On A Nascent Mathematical-Physical Latency-Information Theory, Part II: The Revelation Of Guidance Theory For Intelligence And Life System Designs

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Since its introduction more than six decades ago by Claude E. Shannon information theory has guided with two performance bounds, namely source-entropy $\boldsymbol{H}$ and channel capacity $\boldsymbol{C}$, the design of sourced intelligence-space compressors for communication systems, where the units of intelligence-space are 'mathematical' binary digit (bit) units of a passing of time uncertainty nature. Recently, motivated by both a real-world radar problem treated in the first part of the present paper series, and previous uncertainty/certainty duality studies of digital-communication and quantized-control problems by the author, information theory was discovered to have a 'certainty' time-dual that was named latency theory. Latency theory guides with two performance bounds, i.e. processor-ectropy $\boldsymbol{K}$ and sensor consciousness $\boldsymbol{F}$ the design of processing intelligence-time compressors for recognition systems, where the units of intelligence-time are 'mathematical' binary operator (bor) units of a configuration of space certainty nature. Furthermore, these two theories have been unified to form a mathematical latency-information theory (M-LIT) for the guidance of intelligence system designs, which has been successfully applied to real-world radar. Also recently, M-LIT has been found to have a physical LIT (P-LIT) dual that guides life system designs. This novel physical theory addresses the design of motion life-time and retention life-space compressors for physical signals and also has four performance bounds. Two of these bounds are mover-ectropy $\boldsymbol{A}$ and channel-stay $\boldsymbol{T}$ for the design of motion life-time compressors for communication systems. An example of a motion life-time compressor is a laser system, inclusive of a network router for a certainty, or multi-path life-time channel. The other two bounds are retainer-entropy $\boldsymbol{N}$ and sensor scope $\boldsymbol{I}$ for the design of retention life-space compressors for recognition systems. An example of a retention life-space compressor is a silicon semiconductor crystal, inclusive of a leadless chip carrier for an uncertainty, or noisy life-space sensor. The eight performance bounds of our guidance theory for intelligence and life system designs will be illustrated with practical examples. Moreover, a four quadrants (quadrants I and III for the two physical theories and quadrants II and IV for the two mathematical ones) LIT revolution is advanced that highlights both the discovered dualities and the fundamental properties of signal compressors leading to a unifying communication embedded recognition (CER) system architecture.

Index Terms—Uncertainty/Certainty Duality, Communication/Recognition Duality, Intelligence/Life Duality, Motion Life-Time and Retention Life-Space, Sourced Intel-Space and Processing Intel-Time, Compression, Guidance Theory for Intelligence and Life System Designs, Communication Embedded Recognition System

1. Introduction

Recently information-theory, guiding mathematical communication system designs, was found to have a time-dual that guides mathematical recognition system designs and has been named latency-theory [1]. More specifically, information-theory is characterized by mathematical binary digit (bit) units of a passing of time uncertainty nature that are linked to a signal-source's 'sourced intelligence-space (or intel-space in short)' as well as an uncertainty, or noisy intel-space channel. On the other hand, it has been found that latency-theory is characterized by mathematical binary operator (bor) units of a configuration of space certainty nature that are linked to a signal-processor's 'processing intelligence-time (or intel-time in short)' as well as a certainty, or limited intel-time sensor. This discovered uncertainty-information-space/certainty-latency-time duality is fundamental in nature since every uncertainty intel-space method in mathematical information theory (or M-IT) must then have a certainty intel-time method dual in mathematical latency-theory (or M-LT) or visa-versa. A method in M-IT for which a certainty intel-time method dual has been found in M-LT is *intel-space channel-coding* or 'the mathematical theory of communication' as originally identified by his creator Claude E. Shannon [2] and later by communication experts [3]. Intel-space channel-coding guides the design of intel-space communication

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systems using as performance bounds the expected source-information in bits, denoted as the source-entropy $\boldsymbol{H}$, and the channel-capacity $\boldsymbol{C}$ of a noisy intel-space channel. More specifically, these bounds guide the design of intel-space channel and source integrated (CSI) coders with the integrated intel-space channel-coder advancing overhead knowledge in the form of mathematical signals, e.g. parity bits extracted from bit streams that have the effect of increasing the amount of channeled intel-space. The certainty intel-time dual for this scheme was found to be M-LT's *intel-time sensor-coding* (or 'the mathematical theory of recognition' as identified from a duality perspective) [1]. Intel-time sensor-coding guides the design of intel-time recognition systems using as performance bounds the minmax processor-latency criterion in bor units, denoted as the processor-ectropy $\boldsymbol{K}$, and the sensor-consciousness $\boldsymbol{F}$ of a limited intel-time sensor. More specifically, these bounds guide the design of intel-time sensor and processor integrated (SPI) coders with the integrated intel-time sensor-coder advancing overhead knowledge in the form of mathematical signals, such as interferences, clutter inclusive, and noise that have the effect of increasing the amount of sensed intel-time. Moreover, the unification of M-LT and M-IT has yielded a mathematical latency-information theory (M-LIT), or mathematical guidance theory for intelligence system designs, that for mathematical intelligence signals addresses in a unified fashion uncertainty communication issues of intel-space and certainty recognition issues of intel-time. Some details and insightful illustrations of the aforementioned mathematical performance bounds are presented in this paper. It is of interest to note that the aforementioned uncertainty-information-space/certainty-latency-time duality revelation had its roots in an earlier 1978 discovery by the author of an existing uncertainty-communication/certainty-control duality between an uncertainty 'digital' communication problem [4] and a certainty 'quantized' control problem [5]. This newly found duality in turn led him to the formulation of a novel and practical parallel processing methodology to quantized control where the controlled processor can be modeled with any certainty linear or nonlinear state-variables representation. This control scheme he named Matched-Processors since it was the 'certainty' control dual of the 'uncertainty' Matched-Filters communication problem. It should be further noticed that this uncertainty/certainty duality perspective for a 'discrete' communication/control problem is also exhibited by Kalman's LQG control formulation of 1960 [6] for the complementary 'continuous' communication/control problem.

Our M-LIT has also been discovered to have a physical dual [1] which has been named physical LIT (P-LIT). Like the aforementioned uncertainty/certainty duality, this newly discovered mathematical-physical duality is fundamental in nature since every mathematical method in M-LIT must then have a corresponding physical method in P-LIT as physical-dual or visa-versa. A mathematical method in M-LIT for which a physical-dual has been found in P-LIT is M-IT's intel-space channel-coding. The physical-dual for this scheme is physical latency-theory (P-LT)'s *'motion life time (or life-time in short)' channel-coding* (or 'the physical theory of communication' as identified from a duality perspective). Life-time channel-coding guides the design of life-time communication systems using as performance bounds the minmax mover-latency criterion in physical time units, denoted as the mover-ectropy $\boldsymbol{A}$, and the channel-stay $\boldsymbol{T}$ of a multi-path life-time channel. More specifically, these bounds are used to guide the design of life-time channel and mover integrated (*CMI*) coders with the integrated life-time channel-coder advancing overhead knowledge in the form of available physical signals that have the effect of increasing the amount of channeled life-time. An illustration of a mover-coder (encoder/decoder) for physical signals is a laser system, and of a life-time channel-coder (encoder/decoder) for a certainty, or multi-path life-time channel is a network router. Another mathematical method in M-LIT for which a physical-dual has been found in P-LIT is M-LT's intel-time sensor-coding. The physical-dual is physical information-theory (P-IT)'s '*retention life space (or life-space in short)' sensor-coding* (or 'the physical theory of recognition' as identified from a duality perspective). Life-space sensor-coding guides the design of life-space recognition systems using as performance bounds the expected retainer-information in physical space units, denoted as the retainer-entropy $\boldsymbol{N}$, and the sensor-scope $\boldsymbol{I}$ of a noisy life-space sensor. More specifically, these bounds are used to guide the design of life-space sensor and retainer integrated (*SRI*) coders with the integrated life-space sensor-coder advancing overhead knowledge in the form of available physical signals that have the effect of increasing the amount of sensed life-space. An illustration of a retainer-coder for physical signals is a silicon semiconductor crystal, and of a life-space sensor-coder for an uncertainty, or noisy life-space sensor is a surface mounted leadless chip carrier.

Moreover, as is the case for M-LIT, P-LIT exhibits an uncertainty-information-space/certainty-latency-time duality. Thus like M-LIT this duality is fundamental in nature since for every uncertainty life-space method in P-IT there must be a certainty life-time method dual in M-LT or visa-versa. For example, the certainty speed of light in a vacuum limit of c=2.9979 x 10^8 *m/sec* for energy motion in P-LT, was found in [7] to have an uncertainty intel-space dual in P-IT. This uncertainty intel-space dual is the pace of dark in a black-hole limit of $X=960\pi \boldsymbol{c}^2/hG=6.1123 \times 10^{63}$ $secs/m^3$ where h is Plank's constant and G is the Gravitational constant for energy retention [7]. Moreover, while M-LIT is identified to be 'the mathematical guidance theory of intelligence system designs' because for mathematical intelligence signals it addresses in a unified fashion uncertainty communication issues of intel-space and certainty recognition issues of intel-time, P-LIT is identified to be 'the physical guidance theory of life system designs' because for physical signals it addresses in a unified fashion uncertainty recognition issues of life-space and certainty communication issues of life-time. The integration of M-LIT and P-LIT has been found to be conveniently described and remembered in a LIT revolution that summarizes the advanced unification of four fundamental, two mathematical and two physical, methodologies in science. These four quadrants of the LIT revolution, i.e. quadrant I for P-LT, quadrant II for M-IT, quadrant III for P-IT, and quadrant IV for M-LT can be used to highlight the following three quadrant pair dualities. They are: 1) the (II,III)-(I,IV) quadrant pairs exhibiting an uncertainty-information-space/certainty-latency-time duality; b) the (II,IV)-(I,III) quadrant pairs exhibiting a mathematical-intelligence/physical-life duality; and c) the (I,II)-(III,IV) quadrant pairs exhibiting a channel-communication/sensor-recognition duality. The LIT revolution also highlights the main properties of the signal compressors that naturally lead to communication embedded recognition (CER) system architectures first used in a radar application [1]. The eight performance bounds of the LIT revolution will be stated in this paper and illustrated with simple practical examples. In addition, for the rest of the paper the author will use the same sentence constructions to explain each quadrant theory with the idea of facilitating as much as possible the understanding of the advanced duality perspective. Furthermore, in the assignment of names for the symbols, terminology and methods of each theory care has been taken to make them user-friendly, didactic in nature and also vividly reflect their duality roots.

This paper is organized as follows. In Section 2 and 3 the M-LIT guidance of intel-space and intel-time signal compressors is summarized. In Section 4 and 5 the P-LIT guidance of life-time and life-space signal compressors is presented. In Section 6 the unifying LIT revolution is highlighted.

