Engineering aspects of Gis Education

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Abstract

Engineering of education refers to scientific and technological aspects of education to support philosophical bases necessary to be used on didactics, curriculum structure in an effort to develop an educated character. A GIS is a field with advanced scientific and technological bases, is used to support many and diverse applications of an interdisciplinary nature. Education in such diverse applications must be in first place centered on promoting human values and on such bases proceed with the effort to develop a scientist, a professional and an educated character. Therefore, engineering procedures are adopted in terms of using mathematics as a tool to analyze structures and of using specifications for education planning. This is necessary to develop and use scientifically founded human value models and based on these models to proceed on didactics using scientific and technological tools in a way to create motives for the students, thus contributing to a balanced curriculum environment. This engineering structure and methodology of Gis education will be demonstrated as applied at the University of the Aegean, Greece, Department of the Environment.

Introduction

Most educators give emphasis on learning process and pay little or no attention to the right use of knowledge acquired through such a process. Educating, for example, someone to use a knife to cut onions and carrots for cooking, may not be given attention to the damage caused by the wrong use of a knife. Therefore right and wrong coexist in any action taken and the primary concern of an educator must be to maintain human values (Jaeger Werner 1945) at a level, where the educated ones will clearly understand where are the limits between right and wrong and maintain their actions within such limits.

Nature on the other hand gives us many such examples about limits and check and balances to maintain a stable equilibrium based on engineering aspects of mechanics and specifications with the best example being, the functioning of our planetary system with planets moving around the sun and moons moving around the planets maintaining a stable equilibrium. If someone realizes that the orbit of a moon, or a planet is never the same, but maintains an average and each individual orbit is performed within some variance limits, there is a clear understanding that such an average and variance can be computed and can be considered as the engineering design specifications established by nature to maintain equilibrium in this particular system.

In a similar way Nature has evolved human mind being, according to our knowledge, the highest potential force to produce action, which is hosted within human brain - a neuron based structure (Saxe R., 2010) - and as such is performing within certain specification variance limits. Someone working with GIS has the experience of hardware and software components of a GIS system, where software is an immaterial entity independent of time and therefore being immortal (Plato, Timaios), while hardware is a material quantity dependent on time and therefore mortal. When hardware is outdated goes for recycling, while software even if outdated still is running and undergoes a constant improvement. Although software as being immortal, it exists all the time past, present and future representing knowledge in a latent state, it cannot function without the proper hardware, likely following Descartes' duality (Baker, G. and Morris, K. J., 1996). Most human scientific exploration tasks deal with the discovery of such knowledge at latent state and publish it in a book or in a software form. In a similar way, if the human brain is being considered at the hardware, then the human mind is the software. Therefore, education has to study at first place the hardware specifications, especially its error performance as a neuron based structure (Saxe R., 2010), which actually is human mind's performance. In this respect, education must produce its own engineering aspects in the effort to develop and maintain an educated human mind whose thoughts and actions are within acceptable error limits.

Another philosophical aspect of the right use of GIS presupposes good knowledge of computer and its capacities and overall the ability to develop scripting / software to automate processes. The correct pedagogic process could adopt as an objective that *whoever is educated to use the computer as a tool is always more intelligent than the machine*. This philosophy could drop the myth about computers and help students and professionals to get the power of knowledge and use the computer as an effective tool in all scientific fields and in all kinds of activities. The highest advantage of the computer as a pedagogic tool is that in any subject or problem or work can provide fast results and in this way creates motives for studying with confidence the scientific bases. If people are trained to develop software, then they can study each piece of scientific work or research by testing it in the computer and in this way they obtain an essential confidence that they know this scientific part of study or research. Young people must understand the example of the team which developed the Apple computer and they must realize that any moment they decide to move ahead, they can also take initiatives using their free creative mind putting objectives and standards thus helping themselves and the society.

