Safety Management - Leading Space Information Conception (LSIC)

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This power to abstract is one of the outstanding characteristics of human beings as compared with other animals. And this power is used not only by mathematicians, but also by artists, musicians, poets, and all other "human" beings. Perhaps some day we shall measure a person's "human-ness" by his power to abstract rather than by the I.Q.

Lilian R. Leiber (D. Wells,(1997))

ABSTRACT

What are the common things between ship's voyage plan, ship's ladder, Wall street in New York, International Convention STCW 95, path through the woods, cook- book, fairway in restricted waters, Principle of Universal Gravitation and ... ISM Code check-list ? All of them are tactical or strategic algorithms following which the Man and the Nature reach the definite goals in their activity. These algorithms are constructed in different forms , but they fill every step of our life.

To develop the safe algorithms of activity in any area we have to use the experience accumulated by the Mankind during a lot of years and there is no other ways to do it. For instance, if the Mankind did not accept the negative results of it's industrial activity to the Nature, we hardly began to protect the environment.

Following the vast set of different regulations and principles the Man with the help of technique which is created by himself has learned how to reach safely the different goals and how to solve the very difficult tasks.

In every time and everywhere the unconscious using an *abstract information* helped the Man to find the right way to the goal.

The paper highlights and analysis the link between Shannon abstract information quantity and Safety Management. Our ideology is based only on the conception of minimum redundancy of measurements relatively the enveloping space.

1. Introduction

In every field of mankind activity the obtaining of knowledge is based on analysis of information which is got from the object of research. Measurements in any case are the origin and they carry all the information we can extract.

Measurements are made by a lot of special instruments, devices or sensory with the help of our organs. They may be direct or relative ,discrete or continuous ,but the quality and quantity of information extracted from them is the key to get the goal we want.

In spite of the powerful development of science and technique a lot of failures and accidents take place in all spheres of our life .Navigation is only one small part of Man's activity where the tendency of accidents and catastrophes is not going down.

The pulse for research of this fundamental problem has arisen from practice and applied science of marine navigation and in the origin it has gone from the sea going ships navigation accidents analysis .

Preliminary investigations made in optic and radio- physical redundant measurements applied for fixing position of ships discovered that navigational measurements carry very few of Shannon (abstract) information in them, Loginovsky (1997). It was surprising and has encouraged us to go ahead.

Detailed analysis showed the direct connection between the shortage of Shannon information and navigational accidents at sea.

This paper may be considered as an introduction into the problems which arise not only in navigation but in every field of mankind activity where measurement are applied ,but they are applied everywhere.

2. Shannon information and measurements.

We live in time of upward tendency of civilization and development of techniques ,but nevertheless the *Human Element* (HE) is the main factor of safety in any area. We are of the opinion that difficulties relating to formalization of HE do not permit to compensate the negative influence of it to the *level of safety* .

To compensate the HE is not to exclude the Man from the management of any system, but to make him follow the strict safe algorithms constructed by himself. Electronic aids should help to solve the problem but first of all we have to learn how to abstract a lot of things connected with safety to apply the modern technology .

In this paper we shall begin with information. There are two types of information that may be received by different sensors: concrete (real) information (color, temperature, sum of money, distance, bearing, thickness, time... volume...etc) and abstract information in binary digits (bits).

The main positive features of abstract information are the unification of different types of measurements and direct of it link with the characteristics of measurement errors which are existing everywhere in our life.

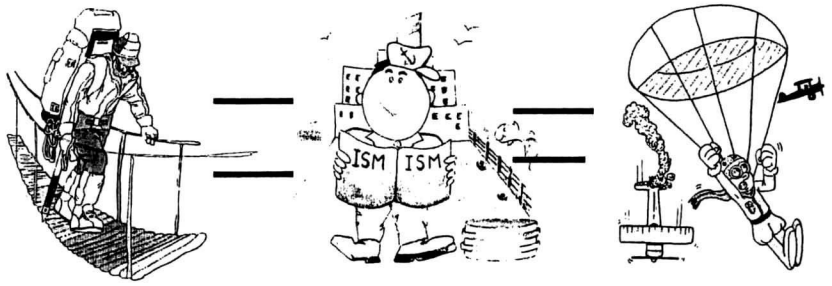

Figure 1. Safe algorithms

Suppose that we control some moving objects: ship at sea, airplane in the air, car on the road , etc. We are high quality specialists and we have a power to control the object ,but some measurement information is necessary to do it. Usually there is an information about the initial and running coordinates of the object .The coordinates of destination point have to be known as well. We begin to steer the ship ,to pilot a plane or to drive a car to the point of destination but make an accident or catastrophe occurs.

