the focus of the paper is on the interaction between processes, each of $P_X$ and $P_Y$ are treated as a black box with a set of attributes, e.g. structural property, geometrical property, functional behavior. The exchange-interaction efficiency is determined by the specific means for essential responsiveness of the particular processes or sub-processes interacting within a particular system or a process, respectively.

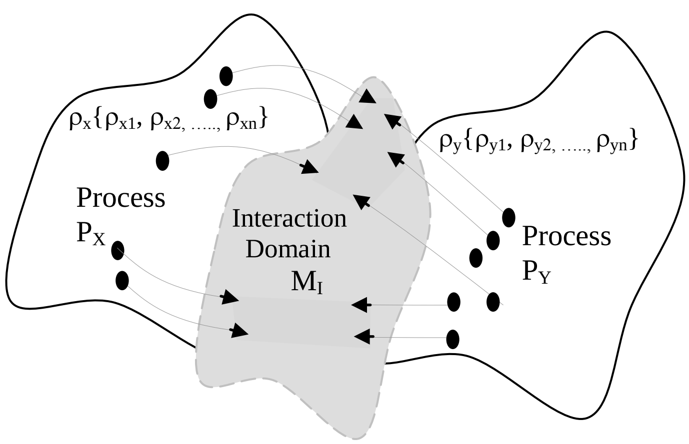


**Figure 1 Process-domain Representation**

If each process is formed by a set of variables:

$$P_X = f\left(G_X, F_X, S_X, \rho_X, ps_X\right) \tag{1}$$

$$P_Y = f\left(G_Y, F_Y, S_Y, \rho_Y, ps_Y\right) \tag{2}$$

In a more compact form

$$P_{i\{..\}} = f\left(G_{i\{..\}}, F_{i\{..\}}, S_{i\{..\}}, \rho_{i\{..\}}, Ps_{i\{..\}}\right)\Big|_{P_{j'} \cap P_{i'} = 0;\, P_{j'}, P_{i'} \in P_{i\{..\}}} \tag{3}$$

$i\{..\}$ a set of integers – each is associated with a unique process; j: an integer greater than zero.

With

$$M = f\left(P_{i\{..\}}\right) \qquad \forall t \tag{4}$$

In more general, hierarchical form:

$$M_i^l = f\{ G_i^l ,F_i^l ,S_i^l ,\rho_i^l ,Ps_i^l \}\Big|_{0\le l<n;i\{..\}} \tag{5}$$

$$\rho_i^l = f\{ \rho_{i''}^l \}\Big|_{i''\{..\}\in i\{..\}} \forall l \tag{6}$$

Such that

$$\prod_{l=0}^{l=n} \rho_{i''} \in \rho_{\overline{i'}} ; \qquad \rho_{i''} \notin \rho_{\overline{j'}}\Big|_{\rho_{i'}\{..\}\cap\rho_{j'}\{..\}=0;\rho_{i'},\rho_{j'}\in\rho_i} \tag{7}$$

and

$$\prod_{l=0}^{l=n} \rho_{j''} \in \rho_{\overline{j'}} ; \qquad \rho_{j''} \notin \rho_{\overline{i'}}\Big|_{\rho_{i'}\{..\}\cap\rho_{j'}\{..\}=0;\rho_{i'},\rho_{j'}\in\rho_i} \tag{8}$$

or

$$\rho_{i''} \in \rho_{\overline{i'}} \Leftrightarrow \rho_{j''} \in \rho_{\overline{j'}}\Big|_{\rho_{i'}\cap\rho_{j'}\neq 0} \qquad \forall t,l \tag{9}$$

Similarly,

$$ps_{i''} \in ps_{\overline{i'}} \Leftrightarrow ps_{j''} \in ps_{\overline{j'}}\Big|_{ps_{i'}\cap ps_{j'}\neq 0} \qquad \forall t,l \tag{10}$$

Considering $G_i$ , $F_i$ and $S_i$ represent unique characteristics for a given process or a system, analytical expressions similar to those in (6) – (8) could be obtained for each of $G_i$ , $F_i$ and $S_i$ , where :

$P_i$ : process.

$n$ : number of interacting processes.

