ACTION-BASED UNION OF THE TEMPORAL OPPOSITES IN SCHEDULING: NON-DETERMINISTIC APPROACH

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It is the time resource that one deals with in scheduling. The task is how one can achieve the optimal allocation of a given time resource over a set of assigned activities. Most of the existing scheduling methods use a parametric time by which the activities are orderly allocated in accordance with the order of events. The parametric methods however fail in incorporating a dynamic aspect of scheduling that unfolds itself as the project proceeds, and also uncertainty that the starting and ending nodes of an activity fluctuate. This paper reformulates the concept of time to match to a dynamic scheduling through a non-deterministic approach. In particular, time can be regarded as an object in the holographic space, which models the dynamic aspects of time as a "mapped/ represented" and "transformed/ processed" temporal movement.

Keywords: *union of opposites, internal and external order of time, initial and final conditions, dichotomy, temporal symmetry and asymmetry, certainty and uncertainty, entropy*

1. INTRODUCTION

It is the time resource that one deals with directly under any scheduling scheme. The task is how one can achieve the optimal allocation of a given time resource over a set of assigned activities. The temporal order of the assigned activities is usually described in a Network Chart schematically. Then there are various existing methods how to allocate the activities over time, such as Gantt chart, CPM, PERT, GERT, Multi-Activity Chart, and many others[1] [2] [3] [4]. Most of the existing methods use a parametric time, single dimension of time, on which the activities are orderly allocated in accordance with the order of events. They provide, however, one with only a means of static description of time resource distribution at his planning stage, or mere projection of his temporary thoughts in succession. One faces two basic problems in scheduling, namely; (1) (planning stage) the provided data by which time resource is allocated to a particular construction activity is usually far from precise unlike machine operation in manufacturing, where the beginning and ending nodes of a time interval allocated for a particular activity are both fluctuating to a notable extent. Most of the existing scheduling methods [5][6][7] can not incorporate uncertainty of this sort sufficiently enough or not at all. (2) (operating stage) One faces often the need to reallocate the time resource as a construction project proceeds. Although the final goal of the project is clearly defined, no existing scheduling method provides a dynamic adjustment mechanism in reference to the project's goal.

This paper deals with these fundamental problems directly which look different apparently, but they are deeply related, and provides the readers with approach to their solution. For that matter, the authors start with a metaphoric introduction of the guiding concept throughout this paper, "Union of Opposites". The main reason why the existing methods fail in incorporating both fluctuation and dynamic decision mechanisms in their models goes back to the origin of static dichotomy. It will be shown (Section 3) that the concept of time, rooted in static dichotomy, is needed to be reformulated accordingly. The final condition then becomes apparent for human activities vis-à-vis the initial condition (Section 4). Temporal symmetry and asymmetry in scheduling will be discussed (Section 5). Finally, incorporation of uncertainty into the scheduling model will be shown (Section 6).

2. GUIDING CONCEPT, "UNION OF OPPOSITES"

2.1 Act of Mutual Determination in Dichotomy

The flocks of wild geese fly in the Escher's paint (Fig.1) [8], white geese to the right, black ones to the left. These two flocks, though toward the opposite directions, do not only fly next each other but, in fact, *determine* each other in dichotomous fashion. Without the black flock drawing the white, no white flock is defined. Without the white drawing the black, no black flock. The act of mutual drawing is indeed the characteristic of this picture here. Before this act of drawing, none altogether, no whole nor parts, that is no picture! After this act, the whole picture becomes itself, parts and whole altogether. Escher draws, in this paint, the act of mutual determination in the dichotomy, black and white. This sort of mutual determinant dichotomy the authors call "extended dichotomy", in which *action* is inherently embedded.