Two models to describe human mind performance

Mother of all scientific fields is philosophy, which comprises all scientific fields. Unfortunately, today philosophy is inactive and the basic reason is its separation of mathematics and science. Therefore, to be able to advance human sciences such as education from their reverse direction, there will be an attempt to use mathematics to analyze two philosophical structures moving one step forward from where such structures were left by ancient philosophers. Aristotle in his book "The Nikomachaean Ethics, B-6, B-7" defines the right and wrong limits as a midway of virtue and if someone is performing inside this midway is doing right while if performing outside is doing wrong. This midway region is, according to Aristotle, located between two extreme locations or badness, the one being towards a sub estimation (*deficiency*) of virtue and the other towards an overestimation (excess) of virtue. Therefore, concerning virtue, we can adopt as significant human error the outside of these limits human actions either they are in excess, or they are deficient to conform to virtue midway limits. Aristotle's example about courage is illustrating this definition of human error stating that "*in midway between a coward and a provocative is the virtuous one (correct one) of courage*". Accordingly, we may say that "*in midway between a stingy and an overspending person is the virtuous one (correct one) of thrift*". Aristotle is also stating that the *effort* to maintain actions within the midway of virtue is the characteristic of a virtuous person, who is learning from mistakes and is trying to minimize them. Aristotle's midway of virtue is actually a basic step towards modeling of human error and therefore, it is the starting point of engineering in education. With other words education without a scientifically derived error model for human actions has no meaning since didactics alone and resulting knowledge can be used both ways for good actions and for bad actions.

A second model concerning the human mind relates to its basic components, which define the *mind space*. According to Plato, the *mind space* is composed of three basic components which are: the *desire,* the *anger* and the *logic* (*reasoning*) (Plato, *The Republic* (435a – 445e) and Plato, *Phaedrus* (246a – 254e)). Therefore, as shown in Figure 1, mind space may be considered as a *three dimensional system* with axes desire -*D*, anger -*A* and logic -*L*.

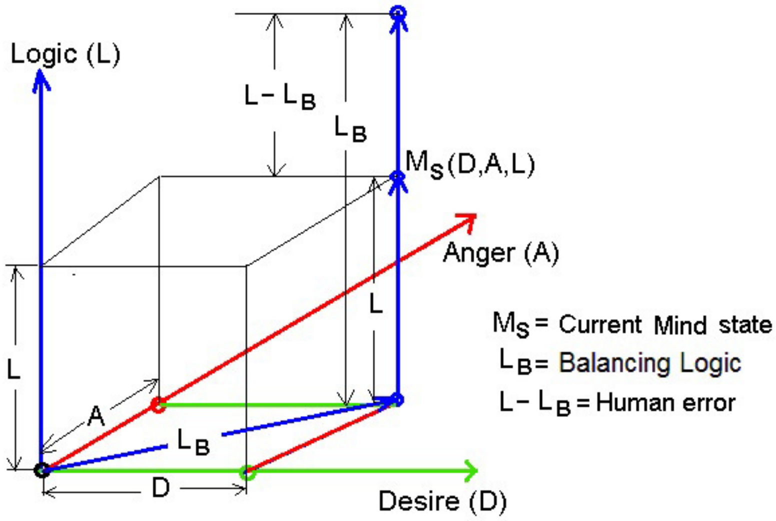


Figure 1. The three dimensional mind space with current mind state M_S(D, A, L) and Human Error ($L – L_B$) with L being the current logic and L_B being the balancing logic of D and A.

Any thought or resulting action, correspond to a set of values of these three basic components which define a specific point M_S in the mind space with coordinates M_S(D, A, L). Quantization of D, A, L components is a matter of research to be done. Plato also defines the ideal situation of *absolute correct human mind state*, where the logic must maintain a balance between the two other components desire and anger.