$l$ : hierarchical level

$G_i$ : geometrical property for process i.

$F_i$ : functional property for process i.

$S_i$ : internal structure property for process i.

$\rho_i$ : process/system dependent parameter

$ps_i$ : pseudo variable/property for process i.

$q$ : integer

For desirable exchange-interaction, the interacting processes (or systems) would have to exhibit specific characteristics in terms of e.g. geometry, structure and functional behaviour.

Therefore, the interaction domain characteristics could be represented as a set of unique properties (i.e. specific to the interaction domain):

$$M_I = f(C_M, E_M, S_M, G_I) \qquad \forall l,t \tag{11}$$

where

$C_M$ : Capacity of the interaction domain to execute tasks

$E_M$ : Performance of executing tasks

$S_M$ : Specificity

$G_M$ : Geometry of the interaction medium/domain/region

Depending on the applications and the nature of the target process, the interaction domain could be viewed as a means of establishing connection between a number of processes, managing and controlling of the data transfer and/or terminating a process when it is completed.

For initiating an interaction

$$P_{i\{\ldots\}} \xleftrightarrow{S_M} P_{j\{\ldots\}} \qquad \forall l,t \tag{12}$$

That is, the specificity criteria must be satisfied for the initiation of an interaction between *n* processes.

Taking (12) into consideration, (11) could be rewritten as

$$M_I = f(C_M, E_M) \qquad \forall l,t \tag{13}$$

with

$$C_M = f\left(S_{i\{\ldots\},j\{\ldots\}}\right)\Big|_{\stackrel{\Delta}{\equiv} F_{I\{..\},J\{..\}}} \qquad \forall l,t \tag{14}$$

and

$$E_M = f\left(G_{i\{\ldots\},j\{\ldots\}}, ps_{i\{\ldots\},j\{\ldots\}}\right) \qquad \forall l,t \tag{15}$$

Such that

$$P_{i\{\ldots\}} \xleftrightarrow{M_I(C_M, E_M)} \Re \qquad \forall l,t \tag{16}$$

A block diagram representation of the interaction medium $M_I$, input $P_{i\{..\}}$ and output $\Re$ is shown in Fig.2.

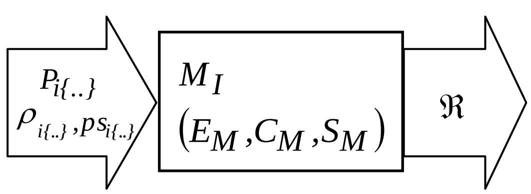


**Figure 2 $M_I$ (input/output) Representation**

Depending on the applications, $\Re$ may represent a product, strategy, decision, functional behavior or a policy.

## 3. Case-Studies

The analytical model is presented at the more abstract level, where each system or a process is represented as a set of variables/properties. This would make it easier to investigate irregular or abnormal functional behavior (regardless of a process's specific domain).

Case-study I:

The threat to ecological integrity is one of the emerging future security issues. Future conflicts can be caused by food shortages (leading to rising food prices) and water use - which includes military, industrial and agricultural uses – with the consequent e.g. economic downsizing, leading to a decline in full-time, secure employment, which in turn may lead to unrest that could threaten political stability [4][5]. If the populations (as users) and resources represent interacting processes, then the interaction between the two processes could be demonstrated as in Fig.3.

For an ideal case:

$$r\{ r_1, r_2, .., r_y \} \overset{\Delta}{\equiv} u\{ u_1, u_2, .., u_y \} \quad \forall l, \tau \Big|_{\tau \in t} \tag{17}$$

The maximum capacity for the interaction exchange:

$$maxC_I^{u,r} \equiv \left( \sum_{1}^{u,r} (m_u, m_r) \right) \to n \Bigg|_{u,r<n<\infty; u,r \in P_{i\{...\}}; m_r \in r; m_u \in u} \quad \forall l, t \tag{18}$$

with

$$E_M \xrightarrow{> maxC_I^{u,r}} 0 \quad \forall l, t \tag{19}$$

Where $r$ and $u$, respectively, represent resources and users, as two opposing dynamic processes.