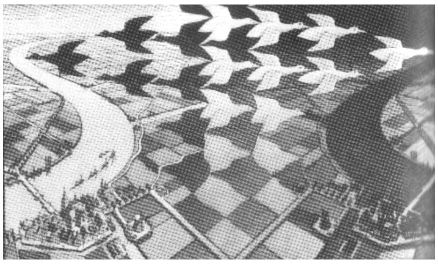

Fig1. Day and Night, M.C. Escher (1938)

2.2 Reflectors

Two mirrors stand still face to face, the one called "white mirror" and the other called "black mirror". The two mirrors reflect each other. The image of the white mirror is at the black mirror, and its image is then reflected back onto itself. The other way around for the black mirror is also true. It can be said, though admittedly metaphor, that when the mirror's image is reflected back onto itself, it becomes itself as *is* a mirror. If a shade screen is set between the mirrors, they are no longer reflecting mirrors. They are not mirrors without continuous movement of reflection of two. The act of continuous reflection maintains the dichotomy, black and white. The two flocks in the Escher's paint are, in this sense, reflectors [9].

2.3 Formalism in Abstraction

The action-based "extended dichotomy" described at (1), (2) can be formalized as follows. Let σ be the underlined action operator, and σ^{-1} be the reverse action operator. In the case of the Escher's paint, σ may be "(the white flock) draws …." σ^{-1} be "(the black flock) draws …." In the case of the mirror reflection, σ may be "(the mirror A) reflects itself on…." σ^{-1} be "(the mirror B) reflects itself on…." In either case the following property of the operators is required;

$$\sigma^2 = \sigma^{-2} = 1 \qquad (1)$$

The operator σ contours the whole circle Ω (logical whole) clockwise, whereas the operator σ^{-1} contours the whole circle Ω counter-clockwise. Then, by combining these two movements, the right-hand of the equation in Fig.2 follows, where both A and not-A are defined explicit, while the movements are hidden behind ($\sigma\sigma^{-1}$=1). It is needed however to keep A and not-A defined explicit that the operator and reverse operator act restlessly behind the back.

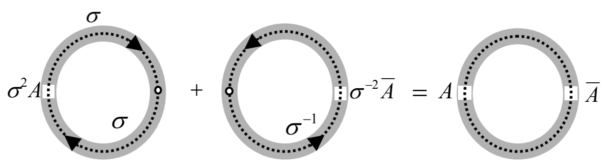

Fig.2 Movement of Action
Holding the Dichotomy Explicit

The continuous convolution of movements, back and forth ceaseless movement between the right-hand and left-hand sides of the equation in Fig.2 to hold the underlined dichotomy explicit, is indeed the notable characteristic of the "extended dichotomy". Under this scheme, it can be said "A is an implicit constituent of not-A. Not-A is an implicit constituent of A.", for both A and not-A equally cover the whole dichotomy space. Or equivalently, "The whole dichotomy space Ω is an implicit constituent of A and of not-A." The usual dichotomy is a degenerated case of the "extended dichotomy", where the operator σ is the set theoretical operation, taking the complement, Ω-A, or Ω-(not-A).

This movement is dictated in the Escher's drawing, for all its compositions, the white and black flocks, and the whole are carefully being adjusted under the movement. The white and black flocks in the picture are therefore restlessly flapping around the sky of logics, back and forth ceaseless movement

3. IMPLICIT AND EXPLICIT ORDER OF TIME

It is the time resource that scheduling deals with. One's parametric conception of time causes action of any kind dropped off from a scheduling model. However useful the parametric conception may be as scaling tool to determine the time interval during which an activity proceeds. It should be realized however an activity comes first and determines the time interval, but not the other way around. The fact that there exists the order of action behind the parametric time must be incorporated into a scheduling model. It is the implicit internal time, another temporal order, more fundamental one, which casts its shadow over the parametric time. It is this temporal order within which the current activity is adjusting to its immediate as well as accumulated past and anticipating the coming future.

There are two distinct temporal orders, implicit and explicit. The implicit order of time is the order of action in which the past, present, and future of an activity are convoluting as potentials, while the explicit order of time is the parametric time of events measured by mechanical clock.

3.1 Schematic Formulation of Internal and External Time

Two streams of activities in the form of potentials flow into the current activity, one from the past and the other from the future [1)]. They convolute at present, bounce around their way of settlement, come to a conclusion as to their optimal mixture, and in the end transform the integrated potentials into an event at now which belongs to the explicit order of time. The implicit and explicit temporal orders categorically differ in such a way that one deals with *potentials* in the implicit order of time, but deals with *events* in the explicit order of time. However they are distinctively different, they are dynamically integrated within the dynamics of the current action, two sides of the same coin.