2. Mathematical Information Theory (M-IT)

The principal task of M-IT is to guide the design of intel-space compressors using the performance-bounds of source-entropy H and channel-capacity C for a noisy intel-space channel. The units of intel-space are mathematical bits, thus in this kind of setting information theory offers a mathematical guidance methodology for intel-space compressor designs. The bits of intel-space are sourced through time, and are communicated through space via an uncertainty, or noisy intel-space channel of given capacity. Moreover, the mathematical bit unit of intel-space has a passing of time uncertainty nature since its creation is traced to an uncertainty signal-source. The uncertainty nature of M-IT is modeled by assigning probability distributions to the uncertainty signal-source intel-space that are driven by the passing of time, e.g. a uniform distribution may be associated with the 0/1 outputs of a binary signal-source such as a digital computer.

In Fig. 1 the M-IT's communication system for intel-space compression is shown. It consists of a given signal-source's mathematical signal **X** to be communicated and a given noisy intel-space channel, assumed memoryless, plus a source-coder (encoder/decoder) and an intel-space channel-coder (encoder/decoder) to be designed. Also, when designed together, the two coders form a channel and source integrated (CSI) coder. The signal-source produces a discrete random variable output $\mathbf{X} \in \{x_1, x_2, .., x_\Omega\}$ with Ω possible scalar outcomes $\{x_i\}$.

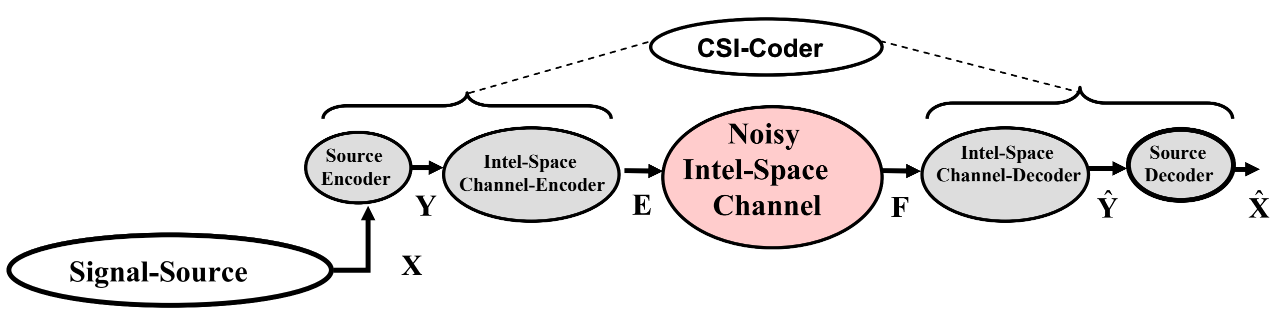

Fig. 1. Mathematical Information Theory's Communication System for Intel-Space Compression

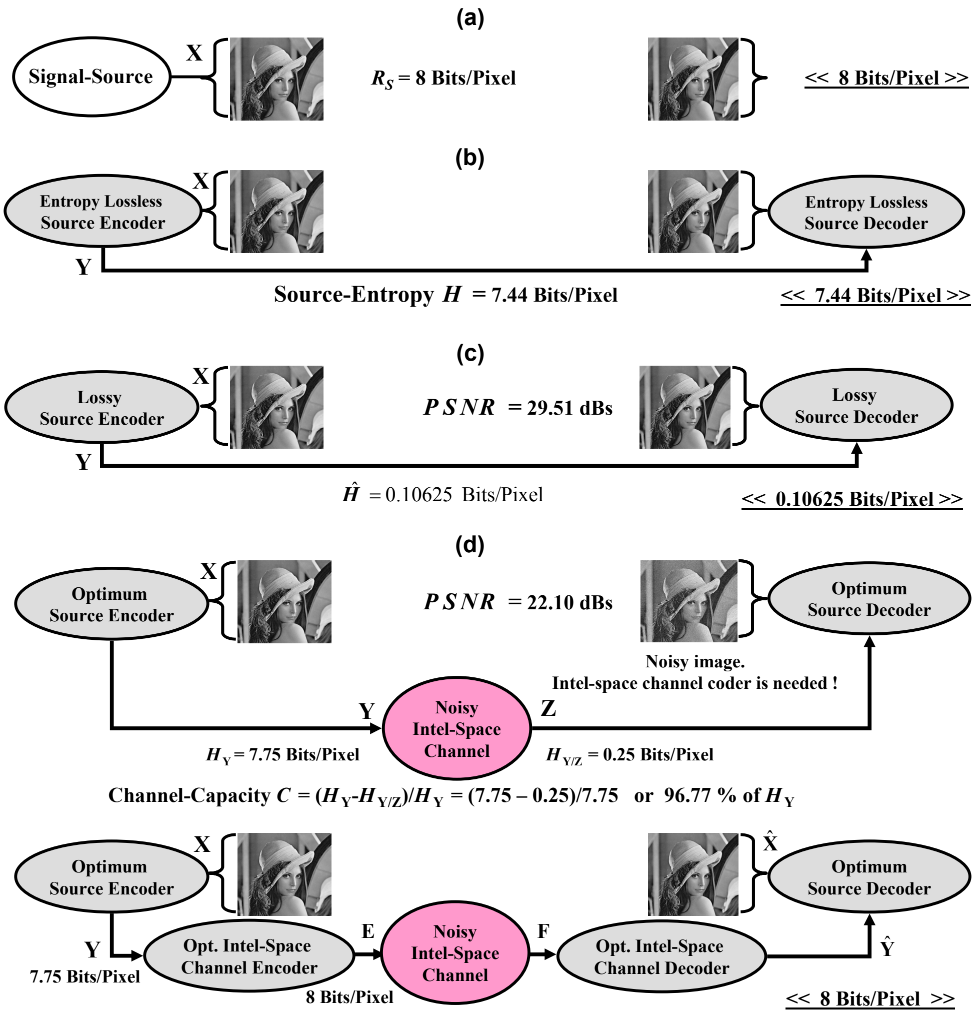

Fig. 2. Illustration of Intel-Space Source-Entropy H and Channel-Capacity C for Image System

The expected number of bits of the signal-source outcomes is called the source-rate R_S. For instance, for the 512x512 Lena image of Fig. 2 [8] each pixel is represented with 8 bits which results in an intel-space of 256 kilo-bytes and R_S = 8 bits/pixel. The uncertainty in the outcome set $\{x_i\}$ is modeled with the source-probability set $\{P_S[x_i]\}$. These probabilities are then used to derive the amount of source-information in the outcome set $\{x_i\}$ in bit units, i.e.

$$I_S(x_i) = \log_2(1/P_S[x_i]) \text{ for all } i. \quad (1)$$

The expected value of the source-information, called the source-entropy and expressed by

$$H = \sum_{i=1}^{\Omega} P_S[x_i] I_S(x_i), \quad (2)$$

then guides as a lower performance bound source-coder designs. For the Lena image H = 7.44 bits/pixel.

The source-coder of Fig. 1 is characterized by the source-encoder rate R_{SE}. In particular, when the noisy intel-space channel is not present and R_{SE} is greater than the source-entropy H a lossless source-coder, i.e. yielding $\hat{\mathbf{X}} = \mathbf{X}$, can always be designed using algorithms such as Arithmetic, Huffman, and Entropy coding [9]. In Fig. 2b the source encoding and decoding of the Lena image is shown for the case where the source-coder is lossless and its rate is the same as that of the source-entropy, i.e. $R_{SE} = H$. On the other hand, the source-coder is said to be lossy when its rate is less than the source-entropy. For instance, in Fig. 2c the source encoding and decoding of the Lena image is shown for the case where a MMSE predictive-transform source-coder with subbands is used [8]. The lossy source-encoder rate for this system is of R_{SE} = 0.10625 bits/pixel which is significantly less than the image entropy and still yields an image quality that is satisfactory in many practical applications.

Yet when the noisy intel-space channel of Fig. 1 is present an unsatisfactory degradation of the communicated intel-space may occur. Thus when this occurs it becomes necessary to use an intel-space channel-coder that advances overhead knowledge to satisfy the intel-space capacity needs introduced by a noisy intel-space channel. More specifically, for our illustrative case it becomes necessary to use an intel-space channel-coder that introduces sufficient overhead intel-space, such as parity bits from bit streams to elicit satisfactory 'bit corrections' when the sourced bits so require it. This overhead intel-space is an unavoidable channel-induced intel-space penalty. To guide the design of a CSI-coder, which includes the intel-space channel-coder, an upper performance bound is then defined which tell us about the maximum possible percentage of the channeled intel-space that is not overhead intel-space. This upper performance bound is the channel-capacity $\mathcal{C}$ that for a memoryless noisy channel with an input $\mathcal{E}$ and output $\mathcal{F}$ denoting n-bit random codewords is defined as

$$\mathcal{C} = (H_{\mathbf{E}} - H_{\mathbf{E/F}})/H_{\mathbf{E}} = \max_{\{P_S[e_i]\}} (H_{\mathcal{E}} - H_{\mathcal{E}/\mathcal{F}})/H_{\mathcal{E}} \qquad (3)$$

where **E** and **F** are the $\mathcal{E}$ and $\mathcal{F}$ cases with a probability distribution $\{P_S[e_i]\}$ for **E** that maximizes the mutual source-information ratio $(H_{\mathcal{E}} - H_{\mathcal{E}/\mathcal{F}})/H_{\mathcal{E}}$ where $H_{\mathcal{E}/\mathcal{F}}$ is the *channel-induced intel-space penalty*.

In Fig. 2d an illustration is given of the channel-induced intel-space penalty associated with a noisy intel-space channel which results in a noisy image communication when an intel-space channel-coder is not used. The channel-induced intel-space penalty is assumed to be of 0.25 bits/pixel for this case with the channel-capacity $\mathcal{C}$=0.9677 covering 96.77% of the optimum source-entropy $H_{\mathbf{E}}$ = 7.75 bits/pixel. Notice that $H_{\mathbf{E}}$ is also assumed to be larger in value by 0.31 bits/pixel than the source-entropy case displayed in Fig. 2b of 7.44 bits/pixel when the noisy intel-space channel is not used. In the same figure it is also shown how an optimum intel-space channel-coder improves image communications through a noisy intel-space channel. Clearly the improved performance achieved with the CSI-coder yields an added cost. This cost is the need to design and implement an intel-space channel-coder as well as the need to increase the inter-space rate from 7.75 bits/pixel to 8 bits/pixel. To end the discussion it should be noted that the displayed images of Fig. 2d and stated source-compression values are only stated to convey basic signal compression ideas that will be extended to three other major areas of research, and not to give any state-of-art algorithm results such as is done in Figs. 2c for a lossy source-coder that is noisy intel-space channel free [8].

The intel-space mathematical methodology that seeks to achieve the channel-capacity of (3) is called channel-coding or equivalently intel-space channel-coding to differentiate it from life-time channel coding to be discussed later. Intel-space channel-coding is also called 'the mathematical theory of communication' [3] and is a special case of M-IT that may cover other uncertainty intel-space topics.