Plato's example to illustrate the absolute correct human mind state (Plato, *The Republic* (441e) is shown in Figure 2, where the desire is represented by a *blind horse*, the anger is represented by a *crazy horse* and the logic is represented by the *coachman* who tries to move the car in the correct direction, the virtue. Notice that in Figure 1, logic *L* represents the current logic of a person and logic L_B represents the balancing logic according to the current status of *D* and *A*. However, *Human error* may be defined by Equation 1 as follows:

$$\textit{Human error} = L - L_B \qquad (1)$$

Actually, midway of virtue defines the threshold limits so that human error is insignificant and the resulting action is being considered as *acceptably correct*. Notice that these threshold limits define the boundaries of wrong and right and within these limits the mind energy is correct (constructive), this area is also defined by Aristotle as "*the midway of virtue*". A combination of these two models is shown in Figure 2, where the *absolute correct logic* balances precisely desire and anger, while the *acceptable as the correct logic* may be less or more than the balancing one of a small quantity (threshold value) of human error to be defined.

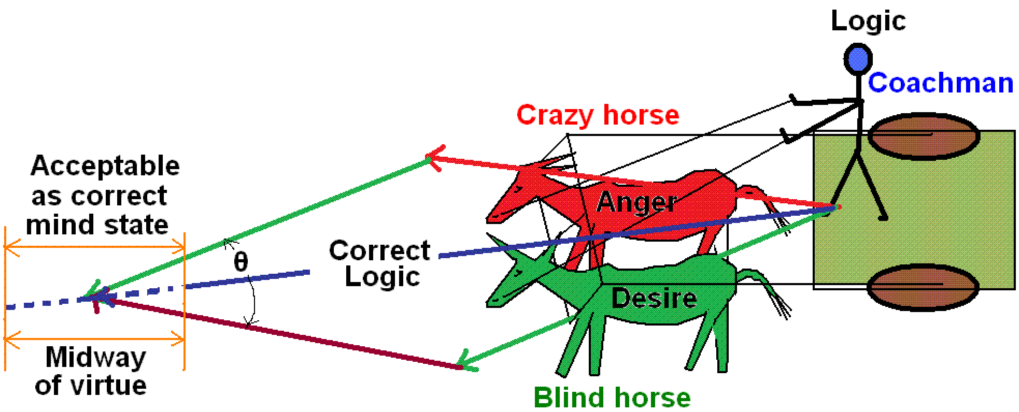


Figure 2. The absolute correct human mind state as defined by Plato, where the logic balances desire and anger and the acceptable correct human mind state as defined by the Aristotelian midway of virtue.

Summarizing the models describing the human mind performance, one may say that the mind space is composed of three axes (D, A, L) and of corresponding coordinates to describe any current mind state M_S(D, A, L). This state of the mind defines a new logic parameter named L_B which is the *absolutely correct logic* balancing D and A. Such balancing relationship may be expressed by the Pythagoras theorem as shown in Figure 1 (Hatzopoulos, J. N. 2009):

$$L_B^2 = D^2 + A^2 \qquad (2)$$

or as shown in Figure 2:

$$L_B^2 = D^2 + A^2 + D.A.\cos(\theta) \qquad (3)$$

Human error is mathematically expressed by Equation (1) and if it is within certain threshold limits defined by the Aristotelian midway of virtue, it is considered insignificant and the resulting action is being considered as *acceptably correct*, otherwise it is significant being considered as error. Any action is the result of a specific mind state and in such action correct and error coexist. Therefore, education may be defined as the effort to maintain human mind performance within specified error limits as defined by Aristotle's midway of virtue, thus being constructive concerning the quality of life of human society and working towards the scientific exploration.

Evaluation of describing models and definitions of the threshold limits

The best way to evaluate the described models is to study a simple human action as shown in Figure 3. Suppose someone, in a good physical condition, is trying to walk over an obstacle while walking in a flat terrain being necessary to raise the foot. There is an "*optimum*" or *the perfect height* to raise the foot, i.e., the average of all possible correct attempts. However, raising the foot a little higher or a little lower from the optimum height, the action is considered as being correct because in this range there is no false step. If the height of the foot is lower than the correct height (underestimation - deficiency), then there is a false step and the action may be considered error with negative sign (Figure 4). If the height of the foot is higher than the correct height (overestimation - excess), then there is a false step and the action may be considered error with a positive sign (Figure 4). The magnitude of the error varies from a temporary loss of balance and return to the right position, to a serious injury.