[1)] *The potentials from the past and those from the future are distinctive, for the activities in the past have already happened and became events once, while the activities in the future are in the mode of pure potentials. Though the past activities became unchangeable events as they were, they can be viewed from the standpoint of the current activity as potentials, for the ones who conduct the current activity must give them a particular interpretation among many possible interpretations to find an optimal fix with reference to its immediate, intermediate, and final goals, all to be happened in the future.*

The authors now formulate the combinatory temporal order, Internal Time x External Time at Fig. 3.1. Each internal time is non-locally distributed over the pre-assigned temporal whole, Ω with density function $f_j(t)$ *such that* $\sum_j f_j(t) = 1, \forall t \in \Omega$ The dynamic movement between the internal time and external time described above can be formulated as Temporal Engine, and put into the schematic form diagrammed at Fig. 3.2.

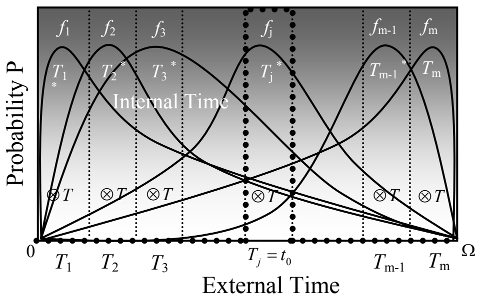

Fig.3.1 Internal Time and External Time

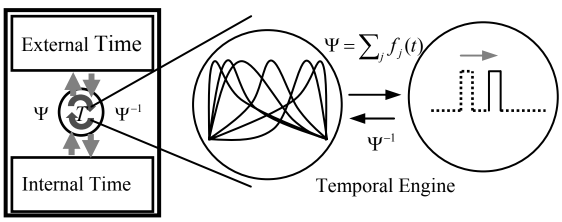

Fig.3.2 Temporal Engine: Two-way Transformation Between Non-Local Internal Time and Local Time

The event produced by the current activity is indeed dichotomous whether it happens (1) or it does not happen (0). This eventual dichotomy however becomes explicit only through superposition of all the internal potentials and its transformation. There is yet another fundamental dichotomy between the internal and external time, two-way action-based dichotomy actuated by the Temporal Engine. It is more fundamental for it makes the former possible.

3.2 Mathematical Formulation: Holographic Modeling

In this section, a more rigorous formulation will be outlined and reveal it has a holographic characteristics. Let the set of the probability density functions shown at Fig.3.1 be denoted by $\{f_\theta(x)\}_{\theta\in\Omega}$, each of whose elements is a non-locally distributed internal time centered at each time $\theta \in \Omega$. One can change the x-coordinate to $[-\pi, \pi]$ without loss of generality. The set of densities $(\int_{-\pi}^{\pi} f_\theta(\tau)d\tau = 1, \forall \theta \in \Omega)$ is assumed to satisfy either of the following conditions.

(1) Stronger condition (symmetry)

$$\vartheta_1 = \{f_\theta : f_\theta(\tau) = f_\tau(\theta)\}$$

(2) Weaker condition (integral symmetry)

$$\vartheta_2 = \{f_\theta : \int_{-\pi}^{\pi} f_\theta(\tau)d\tau = \int_{-\pi}^{\pi} f_\tau(\theta)d\tau\}$$

Even the stronger condition holds for most of applications because of the homogeneity of time, that is no time is usually special to any other time.

One can decompose each density function by Fourier Harmonic Decomposition, that is;

$$\bar{f}_\theta^{c(n)} = b_\theta(n)\cdot\cos n\tau$$
$$\bar{f}_\theta^{s(n)} = a_\theta(n)\cdot\sin n\tau \qquad (2)$$
$$\textit{where} \quad a_\theta(n) = \frac{1}{\pi}\int_{-\pi}^{\pi} f_\theta(t)\sin ntdt$$
$$\textit{and} \quad b_\theta(n) = \frac{1}{\pi}\int_{-\pi}^{\pi} f_\theta(t)\cos ntdt$$

Those harmonic components can be rearranged on the surface of a unit sphere, for it gives the circumference on the unit sphere to multiply by 2π the sine and cosine functions in each harmonic component (Fig.3.3). Thus one obtains its geometric interpretation.