3. Mathematical Latency Theory (M-LT)

The principal task of M-LT is to guide the design of intel-time compressors using the performance-bounds of processor-ectropy K and sensor-consciousness F for a limited intel-time sensor. The units of intel-time are mathematical bors, thus in this kind of setting latency theory offers a mathematical guidance methodology for intel-time compressor designs. The bors of intel-time process across a space surface area, and are recognized across a time interval via a certainty, or limited intel-time sensor of given consciousness. Moreover, the mathematical bor unit of intel-time has a configuration of space certainty nature since its creation is traced to a certainty signal-processor. The certainty nature of M-LT is modeled by assigning constraints to the certainty signal-processor intel-time that are driven by the configuration of space, e.g. of two-input NAND gates when implementing a binary-adder signal-processor.

In Fig. 3 the M-LT's recognition system for intel-time compression is shown. It consists of a given signal-processor's mathematical signal **y** to be recognized and a given limited intel-time sensor plus a processor-coder and an intel-time sensor-coder to be designed. A signal-source also feeds intel-space to the signal-processor and intel-time sensor-coder. Furthermore, when designed together, the two coders form a sensor and processor integrated (SPI) coder. The signal-processor produces a vector output $\mathbf{y} = [y_1, y_2, .., y_G]$ with G scalar outputs $\{y_i\}$ that may be real or complex. In particular, the following three space/time or uncertainty/certainty dualities between the M-LT and the M-IT

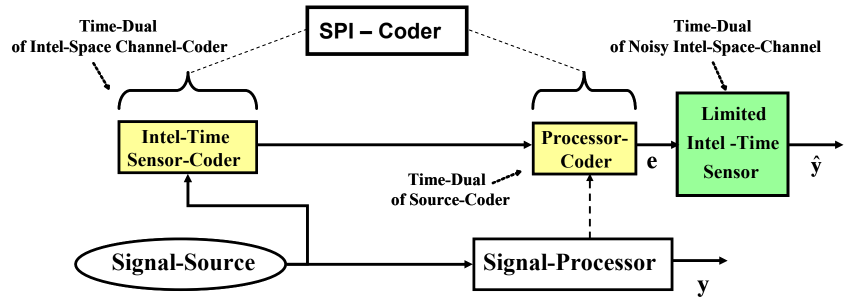

Fig. 3. Mathematical Latency Theory's Recognition System for Intel-Time Compression

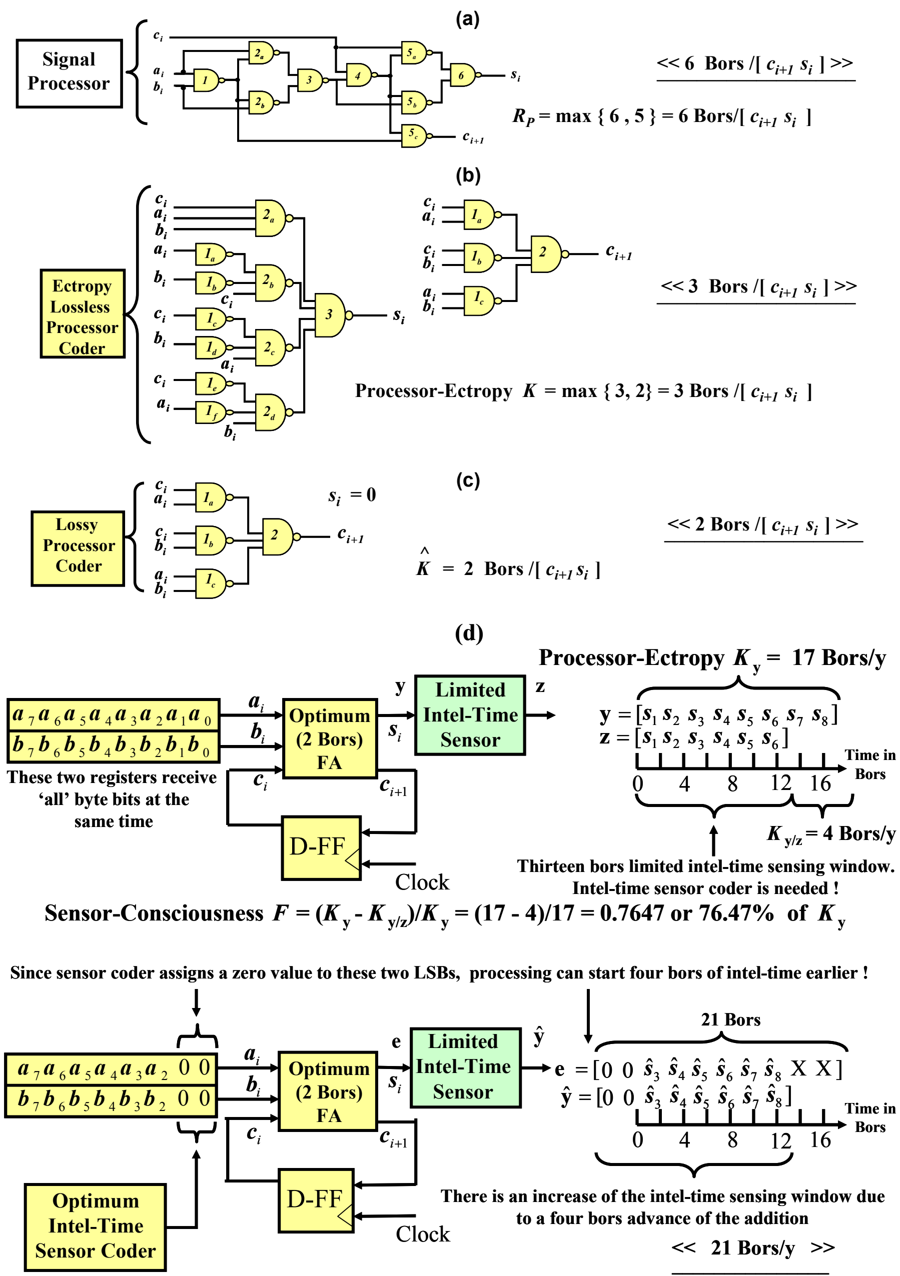

Fig. 4. Illustration of Intel-Time Processor-Ectropy K and Sensor-Consciousness F for Binary-Adder System

subsystems are highlighted: 1) the intel-time sensor-coder is the time (or certainty) dual of the intel-space channel-coder; 2) the processor-coder is the time (or certainty) dual of the source-coder; and 3) the limited intel-time sensor is the time (or certainty) dual of the noisy intel-space channel.

The maximum number of intel-time bors of the signal-processor scalar outputs is called the processor-rate R_P. For instance, for the full adder of Fig. 4a [10] with the two added bit inputs a_i and b_i and the carry in bit c_i, the intel-time of the sum output s_i is of six bors and for the carry out c_{i+1} is of five bors. The maximum of these two intel-times is the processor-rate which is of six bors in this case, i.e. R_P=6 bors/[c_{i+1} s_i]. The certainty in the scalar output set $\{y_i\}$ is modeled with the processor-constraint set $\{C_P[y_i]\}$, e.g. it can be assumed that each of the scalar outputs arises from cascading NAND gates that have an arbitrary number of inputs. These constraints are then used to derive the 'minimum' number of bor levels, denoted as the processor-latency $L_P[y_i]$ in bor units, of each member of the set $\{y_i\}$. For instance, for the full-adder of Fig. 4a, it is noted that the processor-latency of s_i and c_{i+1} is of three and two bors, respectively, since the full-adder can be redesigned as shown in Fig. 4b subject to the constraint of NAND gates with an arbitrary number of inputs which yields

$$L_P[y_1 = s_i] = f_P(C_P[s_i]) = 3 \text{ bors} \quad \text{and} \quad L_P[y_2 = c_{i+1}] = g_P(C_P[c_{i+1}]) = 2 \text{ bors}. \tag{4}$$

The processor-latency with a maximum value, called the processor-ectropy and expressed by

$$\mathcal{K} = \max\{L_P[y_1],..,L_P[y_G]\}, \tag{5}$$

then guides as a lower performance bound processor-coder designs. For the full-adder of Fig. 4a the processor-ectropy $\mathcal{K}$ is of 3 bors as depicted in Fig. 4b.

The processor-coder of Fig. 3 is characterized by the processor-coder rate R_{PC}. In particular, when the limited intel-time sensor is not present and R_{PC} is greater than or equal to the processor-ectropy $\mathcal{K}$ a lossless processor-coder, i.e. yielding $\hat{\mathbf{y}} = \mathbf{y}$, can always be designed, e.g. a fast Fourier transform is such a processor-coder when it replaces a Fourier transform signal-processor. In Fig. 4b the processor-coder is shown for the case where it is lossless and its rate is the same as that of the processor-ectropy, i.e. $R_{PC} = \mathcal{K}$. On the other hand, the processor-coder is said to be lossy when its rate is less than the processor-ectropy. For instance, in Fig. 4c the processor-coder is lossy since it only implements the carry out section of the lossless processor-ectropy full adder of Fig. 4b and assigns to s_i the value of zero. The rate for this coder is of 2 bors/[c_{i+1} s_i] which is 66.66 % of the processor-ectropy $\mathcal{K}$= 3 bors/[c_{i+1} s_i].

Yet, when the limited intel-time sensor of Fig. 3 is present an undesirable degradation of the recognized intel-time may occur. Thus when this occurs it becomes necessary to use an intel-time sensor-coder that advances overhead knowledge (also called prior-knowledge) to satisfy the intel-time consciousness needs introduced by the limited intel-time sensor. More specifically, for our illustrative case it becomes necessary to use an intel-time source-coder that introduces sufficient overhead intel-time, such as the bors of the added least significant bits (LSBs) to elicit satisfactory 'bor corrections' when the processing bors so require it. This overhead intel-time is an unavoidable sensor-induced intel-time penalty. To guide the design of a SPI-coder, which includes the intel-time sensor-coder, an upper performance bound is then defined which tell us about the maximum possible percentage of the sensed intel-time that is not overhead intel-time. This upper performance bound is the sensor-consciousness $\mathcal{F}$ that for a limited intel-time sensor with a G dimensional vector input $\mathfrak{e}$ and vector output $\mathfrak{f}$ is defined as

$$\mathcal{F} = (\mathcal{K}_{\mathbf{e}} - \mathcal{K}_{\mathbf{e/f}})/\mathcal{K}_{\mathbf{e}} = \max_{\{C_P[e_i]\}} (\mathcal{K}_{\mathfrak{e}} - \mathcal{K}_{\mathfrak{e}/\mathfrak{f}})/\mathcal{K}_{\mathfrak{e}} \tag{6}$$

where $\mathbf{e}$ and $\mathbf{f}$ are the $\mathfrak{e}$ and $\mathfrak{f}$ cases with a constraint distribution $\{C_P[e_i]\}$ for $\mathbf{e}$ that maximizes the mutual processor-latency ratio $(\mathcal{K}_{\mathfrak{e}} - \mathcal{K}_{\mathfrak{e}/\mathfrak{f}})/\mathcal{K}_{\mathfrak{e}}$ where $\mathcal{K}_{\mathfrak{e}/\mathfrak{f}}$ is the *sensor-induced intel-time penalty*.