What are the main reasons of such things ? Let's try to find the most general , but come to agreement to exclude force- majeure situations from our discussion.

Grounding of the ship - what may be a reason of it ? It may be : not accurate navigational charts, poor visibility, HE (skill of a master, he is tired , etc.).

The ship was off the safe way because the navigator for example was not attentive due to some health troubles or his experience in that situation was not enough. But in any case the navigator did nothing to correct the situation. May be he did not identify the safe way ? May be, and it is very important.

Airplane catastrophe while landing- it's possible to find a lot of reasons but the most generalized one may be that the plane was just the same off the safe trajectory of landing.

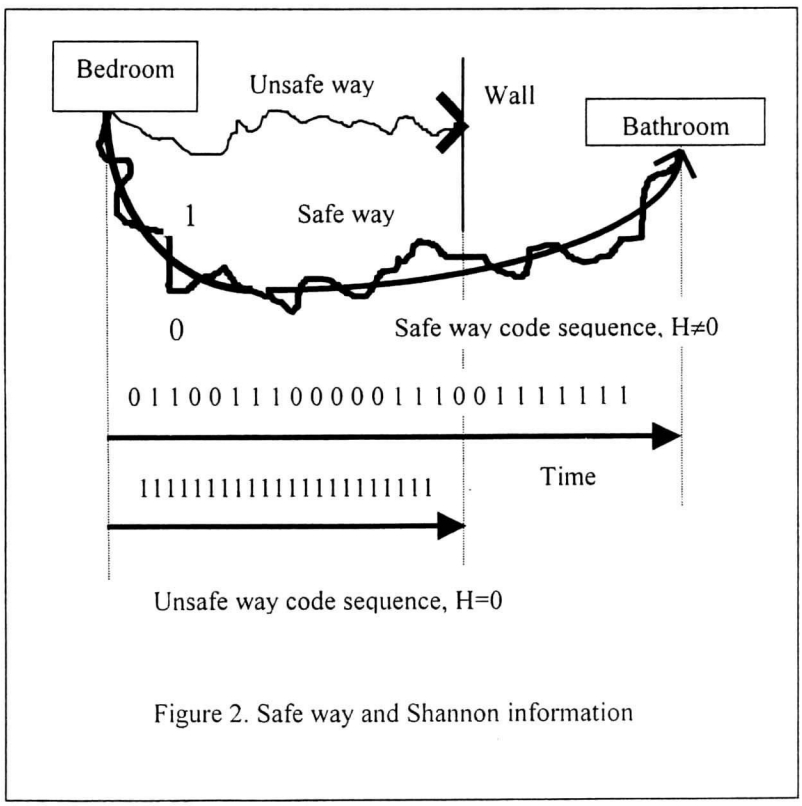

Figure 2. Safe way and Shannon information

The real and direct reason of every accident and catastrophe exists , but it's generalized as the bias of moving object from the safe way. One can say there was not enough reliable information to control the object along the safe way, that's why the control procedure was not effective. You may state that the information was reliable ,the information was enough ,but improper

interpretation of it may be the reason of an accident as well . It's just the same thing if the navigator did not recognize the safe or unsafe way.

It is very simple to understand that the systematic errors in measurements are the reason of bias in position and if this bias in position is unidentified it is the reason of different types of disasters not only in navigation .The navigator has to recognize such a situations and make corrections in control procedure to avoid danger. There are a lot of problems to discuss but the main is that the navigator compulsory needs to know if the moving object is on the safe way or not ?

We are sure to state a fact that there is clear resemblance and exact formal link between the information fields of such events as not correct proving of mathematical theorem ,not correct made diagnosis of man's illness or weather forecast ; grounding ,collision or capsizing of a ship or perishing of a space vehicle etc. In all events the control procedure was based on improper estimation of measurements and misunderstanding of the situation that has grown into uncontrollable state.