It is further possible to reduce all the sine and cosine harmonic components to the sine harmonics only, for a cosine harmonic can be viewed as sine harmonic when the

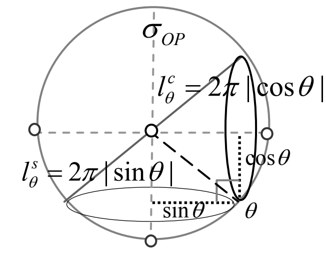

Fig.3.3 Geometric Interpretation of Fourier Harmonic Decomposition

unit sphere is rotated to counter-clockwise by $\pi/2$ (angular duality of sine and cosine circumferences). After such rearrangement of Fourier coefficients and sine-reduction, one can assign each slice of the unit sphere a unique value of coefficient (Fig.3.4) named as "holographic coefficient" (by the authors). Those coefficients are uniquely determined by the underlined set of probability density functions which represent collectively the structure of the internal time under consideration.

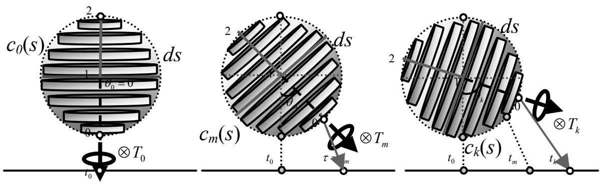

Fig.3.4 Unit Sphere Representation of the Internal Time with Holographic Coefficients

The unit sphere therefore encodes all the information as to the internal time configuration on its surface with the values of coefficients assigned to each slice that will vary in general by its angular inclination. When one takes the integral of the coefficients over the sphere surface from a particular angle (say θ_m), one gets the corresponding external time t_m. One can now defines an operator called "holographic operator" (by the authors) which acts on the sphere surface, and whose action produces an external time each time it acts on the surface.

$$\sigma_{OP} = 1 + \frac{1}{2\pi}\int_0^{4\pi} < operand > ds$$

$$\otimes T_\tau = \{c_\tau(s) : 0 \le s \le 4\pi\}$$

= set of coefficients as operand at time

$$\sigma_{OP} \otimes T_\tau = 1 + \frac{1}{2\pi}\int_0^{4\pi} c_\tau(s)ds = 1 \qquad (3)$$

The holographic operator acts on the same sphere all the time, changing its angular direction in succession, casting the shadow of the sphere, producing the eventful world, and thus bridging the potentials with reality, that is that the action-based "extended dichotomy" is.

4. INITIAL CONDITION AND FINAL CONDITION

In physics or engineering alike, physical events evolve over time by certain differential equations autonomously once given initial conditions. The equations and its initial conditions determine the whole sequence of the following events. The Newtonian physics and Einstein's relativistic physics both belong to this deterministic world. The Schrödinger's wave equation in the Quantum physics is not an exception, though the square of the wave amplitude gives probability with which an underlined particle may be there. Moreover, most of the physical laws cannot distinguish two directions of time [10], from past to future, and future to past. They are temporally symmetric from the standpoint of the underlying physical equations. The initial conditions can be set in the future in stead of the past to get exactly the same sequence of events, but in the reversed order.

But in reality or at least reality of large-bodies nobody says time runs backward. It is the thermodynamics that provides us with the arrow of time. The entropy, the measure of disorder, always increases according to the law. Suppose there is a cluster of gas molecules at one corner of an enclosed box. These molecules tend to move to random directions due to their bouncing around collisions so that they diffuse eventually to the whole space in the box. However the probability that the once diffused molecules gather back to a corner is negligibly small though not zero, but very rare statistically, for the number of ways of the diffused state far exceeds that of consolidate states. It is the thermodynamic law that preserves the time symmetry of the basic physical equations, while reveals the phenomenological arrow of time. The physics of non-equilibrium processes describes the profound effects of unidirectional time which lead to concepts such as self-organization and dissipative structures [11][12].