The rate of the interaction-exchange is dependent on the concentration of resources and users. Considering the concentration aspect of the interaction-exchange is a function of a set of variables $F$, such as the environment, economics, technology and globalization [5][6]:

$$maxC_I^{u,r,F} \equiv \left( \sum_{1}^{u,r} (m_u, m_r) \right) \to q \Bigg|_{u,r<m<\infty; q \neq n; r \neq u;} \quad \forall l, t \tag{20}$$

For exchange-interaction:

$$C_I(u, r, F) \xrightarrow{\equiv} urc(F) \quad \forall l, t \tag{21}$$

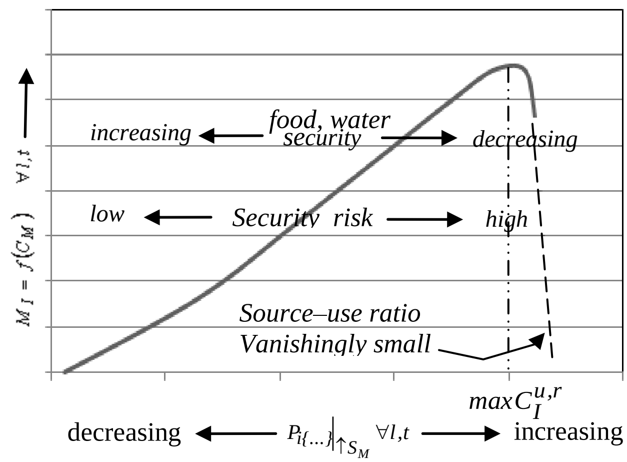


**Figure 3 Performance profile of the exchange-interaction as a function of source-user ration.**

From Fig.3, the exchange-interaction ceases beyond $maxC_I^{u,r}$ - indicating a progressive (depending on demands and availability of resources) deterioration of security with potential for conflicts.

Case-study II:

We are currently observing the exponentially growing use of the internet – fueled by the technological development of the web and its applications. This platform poses more challenging security threats compared to their conventional counterparts [3]. The value of the internet increases with the number of users connected to it. For absolute security, a computer network would have to be severely limited to certain well known and trustworthy connections. However, such reduction in connectivity reduces e.g. the information acquired and the commerce attained.

Modeling a network's computers and users as two interacting processes, $P_{i\{..\}}$, with the interaction between the two processes, $M_I$, represents activity, then the properties (or characteristics) of $M_I$ could be investigated for better performance (i.e. desirable exchange-interaction).

$$M_I = f(C_M, E_M) \qquad \forall l,\tau\big|_{C_M, E_M = f(ps), \tau\in t} \tag{22}$$

Assuming

$$ps_i = \{\Im, \hbar\} \tag{23}$$

Then $M_I(C_M, E_M) = f(\Im, \hbar) \qquad \forall l,\tau$ (24)

If each of $\Im$ and $\hbar$ is represented as a scale with limits $0 \rightarrow 1$, then

$$ps_i(1,0) \xleftrightarrow{C_M, E_M} ps_i(0,1)\Big|_{\uparrow S_M} \tag{25}$$

$\Im$ : Security factor (or variable); $\hbar$ : Profit factor (or variable).

Equation (25) assumes $\Im$ and $\hbar$ have equal impact on outcome $\Re$ (in terms of performance/efficiency). Fig.4 shows the performance $M_I$ for varying $\Im$ and $\hbar$. Assuming a linear relationship between $\Im$ and $\hbar$ , an optimal trade-off between security and profit could be realized.