In Fig. 4d an illustration is given of the sensor-induced intel-time penalty associated with a 13 bors limited intel-time sensor which results in the limited sum recognition (only six out of 8 sum bits can be sensed) of an optimum processor-coder (a one byte sequential full adder) output when an intel-time sensor-coder is not used. Notice that the optimum processor-coder has been constrained to have a one byte sequential full adder architecture and thus uses the 2 bors carry-out full-adder of Fig. 4b to yield the smallest possible number of bors. The sensor-induced intel-time penalty is of 4 bors/$\mathbf{y}$ (with $\mathbf{y} = [s_1, s_2, ..., s_8]$ being the sum output) with the sensor-consciousness $\mathcal{F}$=0.7647 covering 76.47% of the optimum processor-entropy $\mathcal{K}_{\mathbf{y}}$ = 17 bors/$\mathbf{y}$. In the same figure it is also shown how an optimum intel-time source-coder may be used to improve sum recognitions across a limited intel-time sensor. First it is noticed that to recognize the

17 bors of the 8 bits sum the sequential adder must start at least four bors earlier in time than when the two bytes first become available. This time-dislocation of the processing initiation is achieved in our example by having the sensor-coder advance as prior-knowledge zero bits for the first two least significant bits of the sequential addition. Clearly the improved performance of the SPI-coder is achieved with an added cost. This cost is the need to design and implement an intel-time sensor-coder as well as the need to increase the inter-time rate from 17 bors/**y** to 21 bors/ **y**. Notice that in the count of 21 bors, bors have been included that correspond to the four bors idle time of the processor after the sum ends.

The intel-time mathematical methodology that seeks to achieve the sensor-consciousness of (6) is called intel-time sensor-coding. Furthermore using our duality perspective we have that intel-time sensor-coding is called 'the mathematical theory of recognition', and is a special case of M-LT that may cover other certainty intel-time topics.

4. Physical Latency Theory (P-LT)

The principal task of P-LT is to guide the design of life-time compressors using the performance-bounds of mover-ectropy $\mathcal{A}$ and channel-stay $\mathcal{T}$ for a multi-path life-time channel. The units of life-time are physical time units, thus in this kind of setting latency theory offers a physical guidance methodology for life-time compressor designs. The physical time interval of life-time accompanies energy motion through space (or space-dislocation), and is communicated through a time interval via a certainty, or multi-path life-time channel of given stay. Moreover, the physical time unit of life-time has a configuration of space certainty nature since its origin is traced to a certainty signal-mover for the space-dislocation of physical signals. Furthermore, the life-time required for any desired space-dislocation of a physical signal can never be zero due to an upper bound on energy motion. This upper bound is the 'certainty' speed of light in a vacuum which tells us that the maximum space-dislocation for energy per second is of 2.9979×10^8 meters. The certainty nature of P-LT is modeled by assigning constraints to the certainty signal-mover life-time that are driven by the configuration of space, e.g. of four-wheeled movers for people that are being space-dislocated.

In Fig. 5 the P-LT's communication system for life-time compression is shown. It consists of a given physical-signal **p** to be communicated plus a mover-coder (encoder/decoder) and a life-time channel-coder (encoder/decoder) to be designed. Furthermore, when designed together, the two coders form a channel and mover integrated (CMI) coder. In particular, the following three mathematical-physical dualities between the P-LT and the M-IT subsystems are highlighted: 1) the life-time channel-coder is the physical dual of the intel-space channel-coder; 2) the mover-coder is the physical dual of the source-coder; and 3) and the multi-path life-time channel is the physical dual of the noisy intel-space channel. Also a special case of the mover-coder is any initial mover-coder which is denoted as the signal-mover and is the physical-dual of a signal-source. The signal-mover moves a vector physical signal $\mathbf{p} = [p_1, p_2, .., p_D]$ with D scalar elements $\{p_i\}$.

The maximum amount of life-time physical time due to the signal-mover is called the mover-rate R_M. For instance, consider the persons (or physical signals) signal-mover of Fig. 6a, where the couple is assigned the physical variable p_1 and the single man is assigned the physical variable p_2. It is then noted that it takes the displayed signal-mover, in the form of non-motorized bicycles, 7 hours of life-time for p_1 and 5 ½ hours of life-time for p_2 to move from one location to another in space. Thus the mover-rate for this case is of 7 hours, i.e. $R_M = 7$ hrs/**p**. The certainty in the

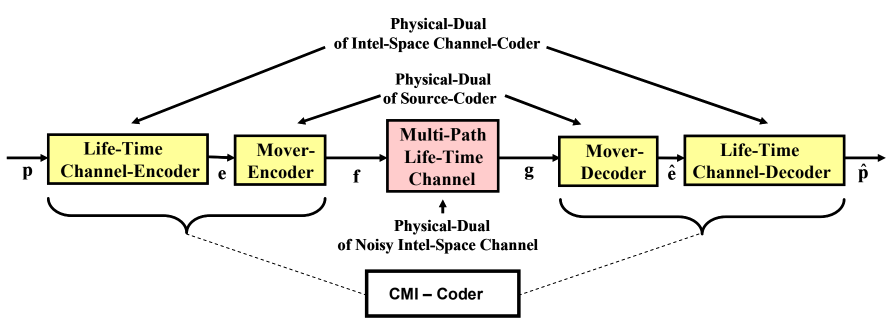

Fig. 5. Physical Latency Theory's Communication System for Life-Time Compression

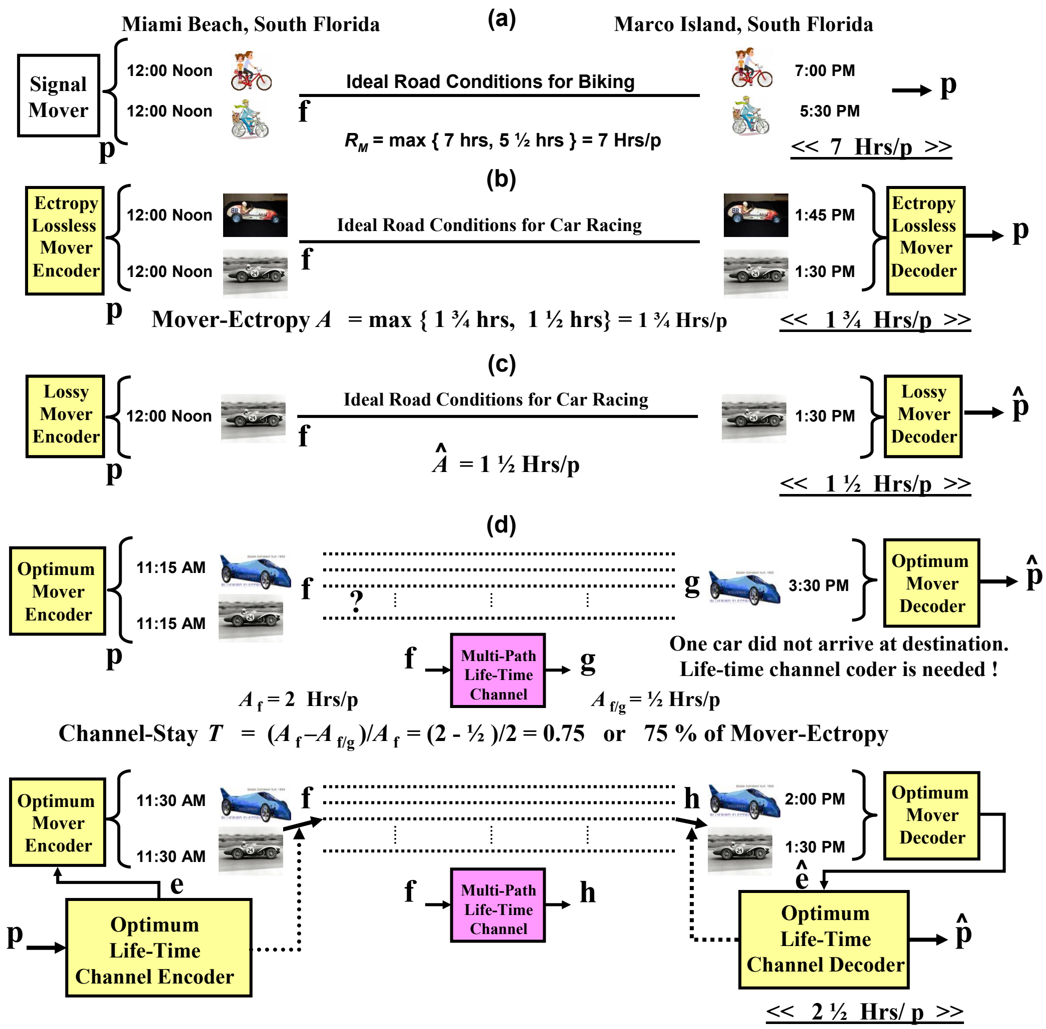

Fig. 6. Illustration of Life-Time Mover-Ectropy $\mathcal{A}$ and Channel-Stay $\mathcal{T}$ for People Space-Dislocation System

physical signals $\{p_i\}$ is modeled with the mover-constraint set $\{C_M[p_i]\}$, where these constraints are assumed when seeking physical signals movers, e.g. in the case of Fig. 6a the mover-constraint is a non-motorized two-wheeled mover. These allowed constraints are then used to derive the 'minimum' amount of physical time, denoted as the mover-latency $L_M[p_i]$ in physical time units, of each member of the set $\{p_i\}$. For instance, for the people motion system of Fig. 6a, it is noted that the mover-latency of the illustrated motion system will be of 1¾ hours and 1 ½ hours, respectively, when four-wheeled motorized movers are allowed constraints. More specifically we have for this case the following mover-latencies,

$$L_M[p_1] = f_M(C_M[p_1]) = 1\tfrac{3}{4} \text{ hours} \quad \text{and} \quad L_M[p_2] = f_M(C_M[p_2]) = 1\tfrac{1}{2} \text{ hours}, \tag{7}$$

The mover-latency with a maximum value, called the mover-ectropy and expressed by

$$\mathcal{A} = \max\{L_M[p_1],..,L_M[p_D]\}, \tag{8}$$

then guides as a lower performance bound mover-coder designs. For the mover system of Fig. 6a the mover-ectropy $\mathcal{A}$ is of 1¾ hours as seen from Fig. 6b.

The mover-coder of Fig. 5 is characterized by the mover-coder rate R_{MC}. In particular, when the life-time channel is not present and R_{ME} is greater than or equal to the mover-ectropy $\mathcal{A}$ a lossless mover-coder, i.e. with $\hat{\mathbf{e}} = \mathbf{e}$, can always be designed. In Fig. 6b the mover-coder is shown for the case where it is lossless and its rate is the same as that of the mover-ectropy, i.e. $R_{ME} = A$. On the other hand, the mover-coder is said to be lossy when its rate is less than the mover-ectropy. For instance, in Fig. 6c the mover-coder is lossy since only the physical signal p_2 is moved. The rate for this coder is of 1 ½ hours which is 85.71 % of the mover-ectropy A = 1¾ hours.