It's possible to say that the shortage of reliable information about position does not permit to predict the result although there is a power to control the object or some procedure. We observe such examples every day in our life. The information we use everywhere is a concrete information that is hardly able to be calculated. For instance we had an information about the coordinates of the ship before the grounding , but we did not know if this information was wrong or correct, reliable or not.

It is obviously to have a Hypothesis that there is a discrepancy between measurements and information they carry. We'd like to know what is a reliable information. Let's try to formalize the procedure of obtaining information and link the quantity of it with the of bias from the safe way.

Imagine that early in the morning you get up and go from the bed room into your bath room. You begin to navigate your body with the help the most modern integrated navigation system in the world that is located in your head. You know the safe way and use such your sensors as eyes to obtain the navigational information. The picture of your track is on fig.2.

Certainly it's possible to draw the safe way on the floor but it is in your head. You can't follow the way without any errors ,so your the track may be drawn as on fig. 2.

The safe way divides the space on the floor in two subspaces or it divides the plane of the floor in two arears. If you are in the left part we shall code such position as 1, and if your location is in the right side -it is 0. Let's take time interval to fix positions, for example ,in some seconds and make code sequence of your fluctuations near the safe way as a function of time. If you change the position from 1 to 0 or from 0 to 1 your track intersects the safe way in certain points , or in other words all these sectors include the points of the safe way. We shall call these points as information points or H-points. It is impossible to go strictly along the line and your fluctuations are random. The procedure is exactly the same as if you toss the coin to find the number of heads (p_0) or tails (p_1). So, you can calculate the information H about the safe way in bits (binary digits) . Ambiguity creates the information. You get it while traveling. This is so called Shannon (abstract) information and it's very easy to be analyzed by the following formula, Harmuth, (1989):

$$H = -l\,(p_0 \log_2 p_0 + p_1 \log_2 p_1),$$

where l - is the order (length) of binary code sequence , p_0,p_1- are the probabilities (frequencies) of *ones* and *zeros* in this sequence.

The maximum of H will be if your fluctuations are symmetrical relatively the safe way. But something had happened with your eyes ,you closed them and the real track had a bias into the 1-area. There were neither $0 \rightarrow 1$, nor $1 \leftarrow 0$ fluctuations and code sequence did not contain any information about the safe way. This was not good way and you l collided with the wall !

So, in this case you had the safe way in your head and got the concrete information about it by your eyes. The more such an information you have the closer to the safe way you go. But it's impossible to calculate the concrete information that you get by your eyes , so you have to calculate the abstract one relatively the safe way.

The reason of your early morning accident was the shortage of Shannon information about the safe way .You was off the way and did not identify the bias.

3. Shannon information on the leading line.

Imagine yourself on the navigation bridge and you ,as a navigator, control the ship's position on the leading line R, fig.3 .You observe the navigation leading lights and you know when your ship has a port side cross track error or a starboard side one . The plane in the vicinity of the leading line is just the same divided in 0-area and 1-area and it's possible to calculate H . So , in accordance with the above said ,$H \neq 0$ when the ship's track is on the leading line R and H=0 ,when the ship's track is off it. Now the safe way is indicated to navigator by leading

lights or marks, but the situation is just the same it was before. How to link systematic and random errors of measurements with the quantity of abstract information ? Figure 3 shows us the quantity of Shannon information as the function of a systematic cross track error ε and random fluctuations with reference to the safe way . So the rule is : *the more intersections mean the more abstract information.* In this case it is mach more simple not to use formula for calculation of H but to estimate the number of information H-points, so on the track *a* H=8 and on the track *b* H=0. The corresponding graph is shown on figure 3.

The amplitude of fluctuations of the ship near the leading line depends on the accuracy of the line and the skill of the helmsman. The modern measurement systems are very precise (random errors are very small) But good precision (mean square error) is nothing if the system is not Shannon informative. Non-informative bias way (*b*) approaches the ship to the catastrophe.

When the ship is proceeding along the leading line there is one very serious feature (advantage) that helps the navigator to steer the ship: in every time the navigator can observe the error of ship's position relatively the leading line.

Do you know any other measurement system where the operator (*safety manager...*, why not ?) can do the same ? I guess it's not difficult to find an example.