Here raises a basic question, however, whether the human activities are bounded by the second law of thermodynamics. The physical law is so basic that the answer should be affirmative. That is why some people's desktop becomes messy. Then the next question follows immediately whether the consolidate states in human activities are so rare compared to their disorder states as the law of thermodynamics may suggest. How about in the case of scheduling? How about in the case of baseball spectators? After an inter-company baseball match between Company A and Company B is over, a crowd of spectators once seated orderly leave the stadium to different directions to home. The ordered state is broken there, that is increase of entropy. Next morning people from Company A go work at Company A and people from Company B go work at Company B. They are in very orderly state to work for their company's profit-making. If you replace the molecules with humans in the box, perhaps in a room this case, the consolidate states are likely, or at least as likely as the diffused states.

What makes them different is due to that the final condition (goal) which acts on their activities throughout time become notable in the case of human activities. For it is the human activities that are arranged in construction scheduling, one must consider two conditions lie at the two opposite ends of the construction period, the initial condition and final condition. They are defined as follows;

Initial Condition − the ordered state of the initial plan or design on the onset

Final Condition – the ordered state of the physical achievement at the end.

The two conditions are both in ordered states, but distinctively different ones. The initial condition lies at the onset of the project when no events have yet happened. It is therefore something to do with the planning or design of the scheduling. The final condition lies at the end of the project. It is therefore something to with the physical achievement (say a building). The initial condition acts on the internal time throughout time for it deals with potentials, while the final condition acts on the external time throughout time for it deals with events. As the project proceeds, the initial condition acts less and less, while the final condition acts more and more and reaches to the completion of the project. When reversing the time backward, the initial condition acts more and more, while the final condition acts less and less. Such two ways process is depicted at Fig.4.1 (a) (the white flock represents the initial condition on the internal time, while the black flock does the final condition on the external time). At any section of time one finds both orders act.

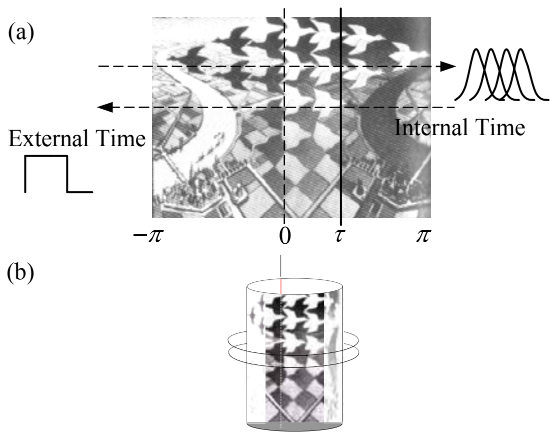

Fig.4.1 Initial Condition and Final Condition

After the project is over, it spins off new different but similar projects and lets them commence at the point that it ends (Fig.4.1 (b)). In this way the following independent projects are the precedent project's offspring that have both continuity and discontinuity from the precedent ones. The phase transition occurs at the point that the parent project ends from the physical external order to the internal order in which "genetic" crossovers [13] with other projects occur.

5. TEMPORAL SYMMETRY AND ASYMMETRY

The holographic operator acts on the operand distributed over the sphere surface from a different angle at each time and sums it up to produce the external event (Fig.5.1 (a)). All the information on the whole surface of the sphere is encoded at each slice on the sphere due to the underlying holographic characteristics. Therefore each coefficient can be decomposed into its past and future parts ($c_\tau(s) = c_\tau^{past}(s) + c_\tau^{future}(s)$). One can therefore decompose the holographic operator (Section 3.2) into the past and future sub-operators as follows;

$$\frac{1}{2\pi}\int_0^{4\pi} c_\tau(s)ds = \frac{1}{2\pi}\int_0^{4\pi} c_\tau^{past}(s)ds + \frac{1}{2\pi}\int_0^{4\pi} c_\tau^{future}(s)ds \qquad (4)$$

$$\text{that is } \sigma_{op} = \sigma_{op}^{past} + \sigma_{op}^{future}$$

The information of the past is distributed over the whole surface of the sphere. So is the information of future. It is a perfect symmetry as a sphere is. When the holographic operator acts on the sphere at each time and sums it up to produce the external event, the symmetry is broken (Fig.5.1.(b)). Each time when it happens, the sphere remains symmetric, but attains an induced asymmetry (redefined past, present, and future).