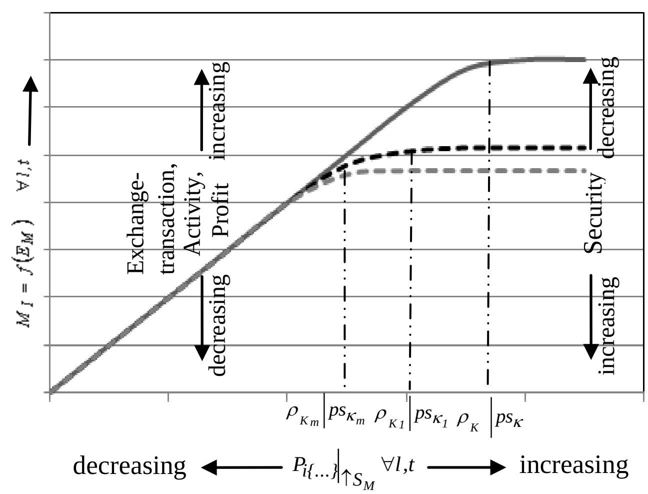


**Figure 4 Performance of $M_I$ under the effect of $\rho_i$ and $ps_i$ .**

However, a tiny probability of security violation/breach $P(\Im_v)$ may have infinite impact on a system's integrity. Therefore, (25) is valid *iff* $P(\Im_v) \to 0$ . To express the effect of such probability:

$$M_I(C_M, E_M) = f\left((\Im(\gamma_\Im), \hbar(\gamma_\hbar))\right)\Big|_{\uparrow S_M} \qquad \forall l, \tau \tag{26}$$

with

$$\gamma_\Im = g(\gamma_\hbar) \tag{27}$$

where $\gamma_\Im$ and $\gamma_\hbar$ represent severity variables associated with $\Im$ and $\hbar$ , respectively; $g$ represents a non-linear function.

Taking into account this nonlinear relationship, (25) could be re-written as follows:

$$ps(1,0) \xleftrightarrow[f(\partial\Im / \partial t) = 0]{C_M, E_M} ps(0,1)\Bigg|_{\uparrow S_M} \tag{28}$$

This could be interpreted as a straight line (representing equilibrium points, Fig.5) stretching across the middle of a saddle, with $P(\Im_v)$ represented by a roll in either uphill direction. In other words, the dotted line and the solid isoclines, respectively, represent the linear and non-linear aspects of the relationship between security and profit.

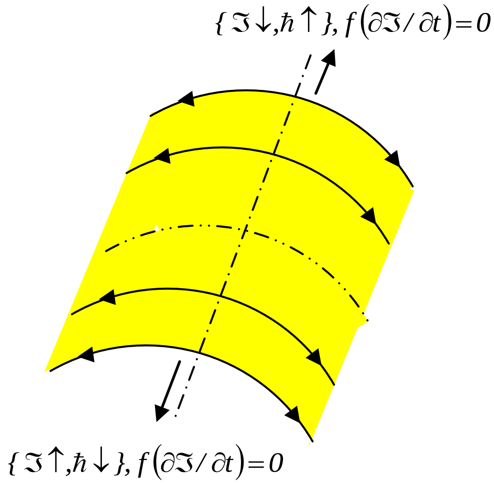


**Figure 5 Non-linear trade-offs.**

Case-study III:

A biochip that is capable of predicting changes in the conformation of a protein – under the influence of abnormal biological events – has potential applications in the fields of medicine, security and defence. For instance, in the event of biological attack, the chemical structure – thus protein structures – in the body may experience structural changes. An algorithm - incorporated in a biochip - that is able to predict a protein's behavioural malfunction, which will be of use in *in-vivo* monitoring as well as for dealing with possible cases of disease or combating stress.

At the biological level, various specialized functions are performed by specialized molecular structures (with different combinations) interacting with each other. Malfunction (leading to diseases) may be of reversible or permanent nature, depending on the causal-effect mechanism. This could be assessed by investigating the interaction domain between the interacting molecular structures. As an example, consider two molecular structures, source and sink. For successful interaction-exchange (leading to a desired biological function), the specificity property must be satisfied. Assuming this property is held true, (11) could be reduced to:

$$M_I = f\left(C_M, E_M, G_I\right)\Big|_{G_I = f(G), \uparrow S_M} \qquad \forall l, t \tag{29}$$

with

$$C_I^{i,j} \equiv \sum_{1}^{i,j} m_i + m_j \qquad \forall l, t \tag{30}$$

Equation (30) assumes each molecular structure is a finite entity.