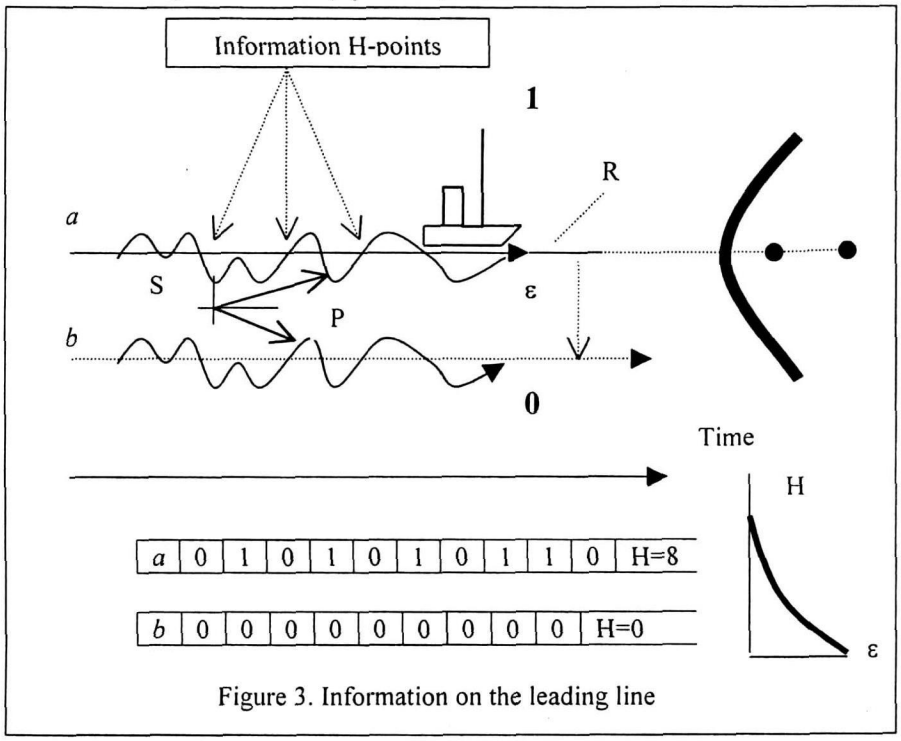

Figure 3. Information on the leading line

4. Generalization of approach

The human activity in any area is a movement. It means not only the physical movement of real object in a real space, but any movement of some point P (abstract moving object – vector P) in any abstract mathematical space S of any dimension. For example, in the case of cooking this space S might be multidimensional: S= {t, x_1, x_2,x_3, x_4... x_n}, where t is time, x_1 - quantity of food, x_2 - salt, x_3 - pepper, x_4 - water,...x_n– temperature of cooking

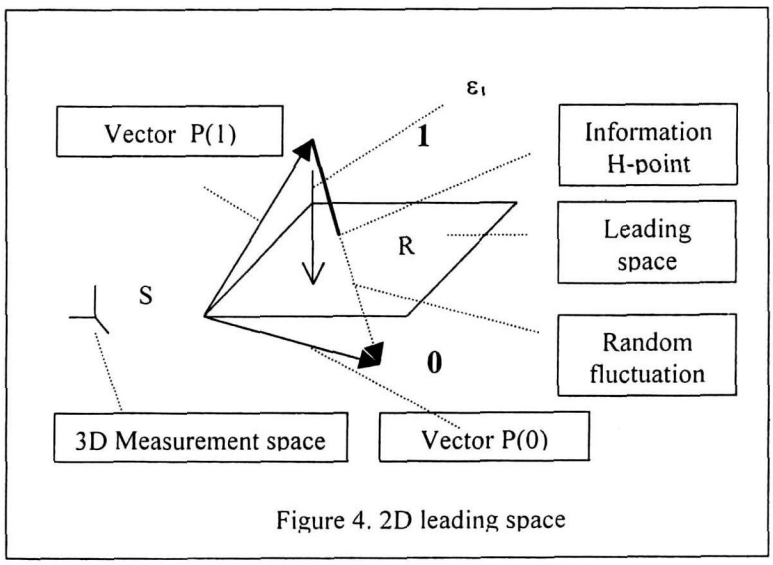

Figure 4. 2D leading space

and in the case of operations relating to Bridge Checklist B11 - Navigation in ice, ICS (1998) the space S may be formed by the following coordinates: S= {t, x_1, x_2,x_3, x_4, x_5, x_6,x_7, x_8 x_9... x_n },where t - time, x_1- latitude ,x_2- longitude ,x_3- time between observations ,x_4- speed ,x_5- depth ,x_7- time between soundings, x_8- time interval between soundings in bilges and tanks ,x_9- information of Master about the approaching to ice, x_n- ... etc.