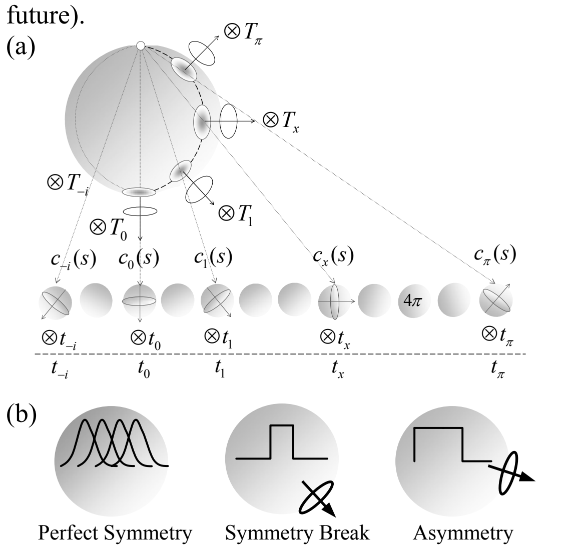

Fig.5.1 Temporal Progression and Symmetry Break

6. CERTAINTY AND UNCERTAINTY

In Section 4, it seemed suggested the second law of the thermodynamics may be broken in the case of human activities. One cannot jump into such a conclusion however. The issue is more subtle than it seemed. Although it is true that once the final condition acts on the component activities to a notable degree (such is the case for scheduling), the ordered states become as likely as the disordered states or more likely, the disintegration pressure due to the thermodynamics law acts on the activities all the while the project proceeds. There are indeed so many sources of disintegration in a project which may halt the project at worst (all sorts of troubles in logistics, crane operation, weather, structures, water leakage, accidents, financing, and so on as you can imagine).

This disintegration pressure comes from the depth of the physical world, back to the turbulent movements of molecules. It suggests all sorts of the dichotomies mentioned in the earlier sections do not stand in the idealists' binomial opposition, but are real opposites.

That is the reason why any planned activity is realized hardly as precise as planned, its beginning and ending points fluctuate to a notable degree, and needs to be continually adjusted under the persisting circumstance that the initial and final conditions actively colliding.

The thermodynamics law is not negligible at all for scheduling. However it is also true it is hard to hold the assertion that the diffused states are more likely in human activities. By the same token, for scheduling. The internal time is non-locally distributed over the whole time with some fluctuation. The thermodynamic fluctuations are in fact implicitly embedded there [3)]. The node between the successive activities becomes vague and is stretched over some interval in this setting (Fig.6.1). Contrarily the event becomes realized with certainty, once it happens.

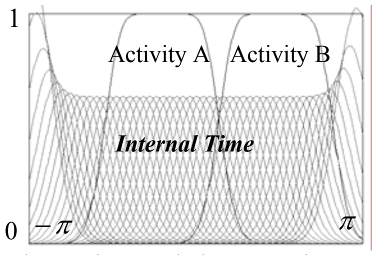

Fig.6.1 Fluctuating Node between the Successive Activities

7. SUMMARY

It was shown that the order of time should be reformulated to model the evolutional aspect of scheduling as the project develops towards its completion. Its dynamics requires dealing with the temporal potentials set for scheduling the whole set of which unfolds events in successions as time passes and enfolds them back to itself to continually refer to both the initial conditions at the onset of the project and the final conditions imposed at its completion. The mathematical modeling of the underlined dynamics by Fourier harmonic decomposition reveals its holographic characteristic *that is* the back and forth movement between encoding and decoding of the information of the whole.

It was also shown that, deeply related to the dynamics, the fluctuation of the activity's nodes can be formulated as the temporal non-locality of the internal time and that the second law of thermodynamics can be reinterpreted in such a way to fit the human activities *per se*.

Whitehead's process philosophy opened up a new line of thoughts that the process of becoming comes before existence [14]. This paper has showed it is indeed the case for scheduling as well.

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