Yet, when the multi-path intel-time sensor of Fig. 5 is present an undesirable degradation of the communication life-time may occur. Thus when this occurs it becomes necessary to use a life-time channel-coder that advances overhead knowledge to satisfy the life-time stay needs introduced by the multi-path life-time channel. More specifically, for our illustrative case it becomes necessary to use a life-time channel-coder that introduces sufficient overhead life-time such as an earlier departure time to elicit satisfactory 'time corrections' when the moving time so require it. This overhead life-time is an unavoidable channel-induced life-time penalty. To guide the design of a CMI-coder, which includes the life-time channel-coder, an upper performance bound is then defined which tell us about the maximum possible percentage of the channeled life-time that is not overhead life-time. This upper performance bound is the channel-stay $\boldsymbol{T}$ that for a multi-path life-time channel with a D dimensional vector input $\mathfrak{f}$ and vector output $\mathfrak{g}$ is

$$\boldsymbol{T} = (A_{\mathbf{f}} - A_{\mathbf{f/g}})/A_{\mathbf{f}} = \max_{\{C_M[f_i]\}} (A_{\mathfrak{f}} - A_{\mathfrak{f}/\mathfrak{g}})/A_{\mathfrak{f}} \qquad (9)$$

where **f** and **g** are the $\mathfrak{f}$ and $\mathfrak{g}$ cases with a constraint distribution $\{C_M[f_i]\}$ for **f** that maximizes the mutual mover-latency ratio $(A_{\mathfrak{f}} - A_{\mathfrak{f}/\mathfrak{g}})/A_{\mathfrak{f}}$ where $A_{\mathfrak{f}/\mathfrak{g}}$ is the *channel-induced life-time penalty*.

In Fig. 6d an illustration is given of the channel-induced life-time penalty associated with a multi-path life-time channel which results in a limited people communication when a life-time channel-coder is not used. The channel-induced life-time penalty is assumed to be of ½ hrs/**p** for this case with the channel-stay $\boldsymbol{T}$ of 0.75 covering 75 % of the optimum mover-ectropy $A_{\mathbf{f}}$ = 2 hrs/**p**. Notice that $A_{\mathbf{f}}$ is also assumed to be larger by ¼ hr/**p** than the mover-ectropy case displayed in Fig. 6b of 1 ¾ hrs/**p** for the case when a multi-path life-time channel is not used. Further notice that the top racing car of Fig. 6b is not available to start the people space-dislocation at the earlier starting time displayed in Fig. 6d. In the same figure it is also shown how an optimum life-time channel-coder may be used to improve people communication through a multi-path channel. This is done by observing that to communicate **p** to its destination at 2 pm (as implied by $A_{\mathbf{f}}$ = 2 hrs/**p** and a starting time of 12:00 noon) the mover must depart to Marco Island at least ½ hr earlier in time, i.e. at 11:30 am. Thus the life-time channel-coder directs the mover to depart at 11:30 am along the channel path yielding the least life-time use. At the receiving end the life-time channel-decoder has the people exiting the mover. Clearly the improved performance achieved with the CMI-coder yields an added cost. This cost is the need to design and implement a life-time channel-decoder as well as the need to increase the life-time rate from 2 hrs/**p** to 2 ½ hrs/**p.**

The life-time physical methodology that seeks to achieve the channel-stay of (9) is called life-time channel-coding. Furthermore using our duality perspective we have that life-time channel-coding is called 'the physical theory of communication', and is a special case of P-LT that may cover other certainty life-time topics.

5. Physical Information Theory (P-IT)

The principal task of P-IT is to guide the design of life-space compressors using the performance-bounds of retainer-entropy $\boldsymbol{N}$ and sensor-scope $\boldsymbol{I}$ for a noisy life-space sensor. The units of life-space are physical surface area units, thus in this kind of setting information theory offers a physical guidance methodology for life-space compressor designs. The physical surface area of life-space accompanies energy retention across a time interval (or time-dislocation) and is recognized across a space surface area via an uncertainty, or noisy life-space sensor of given scope. Moreover, the physical surface area unit of life-space has a passing of time uncertainty nature since its origin is traced to an uncertainty signal-retainer for the time-dislocation of physical signals. Furthermore, the expected life-space for any required time-dislocation of a physical signal can never be zero due to an upper bound on energy retention. This upper bound is the 'uncertainty' pace of dark in a black-hole (the uncertainty space-dual of the speed of light in a vacuum) which tells us that the maximum time-dislocation for energy per cubic meter is of 6.1123×10^{63} seconds [7]. The uncertainty nature of P-IT is modeled by assigning probability distributions to the uncertainty signal-retainer life-space that is driven by the passing of time, e.g. of uniform distributions for the thermal bottle microstates of tea molecules that are being time-dislocated.

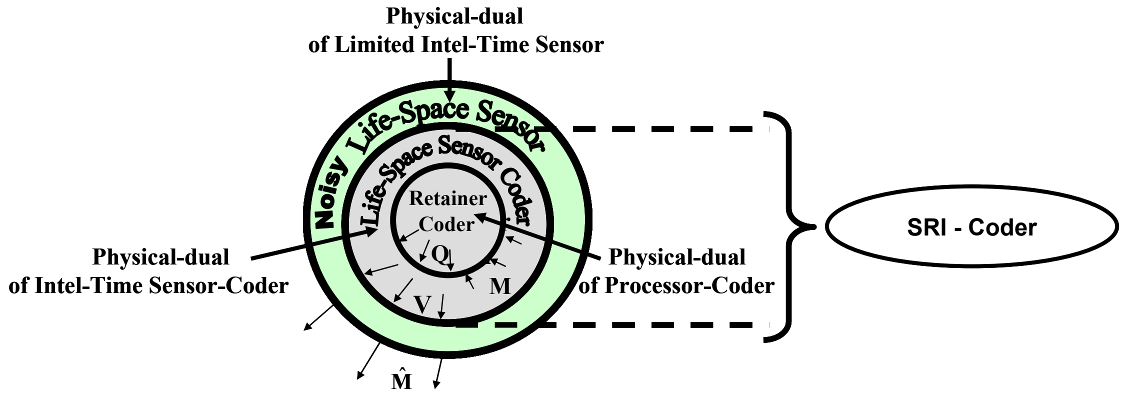

Fig. 7 Physical Information Theory's Recognition System For Life-Space Compression

In Fig. 7 the P-IT's recognition system for life-space compression is shown. It consists of a given physical signal **M** to be recognized and a given noisy life-space sensor plus a retainer-coder and a life-space sensor-coder to be designed. Furthermore, when designed together, the two coders form a sensor and retainer integrated (SRI) coder. In particular, the following three mathematical-physical dualities between the P-IT and the M-LT subsystems are highlighted: 1) the life-space sensor-coder is the physical dual of the intel-time sensor-coder; 2) the retainer-coder is the physical dual of the processor-coder; and 3) the noisy life-space sensor is the physical dual of the limited intel-time sensor. Also a special case of the retainer-coder is any starting retainer-coder which is denoted as the signal-retainer and is the physical-dual of a signal-processor. The signal-retainer retains a random vector physical signal $\mathbf{M} \in \{\mathbf{m}_1, \mathbf{m}_2, .., \mathbf{m}_\Omega\}$ with Ω vector outcomes $\{\mathbf{m}_i\}$ or microstates where each vector outcome $\mathbf{m}_i$ is of dimension U where this dimension is equal to the number of fundamental physical entities, e.g. molecules, present in the signal-retainer. Thus, each vector outcome of **M** represents an identical physical mass for the retained energy.

The expected amount of surface area of the signal-retainer is called the retainer-rate R_R. For instance, consider U tea molecules that are being time-dislocated in the cylindrical thermos bottle of Fig. 8a. It is noted that it takes the thermos 70 cm^2 of life-space surface area for its storage. Since it is assumed that every possible microstate of the tea has the same expected life-space of 70 cm^2, the retainer-rate for this case is then given by R_R=70 cm^2/**M**. The uncertainty in the microstate set $\{\mathbf{m}_i\}$ is modeled with the retainer-probability set $\{P_R[\mathbf{m}_i]\}$. These probabilities are then used to derive the expected life-space or retainer-information $I_R[\mathbf{m}_i]$ in surface area units, of each member of the set $\{\mathbf{m}_i\}$. For instance, for the substance retainer system of Fig. 8a, it is noted that the expected retainer-information is of 70 cm^2 for each tea microstate when the retainer-probability set $\{P_R[\mathbf{m}_i]\}$ is uniformly distributed. More specifically, we have the following expected retainer-information for all the microstates

$$I_R[\mathbf{m}_i] = f_R(P_R[\mathbf{m}_i]) = 70 \text{ cm}^2 \text{ for all i.} \tag{10}$$

A general expression for $I_R[\mathbf{m}_i] = f_R(P_R[\mathbf{m}_i])$ in surface area units that may be viewed as the life-space recognition dual of the intel-space communication source-information expression $I_S(x_i) = \log_2(1/P_S[x_i])$ in bit units has already been obtained in [7] and is given

$$I_R[\mathbf{m}_i] = \eta \frac{T_i}{V_i} \log_2(1/P_R[\mathbf{m}_i]) \quad \text{in } m^2 \text{ units} \tag{11}$$

where: a) T_i is the retention-time of the microstate $\mathbf{m}_i$; b) V_i is the uncertainty volume where the microstate $\mathbf{m}_i$ resides; and c) η is the retainer-information constant of 2.473 x 10^{-133} m^5/sec. The value of the retention constant η is a normalizing constant that is derived in [7] using black-hole conditions as will be noted shortly. More specifically, the expression for η from which its value is derived is

$$\eta = \frac{1920}{c\mathrm{X}^2 \ln 2} = \frac{h^2 G^2}{480\pi^2 c^5 \ln 2} \tag{12}$$

where: a) c is the speed of light in a vacuum; b) h is Plank's constant of 6.6206896 x 10^{-34} Joule.sec; c) G is the gravitational constant of 6.673 x 10^{-11} m^3/kg.sec^2; d) X is the pace of dark in a black hole of 6.1123 x 10^{63} sec/m^3 whose value is derived from the pace of dark expression [7]