The term *leading line* may be generalized on the space of any dimension. So in 3D space it is a *leading plane*, in 4D space it is a 3D *leading space (subspace)*, ... in nD space it is (n-1)D subspace. If the object P is off the leading space R it may be identified by the running deviation vector ε, fig.4.

In practice *leading space* R may be safe or unsafe, linear or non-linear, it may contains the information H-points or does not contain the abstract information about the running position of object P. It may serve as a thwart space, or guard space, but if it does not contain H-points this means that measurements are not informative relating to it and the track has a dangerous bias. In these case you are in the right to ask where we are ?

The very important note is that any deviation from R to S may be identified by vector ε, for example ,if we drive a car along the 1D central line on the highway we can see the deviation ε from this line into 2D plane of a highway. To attract the driver's attention they use the deviation ε of a car from 2D highway into 3D space ("lying policeman"). So, this is the same conception. It is remarkable that ,for example, some GPS receivers have highway mode of data presentation, it is LSIC mode, GPS 12, (1999) . There is preliminary plotted way on electronic charts and the OOW can observe by GPS track every time the deviation ε from the safe way. Problem is if the GPS track contains the information points . The development of DGPS mode shows that there are a lot of doubts about the quantity of information along this track fixed by standard GPS mode. Identification and elimination of systematic errors of measurements is primarily important.

So, if the navigation in S is impossible without measurements, there should be determined navigational marks, navigational parameters, navigational functions and if the number of measurements in nD space is n+1 we may use the LSIC to calculate H for *safety management* of object P.

In this case the linearization of navigational functions gives the local linear leading spaces (the space of solutions of linear system of equations) which may compose the whole non-linear leading space, for example if there is 3D S space and 2D R space, we have the following picture on fig.4, Strang (1976) . In this case measurement vector P is the abstract object that is to be controlled.

In principal any linear space S of Human activity may be constructed where the algorithm of progress is presented by some function F {t, x(1) x(2),x(3), x(4), x(5), x(6),x(7), x(8) x(9)... x(n) } or it's graph R.

From the above said it is possible to come to conclusion that the term *navigation* is ideologically applicable to any real or abstract mathematical space S and the expression *safety of navigation* has the general sense at all times and in all spaces.

One of the main task is to create the multidimensional electronic navigational chart for S space. On such a chart there should be the point of departure (the initial position to start the activity), the point of destination (the goal). To make a progress it leaves to plot the safe way and follow it. To follow this way we need to know where we are now relatively the safe way in order to control the progress.

In the context of the paper it should be defined some popular nowadays terms:

Safety Management is the set of procedures to bring the object (vector) P into the safe space R , using the information H. If the fluctuations of vector P are random the H-points are determined by themselves !

Danger level is the function of vector ε length and quantity of information H and it might be running and average one.

Safety Culture is an ability of a Man to keep vector P along the safe way R in S, and it is measured by average danger level during the time of progress in S.

Safety Culture as a form collective behavior may exists at different levels: IMO, IAMU, Administration, company, ship, Master, OOW,...ratings. At exact time we deal with the *Realization of Safety Culture*. It is the running danger level , that may be estimated if there is a safe way R in S.