If the capacity of the interaction domain $C_I$ is assumed to be a function of the number of molecules $N_m$ occupying the interaction domain $M_I$ ,
then:

$$C_I = f(N_m)\Big|_{N_m = \sum_{m\in M_I,\kappa^*=\{\kappa,\kappa^{\sim}\},\kappa\in P_{i\{...\}},\kappa^{\sim}\notin P_{i\{...\}},} q_m^{\kappa^*} f_m^{\kappa^*}}, \quad \forall\kappa,t \tag{31}$$

Such that

$$\xi(m,t) = \begin{cases} 1 & if \quad m\in M_I\big|_{\uparrow S_M} \\ 0 & otherwise \end{cases} \qquad \forall t \tag{32}$$

$q_m^{\kappa^*}$ and $f_m^{\kappa^*}$ could be viewed as matrices representing a set of molecules that satisfy the specificity property and their corresponding flags, respectively.

The molecules of $N_m$ are asserted depending on satisfying the specificity property $C_x^{k^*}\Big|_{x>1}$. For instance,

$$m^x\uparrow \quad iff \quad S_M^x\uparrow, \xi(m^x,t)=1\Big|_{x>0;x\in q_m^{k^*}} \qquad \forall t \tag{33}$$

Such that

$$f_{m^y}^{k^*} = 0, \forall m^y \notin q_m^{k^*}\Big|_{y>0;y\neq x} \tag{34}$$

Fig.6 shows the interaction-exchange as a function of deviations in certain properties of $M_I$ and $P_{i\{..\}}$. From Fig.6, the maximum exchange-interaction is lowered when $M_I$ encompasses $q_m^{\kappa\sim}$. To achieve the maximum exchange-interaction the number of molecules represented by $q_m^{\kappa}$ must be increased. If the presence of $q_m^{\kappa\sim}$ is temporary, then the maximum performance of $M_I$ is recoverable. Otherwise, it is irreversible. For instance, HMGB1 will replace the Linker-Histone H1 to form a DNA-HMGB1 complex [7][8].

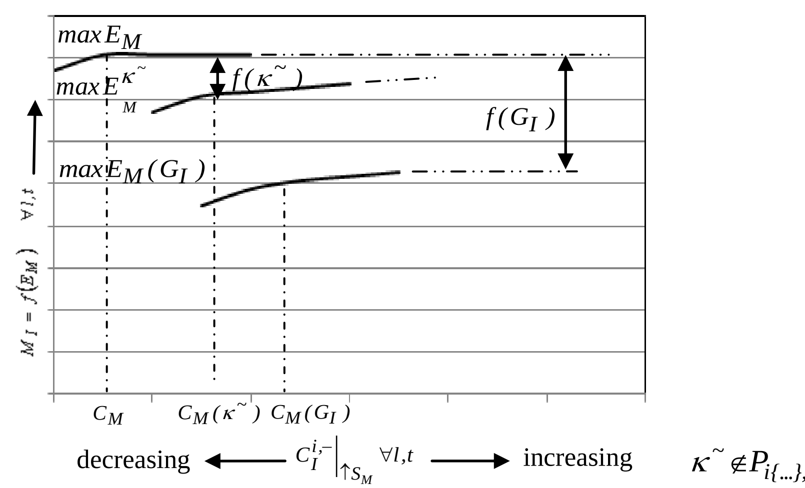


**Figure 6 The exchange-interaction for varying $G_I$ and**

In the case of changes in $G_I$ , the recovery of the maximum exchange-interaction is independent of $q_m^{\kappa}$. The maximum performance (i.e. high exchange-interaction) is reversible *iff* the cause of changes in $G_I$ is temporarily.

Consider for example the case of the CDK protein bound to 2 molecules of 8-anilino-1-naphalene sulfonate (ANS), indicated in Fig.7.(1) by the two red arrows. This complex will have a particular function. Suppose now that a third ANS molecule binds to the complex, as shown in Fig.7.(2), then a conformational change takes place. In Fig.7.(1) the yellow arrow indicates a helix, which disappears in Fig.7.(2). This conformational change will cause the complex of CDK2 plus 3 ANS molecules to have a function different to that of the initial complex. The way that conformational changes alter function is by changing the electrostatic surface profile of the protein. In Figures 7(3) and 7(4) the difference in the electrostatic surface profiles of CDK2 bound to two different molecules can be clearly seen. If the binding of these molecules is temporary, then the function of the initial complex (and thus the initial surface electrostatic potential) is recoverable. This is equivalent to the graph for $max E_M^{\kappa^{\sim}}$ in Fig.6 (i.e. $E_M^{\kappa^{\sim}} = f(\kappa^{\sim})$).