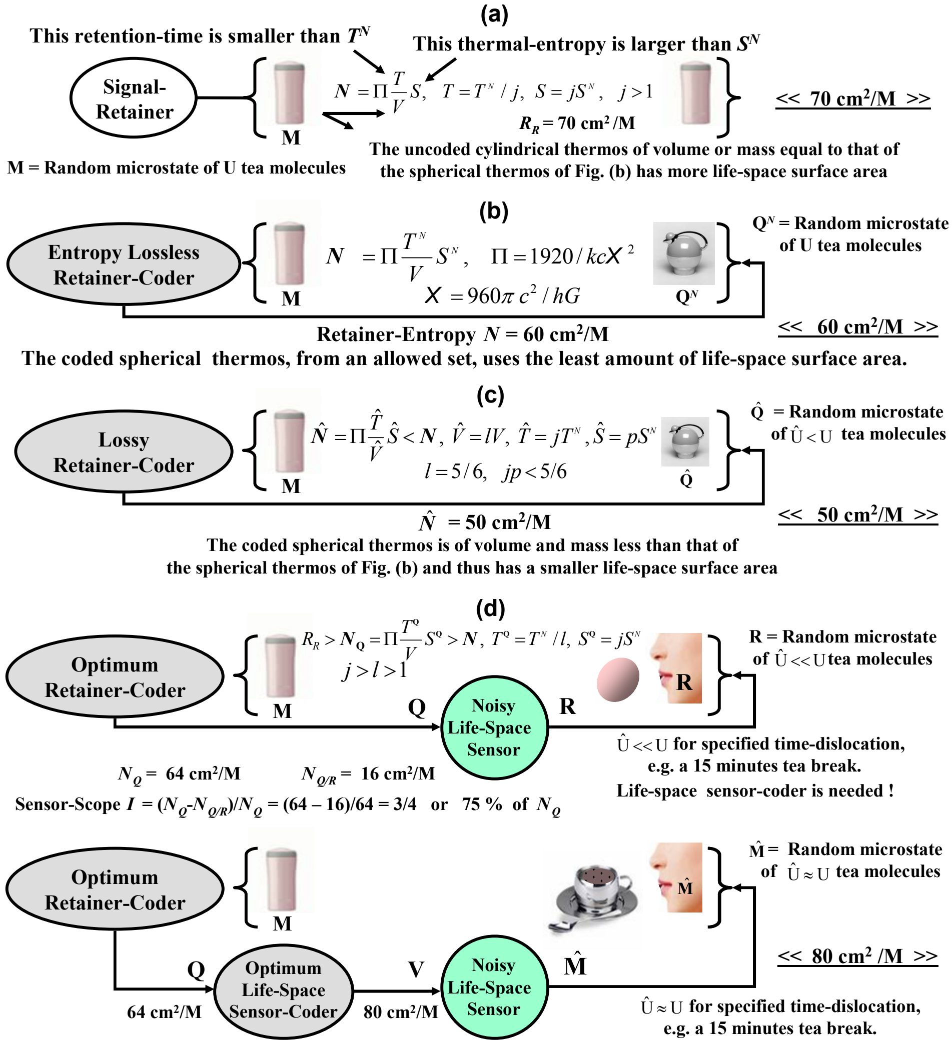

Fig. 8. Illustration of Life-Space Retainer-Entropy N and Sensor-Scope I for Tea Time-Dislocation System

$$X = 960\pi \frac{c^2}{hG} \tag{13}$$

and its derivation is once again given in Appendix A for the benefit of the reader. The derivation of (13) in Appendix A is essentially the same as that of Appendix A in [7] except that some variable symbols have been altered to conform with the notation of the current paper. The expected value of the retainer-information (10), called the retainer-entropy and expressed by

$$N = \sum_{i=1}^{\Omega} P_R[\mathbf{m}_i] I_R(\mathbf{m}_i) \tag{14}$$

then guides as a lower performance bound retainer-coder designs. For instance, for the retainer system of Fig. 8a the retainer-entropy N is of 60 cm^2 as seen from Fig. 8b where a spherical thermos is used to retain the tea**.** Notice that this spherical thermos is the thermos of smallest life-space surface area for the assumed **M** and thus cannot be compressed any further.

An important special case for which an analytical expression can be found for the retainer-entropy is when the the microstates of **M** are equally likely and the ratio of T_i/V_i is the same for all microstates in **M**, i.e. $T_i/V_i = T/V$ for i=1,...,Ω. Then (11) can be used in (14) together with the microstate thermodynamic entropy $S = k \log_2 \Omega / \ln 2$, with k being the Boltzmann's constant 1.3806504 x 10^{-23} Joules/Kelvin, to yield for N the following expression

$$N = \sum_{i=1}^{\Omega} P_R[\mathbf{m}_i] I_R(\mathbf{m}_i) = \eta \sum_{i=1}^{\Omega} \frac{T_i}{V_i} P_R[\mathbf{m}_i] \log_2(1/P_R(\mathbf{m}_i)) = \eta \frac{T}{V} \log_2 \Omega = \eta \frac{T}{V} \frac{\ln 2 \bullet S}{k} = \Pi \frac{T}{V} S \tag{15}$$

$$\Pi = \frac{1920}{kc\mathrm{X}^2} = \frac{\ln 2}{k}\eta \,. \tag{16}$$

where Π is the retainer-entropy constant of 1.2416 x 10^{-110} m^5Kelvin/(sec.Joules). It should be noticed that the analytical as well as quantum-gravity [11] and holographic [12] retainer-entropy expression of (15), i.e.

$$N = \eta \frac{T}{V} \log_2 \Omega = \eta \frac{T}{V} \frac{\ln 2 \bullet S}{k} = \Pi \frac{T}{V} S \,, \tag{17}$$

was first derived in [7] and is given there by expressions (3.7) and (3.17). Next it is noted that (17) has the desirable property that when the retainer-coder is a black-hole it reduces to Hawking's thermal-entropy $S=\pi Akc^3/2hG$ [11]-[12] where A is the surface area of the black-hole. In Appendix A of this paper as well as that of [7] it is shown that the ratio of retention-time T to retention-volume V of any substance in a black-hole is constant. More specifically this ratio is the pace of dark $T/V = \mathrm{X}$ (derived from (A.10) by setting the initial time of mass retention equal to zero, i.e. t_i=0) and thus $N_{BH} = \Pi \mathrm{X}\ S$. Secondly and last using the pace of dark expression (13), the retainer-entropy constant expression (16) and replacing N_{BH} with A in $N_{BH} = \Pi \mathrm{X}\ S$ the Hawking's thermal-entropy expression $S=\pi Akc^3/2hG$ is derived. For the illustrative tea example of Fig. 8 it is assumed that expression (17) holds where **U** tea molecules with a random microstate **M** of Ω possible vector outcomes with a constant volume each are being retained or time-dislocated in a thermos. For the retainer system of Fig. 8a the retainer-entropy N is of 60 cm^2/**M** as seen from Fig. 8b. Four observations can be made about these two cases. They are: 1) both thermos have identical volume but the surface area of the spherical thermos is the smallest that can be attained for any fixed volume and thus results in the greatest surface area savings; 2) it is noted that the larger thermal-entropy and smaller retention-time of the cylindrical thermos is consistent with its more extensive surface area; 3) it is possible for both retainers to have the same retainer-entropy because the product of retention-time and thermal-entropy remains the same for each case; and 4) it is noted that the retention-time of any thermos readily follows if its thermal-entropy can be calculated.

The retainer-coder of Fig. 7 is characterized by the retainer-coder rate R_{RC}. In particular, when the life-space sensor is not present and R_{RC} is greater than or equal to the retainer-entropy N a lossless retainer-coder can always be designed that yields a random microstate **Q** of U tea molecules. In Fig. 8b the retainer-coder is shown for the case where it is lossless and its rate is the same as that of the retainer-entropy, i.e. $R_{RC} = N$. On the other hand, the retainer-coder is said to be lossy when its rate is less than the retainer-entropy. For instance, in Fig. 8c the retainer-coder is lossy since only 5/6 of the mass (or 5/6 of the original U molecules) of the physical signal **M** is retained. The rate for this lossy coder is of 50 cm^2 which is 83.3 % of the retainer-entropy N= 60 cm^2. Two observations can be made about this case. They are: 1) the retainer-coder rate for this lossy but spherically shaped retainer-coder is the same as its retainer-entropy $\hat{N}$; 2) the retainer-entropy $\hat{N}$ is less than that for the two thermos of Figs. 8a and 8b as expected.

Yet, when the life-space sensor of Fig. 7 is present an undesirable degradation of the recognition life-space may occur. Thus when this occurs it becomes necessary to use a life-space sensor-coder that advances overhead knowledge to satisfy the life-space scope needs introduced by the noisy life-space sensor. More specifically, for our illustrative case it becomes necessary to use a life-space source-coder that introduces sufficient overhead life-space, such as the surface area of a tea cup to elicit satisfactory 'space corrections' when the retaining space (surface area) so require it. This overhead life-space is an unavoidable sensor-induced life-space penalty. To guide the design of a SRI-coder, which includes the life-space sensor-coder, an upper performance bound is then defined which tell us about the maximum possible percentage of the sensed life-space that is not overhead life-space. This upper performance bound is the sensor-scope I, that for a noisy life-space sensor with a random vector input $\mathbf{Q} \in \{\mathbf{q}_1, \mathbf{q}_2, .., \mathbf{q}_\Omega\}$ and a random vector output $\mathbf{R} \in \{\mathbf{r}_1, \mathbf{r}_2, .., \mathbf{r}_\Omega\}$ with the U dimension of their vector outcomes $\{\mathscr{q}_i\}$ and $\{\mathscr{r}_i\}$ being the same as the number of occurring physical entities, e.g. tea molecules, is defined by

$$I = (N_{\mathbf{Q}} - N_{\mathbf{Q/R}})/N_{\mathbf{Q}} = \max_{\{P_R[\mathbf{q}_i]\}} (N_{\mathscr{Q}} - N_{\mathscr{Q}/\mathscr{R}})/N_{\mathscr{Q}} \tag{18}$$

where **Q** and **R** are the $\mathscr{Q}$ and $\mathscr{R}$ cases with a probability distribution $\{P_R[\mathbf{q}_i]\}$ for **Q** that maximizes the mutual retainer-information ratio $(N_{\mathscr{Q}} - N_{\mathscr{Q}/\mathscr{R}})/N_{\mathscr{Q}}$ where $N_{\mathscr{Q}/\mathscr{R}}$ is the *sensor-induced life-space penalty*.

In Fig. 8d an illustration is given of the sensor-induced life-space penalty associated with a noisy life-space sensor, i.e. the mouth of a generally unknown tea drinker, which results in a noisy tea recognition over some specified time-dislocation, e.g. a 15 minutes tea break, when a life-space sensor-coder is not used. The noisy life-space sensor may use as overhead knowledge the relevant properties of the physical signal that is being recognized. The sensor-induced life-space penalty is assumed to be of 20 $cm^2/\mathbf{M}$ for this case with the sensor-scope $\boldsymbol{I}$ of 0.75 covering 75% of the optimum retainer-entropy $N_{\mathbf{Q}}$ = 64 $cm^2/\mathbf{M}$. Notice that $N_{\mathbf{Q}}$ is also assumed to be larger by 4 $cm^2/\mathbf{M}$ than the retainer-entropy case displayed in Fig. 8b of 60 $cm^2/\mathbf{M}$ for the case where a noisy life-space sensor is not used. In the same figure it is also shown how an optimum life-space sensor-coder in the form of a tea cup may be used to improve tea recognitions across a noisy life-space sensor, i.e. the tea drinker mouth, over some specified time-dislocation. Clearly the improved performance of the SRI-coder is achieved with an added cost. This cost is the need to design and implement a life-space sensor-coder as well as the need to increase the life-space rate from 64 $cm^2/\mathbf{M}$ to 80 $cm^2/\mathbf{M}$.

The life-space physical methodology that seeks to achieve the sensor-scope of (18) is called life-space sensor-coding. Furthermore using our duality perspective we have that life-space sensor-coding is called 'the physical theory of recognition', and is a special case of P-IT that may cover other uncertainty life-space topics.