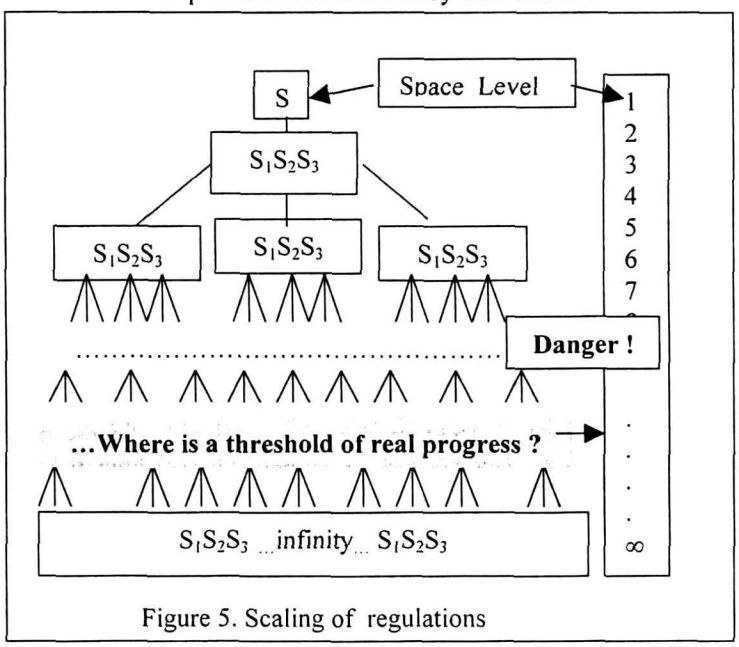

Figure 5. Scaling of regulations

5. Specification of safety procedures

Speaking about specification of procedures we are to take into consideration that every

area S of Human activity needs a lot of information H that should be obtained and developed.
To reach the goal in S let us divide it by 3 sub-spaces , Gludkin (1999) :

- S_1- is the sub-space of preparatory actions (planning)
- S_2 -is the sub-space of control procedures (realization)
- S_3- is the subspace of analysis and corrections

This algorithm is universal and applicable to any space S, but if we use the scaling to $S_{1,2,3}$ we discover that every space contains the same spaces $S_{1,2,3}$. Such structures are investigated in fractal geometry and are called as self-similar structures, Feder (1991), fig.4.The boom of algorithms (regulations) arises and the question is on what level the system effectively works if all the steps are to be documented. It is absolutely clear that the absence of regulations is dangerous, a lot of regulation is just the same dangerous, that is why the optimum for every S should be determined (Human or electronic aids capacity). It is may be the work of IMO Facilitation Committee, but it is obviously that the more higher level of education and training of seafarers the less number of regulations in S they need, so IAMU activity may give the tangible help. These problems are investigated by the information theory but the milestone problem is the quantity of abstract information to follow the safe way in S.

Figure 6. Do these papers contain H ?

We would like to highlight the documentation boom that is observed in international shipping nowadays. It reduces the *Safety* which is in the inverse proportion to danger level.

To develop regulations we have to take into consideration the qualification level of effecters.

So, the less the qualification of the specialist the more detailed algorithms of his activity should be prescribed, and that's why the main part of them must be carried out during the MET program. The STCW 95 Code may be as an example of such a minimum but comprehensive program that should be carried out in MET institutions. The high level of education and training should relieve the effecter from a lot of formal procedures in S.

The ISM Code procedures should be just the same of different levels of specification which depends on Safety culture level of company and seafarers: strategic- for high level, tactic - for middle level.

The STCW 78 Convention was not achieving its purpose . Instead , the Convention was gradually losing credibility as it acceptance widened. The main cause for this appeared to be the general lack of precision in its standards, the interpretation of which was left to the satisfaction of Administrations, IMO Workshop (1997). STCW 78 was too general and oriented on very high Safety Culture level of Parties . We are of the opinion that ISM Code has repeated the STCW 78 lack of precision, there are no tactic requirements for the middle and low level companies. These requirements should be developed to help the classification societies to rise the safety level of companies, taking into consideration Human or electronic aids capacity.

6. Approximation of tracks by H- points.

One of the problem to be learned is the measuring of safety. It may be done by estimation of abstract information H to follow the safe way with the prescribed accuracy.

Below on figure 7 we present some results on approximation of the unit segments of some graphs using LSIC approach, abstract space is presented on fig. 4 and real 2D –space is on fig 3. We used different proportions of measurement errors *k=systematic error/ random error* to obtain the definite sets of H-points applied for approximation of real curve segment by cubic splines. The real "safe track" is shown by bold line and spline numbers (N) are indicated in the boxes, H is the quantity of information as a number of H –points.

The following results were obtained:

- The maximum number of H-points on the curve or the quantity of H, as it is seen from table is obtained when *systematic errors are equal to zero.* It means that the errors of measurements are random and independent. The first spline is very close to the true curve.
- When the k=0.76, the approximated curve converts into a straight lines. So, the k or just the same H or number of H-points changes the shape and length of the curve segment and we may fix the minimum H when the approximated way might be considered as dangerous.
- When $k \leq 0.7$, H=0 . In this case all measurements does not carry any abstract information H. All the measurements are dependent (systematic errors prevail – there is no $0 \rightarrow 1$ or $1 \leftarrow 0$ transfers). Strictly

speaking in the context of this paper we don't know the track at all and we can not approximate it by measurements, if there are a lot of them -they are fiction.