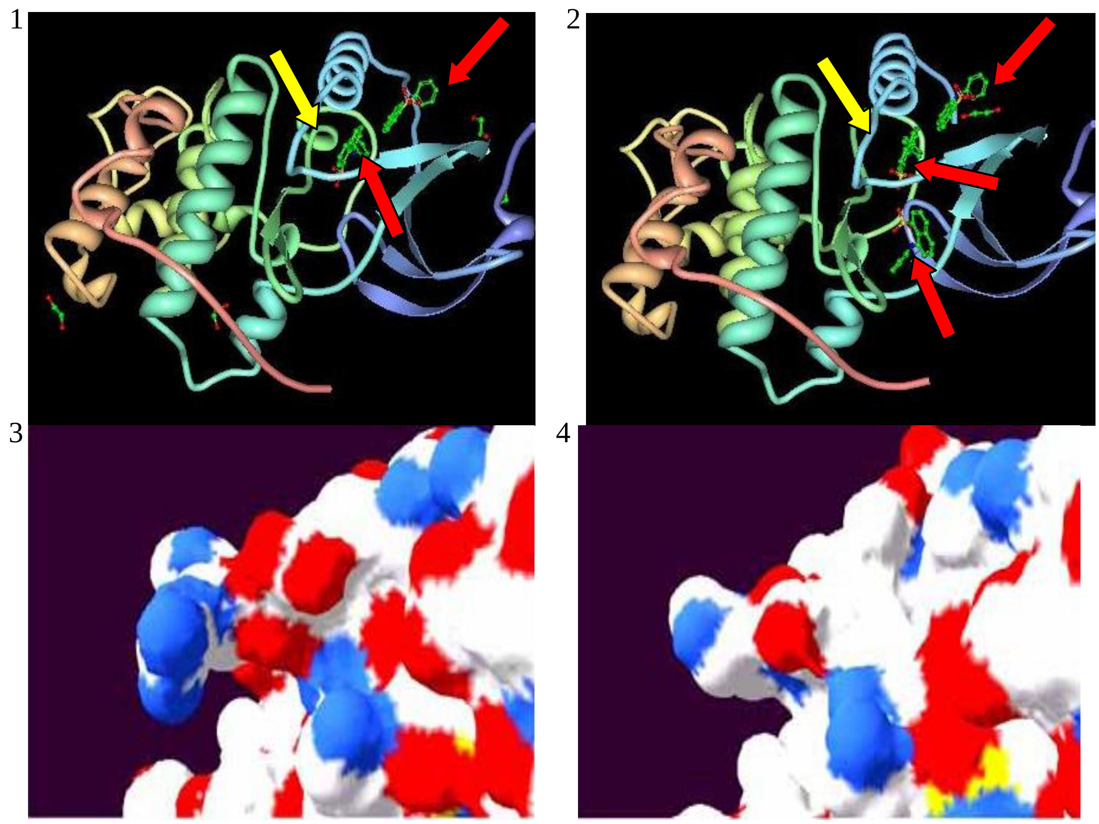

**Figure 7 (1&2): Protein conformation under different non-protein molecular structures; (3&4): Surface electrostatic potentials for different non-protein molecular structures.** ***Note: images 1 and 2 were obtained from Protein Data Bank; images 3 and 4 were obtained from [8] – reproduced with permission.***

## 4. Conclusion

The interdependency between multi-dimensional systems/processes (such as those encountered in the biological sciences, engineering, environment, economics) – and taking into account the range and number of variables involved - poses a high level of uncertainty and complexity. To keep pace with such uncertainty and complexity, abstract modelling would be the preferred approach for complex system-based problems. The effectiveness of the proposed model, which focuses on the identification of interdependency and the interaction-exchange, is dependent on how accurately all relevant processes (including their variables) are identified and also how accurately the strength of all their interactions is assessed. The analytical model is not intended to provide an exact answer or a solution to a problem. Rather, it points to future trends of events (including implications associated with such events) – thus assisting in the postulation and evaluation of alternative solutions.

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