6. The Latency-Information Theory Revolution

The LIT revolution of Fig. 9 conveniently displays in four quadrants the principal dualities that exist between four methodologies, two mathematical and two physical, for the study of systems. Together they advance a guidance theory for intelligence and life system designs. Quadrant 'I' pertains to certainty life-time compressor designs for channel-mediated communication systems that are guided by physical latency theory or P-LT. The physical time interval of life-time accompanies energy motion through space, and is communicated through a time interval via a certainty, or multi-path life-time channel of given stay. More specifically, channel and mover integrated coders or CMI-coders are derived for the compression of a physical signal's motion life-time in units of time. These designs are enabled by the laws of motion in physics, of a configuration of space certainty nature, such as the speed of light $\boldsymbol{c}$ in a vacuum limit. Quadrant II pertains to uncertainty intel-space compressor designs for channel-mediated communication systems that are guided by mathematical information theory or M-IT. The bits of intel-space are sourced through time, and are communicated through space via an uncertainty, or noisy intel-space channel of given capacity. More specifically, channel and source integrated coders or CSI-coders are derived for the compression of a mathematical signal's sourced intel-space in units of bit. These designs are enabled by universal source compression schemes, of a passing of time uncertainty nature, such as MMSE predictive-transform source-coding [8]. Quadrant III pertains to uncertainty life-space compressor designs for sensor-mediated recognition systems that are guided by physical information theory or P-IT. The physical surface area of life-space accompanies energy retention across a time interval, and is recognized across a space surface area via an uncertainty, or noisy life-space sensor of given scope. More specifically, sensor and retainer integrated coders or SRI-coders are derived for the compression of a physical signal's retention life-space in units of surface area. These designs are enabled by the laws of retention in physics, of a passing of time uncertainty nature, such as the pace of dark X in a black-hole limit and the retainer-entropy N. Quadrant IV pertains to certainty intel-time compressor designs for sensor-mediated recognition systems that are guided by mathematical latency theory or M-LT. The bors of intel-time process across a space surface area, and are recognized across a time interval via a certainty, or limited intel-time sensor of given consciousness. More specifically, sensor and processor integrated coders or SPI-coders are derived for the compression of a mathematical signal's processing intel-time in units of bor. These designs are enabled by universal processor compression schemes, of a configuration of space certainty nature, such as the time-dual of transform source-coding treated in [1] and [13].

In particular the LIT revolution highlights several types of dualities guiding compressor designs. They are:

1. The uncertainty–information-space/certainty-latency-time duality exhibited by the quadrant pairs (II,III)/(I,IV). This duality tell us that the uncertainty mathematical intel-space and uncertainty physical life-space methods of quadrants (II,III) have as duals the certainty physical life-time and certainty mathematical intel-time methods of quadrants (I,IV) and visa-versa. Examples are M-IT/M-LT, P-LT/P-IT dualities, etc.

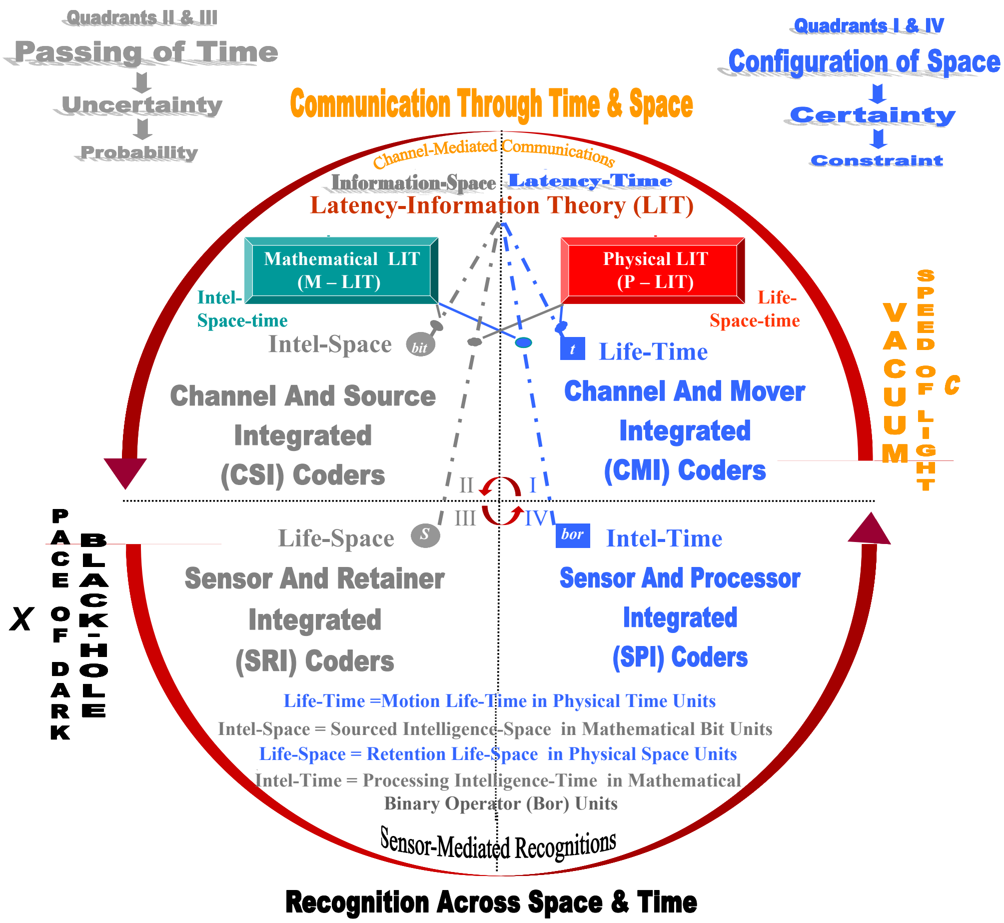

Fig. 9 The Latency-Information Theory Revolution

2. The channel-communication/sensor-recognition duality exhibited by the quadrant pairs (I,II)/(III,IV). This duality tell us that the certainty physical life-time and uncertainty mathematical intel-space methods of quadrants (I,II) enabling communications through time and space have as duals uncertainty physical life-space and certainty mathematical intel-time methods of quadrants (III,IV) enabling recognitions across space and time and visa-versa. Examples are M-IT/P-IT, P-LT/M-LT dualities, etc.

3. The mathematical-intelligence/physical-life duality exhibited by the quadrant pairs (II,IV)/(I,III). This duality tell us that uncertainty mathematical intel-space and certainty mathematical intel-time methods of quadrants (II,IV) have as duals uncertainty physical life-space and certainty physical life-time methods of quadrants (I,III) and visa-versa. Examples are source-entropy/retainer-entropy, mover-ectropy/processor-ectropy dualities, etc.

4. The uncertainty-intel-space/certainty-intel-time duality exhibited by quadrants II/IV. This duality tell us that sourcing-methods of quadrant II have as duals processing-methods of quadrant IV and visa-versa. Examples are transform-source-coding/transform-processing-coding dualities [1], [13], etc.

5. The certainty-life-time/uncertainty-life-space duality exhibited by quadrants I/III. This duality tell us that motion-methods of quadrant 'I' have as duals retention-methods of quadrant III and visa-versa. Examples are laws-of-motion/laws-of-retention dualities such as speed-of-light-in-a-vacuum/pace-of-dark-in-a-black-hole limits, etc.

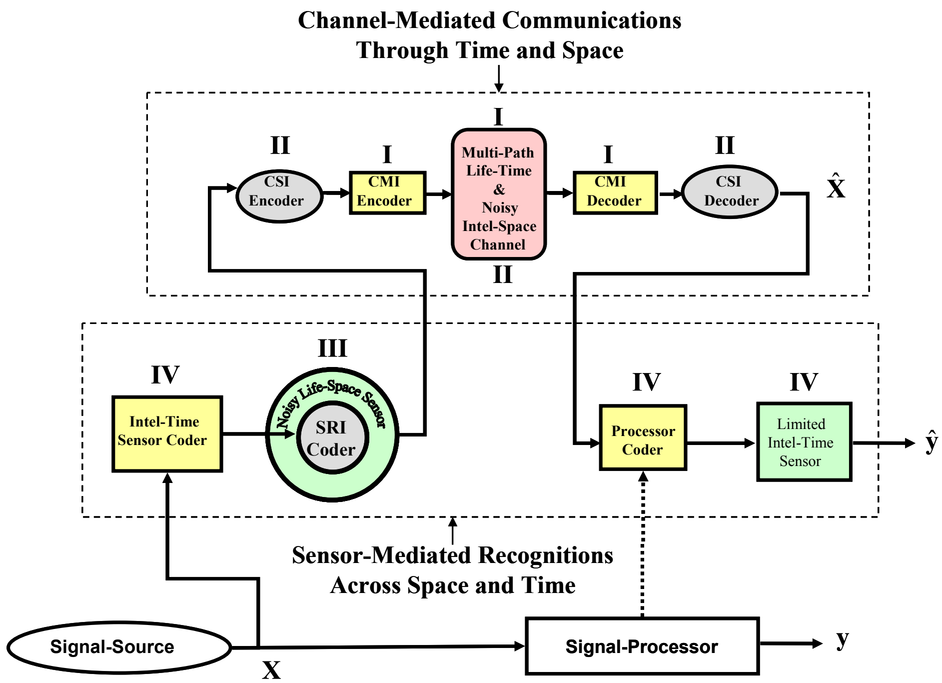

Fig. 10. The Communication Embedded Recognition (CER) System

6. The certainty-life-time/certainty-intel-time duality exhibited by quadrants I/IV. This duality tell us that motion-methods of quadrant 'I' have as duals processing-methods of quadrant IV and visa-versa. Examples are mover-ectropy/processor-ectropy duality, etc.

7. The uncertainty-intel-space/uncertainty-life-space duality exhibited by quadrants II/III. This duality tell us that sourcing-methods of quadrant II have as duals retention-methods of quadrant III and visa-versa. Examples are source-entropy/retainer-entropy duality, etc.

Next in Fig. 10 it can be seen how the four signal compressors of the LIT revolution can be integrated to form a communication embedded recognition (CER) system. The operation of the CER system starts with the intel-time sensor-coder deriving prior-knowledge from a signal-source, e.g. in the form of synthetic aperture radar (SAR) imagery [13]. This prior-knowledge is then stored in the SRI-coder where it is assumed that both the intel-time sensor-coder and SRI-coder reside in the same location at some distance away from the processor-coder. In this same remote location there is also a CSI-encoder followed by a CMI-encoder that communicate the SRI-coder content, available via a noisy life-space sensor, to the processor-coder location. However, before the processor-coder receives the SRI-coder content a CMI-decoder operates on the output of the twofold communication channel, i.e. a noisy intel-space and multi-path life-time channel, and routes it to the input of the CSI-decoder. The output of the CSI-decoder is then fed to the processor-coder with its output sensed by a limited intel-time sensor. This sensing action by the limited intel-time sensor completes the operation of the CER system.

As a concluding remark it should be noted that when one views the unifying LIT revolution via the CER system prism, it becomes apparent that the use of the advanced guidance theory for intelligence and life system designs applies not only to the study of artificial systems but also to living systems. For instance, both intel-space and intel-time compressors can be assumed to exist in the neuron networks of our brains, and both life-time and life-space compressors can be assumed to exist in the heart, arteries and veins of our circulatory system. Clearly, living systems, whose signal compressor evolutionary designs efficiently interact through and across space and time to achieve their own survival in a resources limited environment, should be investigated and used as role models to emulate by the designers of signal compressors of any type. Finally in Appendix B both visual and written reminders are offered whose goal is to genially recall the many symbols, terminology, methods and unifying ideas of the LIT revolution.