- Information H spreads not regularly along the curve: the maximum number of H-points is near the maximum curvature points.

7. Results and Discussion

- The lack of H about safe position of object P in any space of Human (or Nature) activity may be considered in general as the main reason of different types of accidents and catastrophes.
- LSIC gives the key to formalization of different spheres of Human activity including the HE.
- Using LSIC we may formally explain that information is born from redundancy and ambiguity. Observing the real areas of Human activity one can see the similar processes of obtaining information H for the progress to the goal. In this context (binary approach) ambiguity is the origin of progress ,by other words it is competition in industry , democracy in policy ,...redundancy in measurements ...etc. Redundancy and ambiguity (read *information* H) are the origin of progress in everywhere .
- Sometimes they say that redundancy and ambiguity is not need for the safety management because P_1 is much more closer to safety space R than P_0 , but theoretically no one object P is exactly in safe space and information H may be obtained if the competition exists. *One of the actions announced by LR, DNV and ABS is to align ISM with other safety management control measures by linking future issuance of SMC certificates to the classification of the vessels. The objective will be to phase out, over time, the split responsibility that now exists when one society classes the vessel while another judges compliance with the ISM Code* ,LSM :(April 2001) . May be it is the essential step nowadays. This is right if in binary situation one may prove the fact that $\varepsilon_1 << \varepsilon_0$., but the situation in shipping industry space is far from binary.

N	H	*k*
1	9	-
2	9	10
3	7	5
4	4	0.3
5	4	2.5
6	5	2
7	5	1.7
8	9	1.4
9	6	1.25
10	5	1.1
11	7	1
12	6	0.9
13	6	0.8
14	2	0.76
15	0	0.7

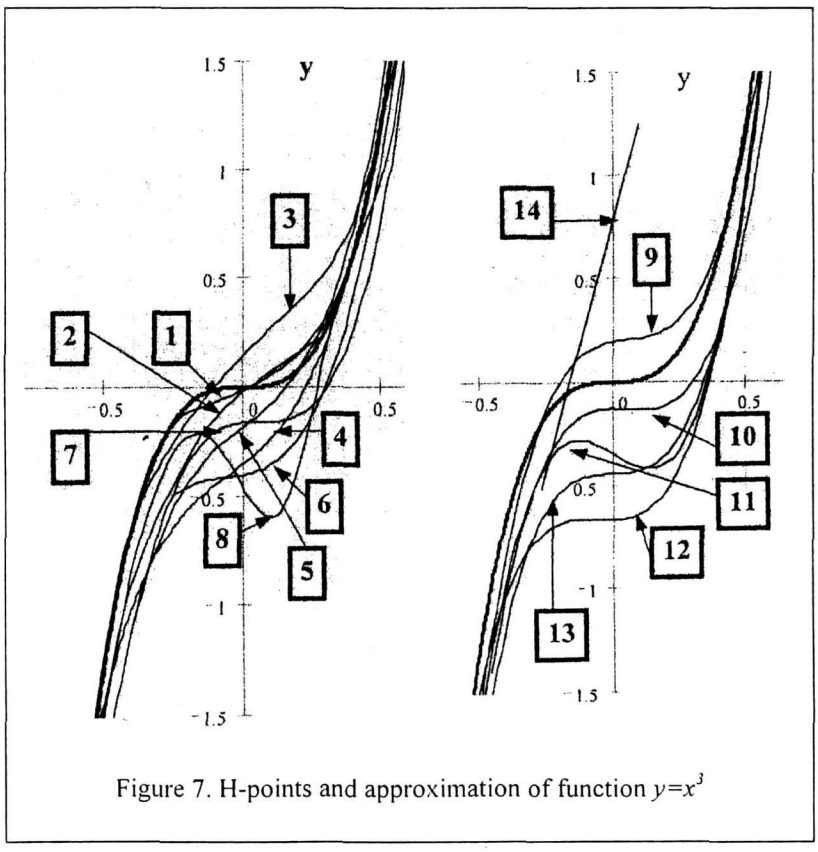

Figure 7. H-points and approximation of function $y=x^3$

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