APPENDIX A
Derivation of the Pace of Dark X

The derivation begins with the power expression

$$P(t\ ) = -\frac{dE(t\ )}{dt} = -c^2 \frac{dm(t)}{dt} \tag{A.1}$$

where $P(t)$ is the rate of change of the energy of an uncharged and nonrotating black hole (UNBH) [11] at the instant of time *t* and $m(t)$ is the UNBH mass that is related to E(*t*) via the energy-mass equation E(*t*)=c^2m(*t*). $P(t)$ is then noted to be equal to the black body luminance $L(t)$ resulting in the expression

$$P(t) = L(t) = (\pi^2 k^4 / 60\hbar^3 c^2) A \Gamma^4(t) \tag{A.2}$$

where *k* is Boltzmann's constant, $\hbar = h/2\pi$ is Plank's reduced constant, *c* is the speed of light and $\Gamma(t)$ is the temperature of the UNBH: the radiation frequency of the black body, or equivalently Hawking's radiation frequency $f(t)$ for a black hole, is related to $\Gamma(t)$ via the expression $f(t) = k\Gamma(t)/2\hbar$. In addition, *A* is the surface area of the spherically shaped UNBH. Next it is noted that $\Gamma(t)$ is given by the reciprocal of the rate of change of the UNBH thermodynamical entropy $S(t)$ with respect to $E(t)$ where the $S(t)$ is given by the Hawking entropy [11]. Thus

$$\Gamma(t) = \left(\partial S(t) / \partial E(t)\right)^{-1} \tag{A.3}$$

$$S(t) = \frac{kc^3}{4\hbar G} A\,. \tag{A.4}$$

Next using Schwarzschild's radius in the expression for *A* in (A.4) and then replacing $m(t)$ with its energy equivalence one obtains the following expression for $S(t)$ as a function of $E(t)$:

$$S(t) = \frac{kc^3}{4\hbar G} A = \frac{k\pi c^3}{\hbar G}\left(\frac{2Gm(t)}{c^2}\right)^2 = \frac{k4\pi G}{\hbar c^5} E^2(t) \tag{A.5}$$

Next using (A.5) in the evaluation of (A.3) one finds

$$\Gamma(t) = \frac{\hbar c^3}{8\pi k G m(t)} \tag{A.6}$$

Using (A.6) in (A.2) and equating the result with (A.1) the following nonlinear differential equation is derived

$$\frac{dm(t)}{dt} + \frac{\hbar c^4}{15360\pi G^2 m^2(t)} = 0 \tag{A.7}$$

The solution of this differential equation is analytical and yields

$$m^3(t) = m^3(t_i) - (\hbar c^4 / 5120\pi G^2)t \tag{A.8}$$

where $m(t_i)$ is the initial UNBH mass. One then sets expression (A.8) to zero to derive the final time t_f when the black hole ends its existence, i.e.,

$$t_f = \frac{5120\pi G^2}{\hbar c^4} m^3(t_i) = \frac{5120\pi G^2}{\hbar c^4}\left(\frac{c^2 r}{2G}\right)^3 = \frac{640\pi c^2}{\hbar G}(r)^3 = \frac{480 c^2}{\hbar G} V \tag{A.9}$$

where *r* and *V* are the mass retention radius and volume, respectively, of the UNBH at the initial time of t_i. The retention-time *T* for the UNBH is then given by the expressions

$$T = t_f - t_i = (480c^2 / \hbar G)V - t_i \tag{A.10}$$

$$V = 4\pi r^3/3 = 4\pi\left(2Gm(t_i)/c^2\right)^3/3 = 4\pi\left(2GE(t_i)/c^4\right)^3/3 \tag{A.11}$$

The rate of change of the retention-time T with respect to the retention-space V (or 'pace of energy retention' which is the 'uncertainty' space-dual of the certainty 'speed of energy motion', i.e. the rate of change of motion-space s with respect to motion-time t) is then derived from (A.10) to give us the sought after pace of dark X for a black-hole, i.e.,

$$X = \frac{dT}{dV} = \frac{480c^2}{\hbar G} = \frac{960\pi c^2}{hG}. \tag{A.12}$$

Appendix B
Latency-Information Theory Genially Remembered

Latency information theory is genially remembered with Fig. B and the following eight lucky reminders:

1) **Like a friendly Cassper ghost** the pace of dark equation $\boldsymbol{hG = 960\pi c^2/X}$ radiating the **LIT** figure permeates information-space of either an intel-space or life-space nature as well as latency-time of either a life-time or intel-time nature. The supreme '2' of this revealing expression further tell us that 'dualities' span vertically, horizontally and diagonally the fabric of information-space and latency-time. The vertical duality has an uncertainty/certainty nature that is exhibited by the information-space of quadrants II and III and the latency-time of quadrants I and IV. The horizontal duality has a channel-communication/sensor-recognition nature that is exhibited by the 'through' integration of motion life-time and sourced intel-space of quadrants I and II and the 'across' integration of retention life-space and processing intel-time of quadrants III and IV. The last diagonal duality has a mathematical-intelligence/physical-life nature that is exhibited by the integration of sourced intel-space and processing intel-time of quadrants II and IV where M-LIT resides and is symbolized by an intelligent brain, and the integration of motion life-time and retention life-space of quadrants I and III where P-LIT resides and is symbolized by a living heart.

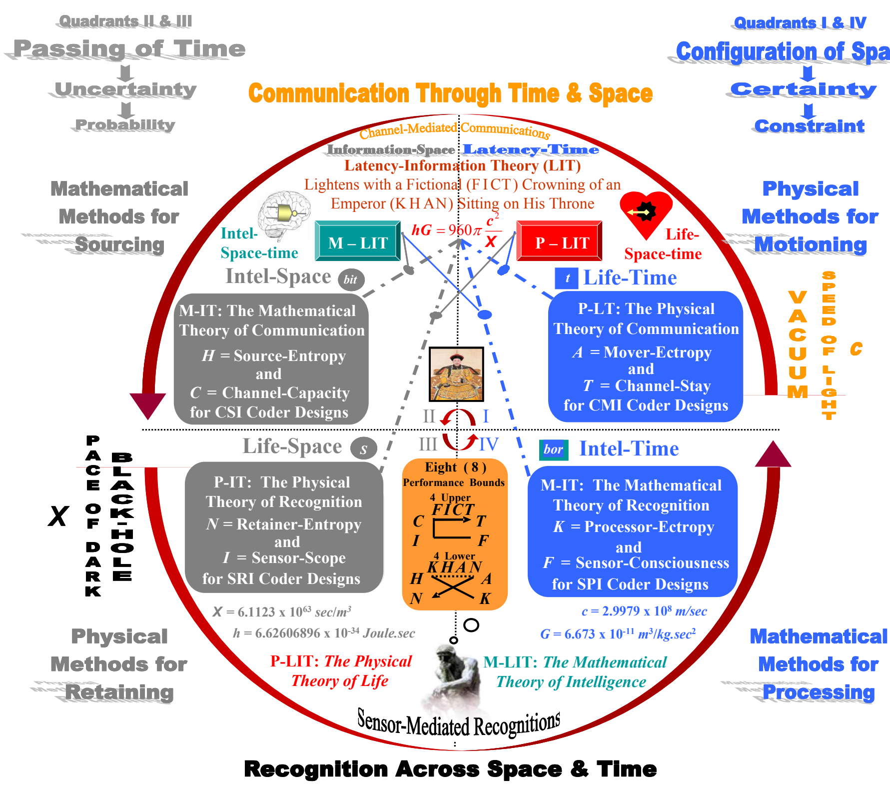

Fig. B. A Genial Reminder for Latency-Information Theory

2) The fictional (**FICT.**) crowning of an emperor (**KHAN**) also permeates information-space and latency-time. The four letters of KHAN denote the 'lower' performance-bounds K=processor-ectropy, H=source-entropy, A=mover-ectropy and N=retainer-entropy guiding respectively, processor, source, mover and retainer coder designs. On the other hand, the four letters of FICT denote the 'upper' performance-bounds F=sensor-consciousness of a limited intel-time sensor, I=sensor-scope of a noisy life-space sensor, C=channel-capacity of a noisy intel-space channel and T=channel-stay of a multi-path life-time channel guiding respectively, sensor and processor integrated (**SPI**), sensor and retainer integrated (**SRI**), channel and source integrated (**CSI**) and channel and mover integrated (**CMI**) coder designs.

3) Following the letter positions in the LIT figure the FICT crown is drawn starting first with the recognition case from the bottom right F to the bottom left I, and then moving on to the communication case from the top left C to the top right T with the caveat that one must be very patient when moving from I to C since this movement is only possible via Hawking radiation as one emanates from a black hole in the third LIT quadrant. The FICT crown, however, has the good fortune of forming the letter ***c*** which stands for the *speed of light* and should help in speeding up things a '***bor***'. Next the KHAN emperor chair is drawn starting with the intelligence case from the bottom right K to the top left H which is then followed by the life case from the top right A to the bottom left N, where it is also noticed that the communication move from the top left H to the top right A has been ignored because it is done so fast, i.e. at the speed of light! The KHAN chair also has the good fortune of forming the letter X which stands for both the *pace of dark* and the unknown nature of a black-hole.

4) Returning to $hG=960\pi c^2/X$ the Plank constant h is to the left of hG just like the uncertainty in information, of a passing of time origin, is to the left of the figure. On the other hand, the Gravitational constant G is to the right of hG just like the certainty in latency, of a configuration of space origin, is to the right of the figure.

5) The ratio c/X in $hG = 960\pi c^2/X$ is easily remembered from the c shaped FICT crown sitting on top of the X shaped KHAN chair.

6) The constant **960π** in $hG = 960\pi c^2/X$ is equal to the product of **480** by **2π**. The '**4**' in the 480 tell us that there are four LIT quadrants as one moves by 2π on the figure, i.e. by a single **LIT revolution** that starts with the **physical latency theory** located in the first LIT quadrant, then the **mathematical information theory** of the second quadrant, then the **physical information theory** of the third and finally the **mathematical latency theory** of the fourth. Furthermore the '**8**' in the 480 tell us that there are eight performance-bounds, i.e. F, I, C, T, K, H, A, N to be found in the LIT figure where it should be noted that the number eight is a lucky number for the Chinese KHAN emperor.

7) The I, N letters of '**the physical theory of recognition**' stand for retaining energy **IN** a black-hole, and the A, T letters of '**the physical theory of communication**' stand for moving energy **AT** some distance in a vacuum.

8) Finally, what the letters C, H of '**the mathematical theory of communication**' and the letters F, K of '**the mathematical theory of recognition**' stand for I will leave for the readers to figure out on their own. Nevertheless, if asked, I would suggest that these letters may stand for the names of artificial and/or former living systems acting as friendly ghosts, where each ghost should of course exemplify a constructive as well as revolutionary intelligence

DEDICATION

This manuscript is dedicated to the memory of Claude E. Shannon 1916-2001

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