Therefore, if human error is to be quantified, it will take values from zero to minus infinity and from zero to plus infinity (see also Figure 4). The midway (mid-space) which is defined as "*correct*", is actually the error variance of the neuron structure (its specification performance) and it is quite similar to the "*midway of virtue*" as defined by Aristotle and is going to be studied bellow.

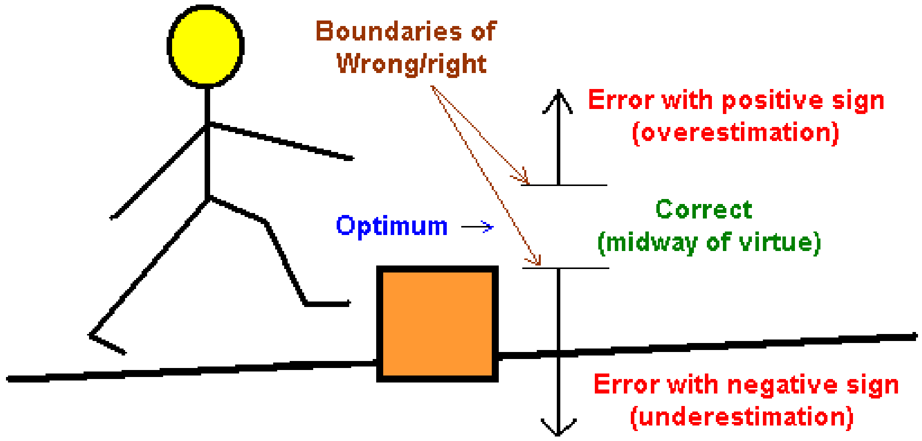


Figure 3. Evaluation of described models with clear definition of threshold limits of right and wrong.

Therefore, one may observe the following:

(a) *The boundaries of wrong and right* are quite clear and can be precisely defined.

(b) The function of a neuron network structure has the following characteristics:

   a. A non trained neuron structure (for example, a little kid) the first time that will try to pass the obstacle it is likely to have a false step.

   b. The next time that will try to pass the obstacle it is going to have a better performance, which means that the neuron based structure can be trained to improve its performance at any desirable level as approaching the optimum (Vasilakos C., et al, 2009).

(c) In the same action, wrong and right (error and correct) coexist and their boundaries are located at a point where the error value is below a threshold limit.

(d) Correct and error are quantities inverse proportional to each other which means that in an action with high error value the correct value is low and in an action with low error value the correct value is high.

(e) Let X be the error value and Y the correct value of a specific action, then the function which relates these two quantities is as follows (Hatzopoulos, J. N. 2009):

$$Y = 1/X \qquad (4)$$

(f) The mid-space of correctness (midway of virtue) shown in Figure 3, contains a diversity of correct actions which define the degrees of freedom or the options a person has for this specific action to pass over the obstacle. Although this mid-space looks to be small, it provides options of unlimited diversity and freedom.

(g) Options outside the error variance or mid-space of correct (see Figure 3) cannot be considered as diversity options or freedom options because they do not help to solve the problem which is to pass over the obstacle and on the contrary they introduce difficulties because they may cause a serious injury. Aristotle characterizes the outside the limits actions *slavery* and *prodigality* ("The Nikomachaean Ethics, B-7"). This means that freedom, as a human value, exists only within specific limits. For specific human actions democracy and democratic procedures are the ones they establish the limits of right and wrong (Gross R. E., Zeleny L. D., Editors 1958), but they succeed only if the voting citizens are educated with minimum bias concerning their vote.

(h) Options outside the error variance or mid-space of correct (see Figure 3) are damaging options and they denote uneducated neuron structure, or bias, or, deception in the effort to pass over the obstacle.

(i) Correct or midway of virtue performance may be considered as shown in Figure 4, the area between the limits X_L and X_R.

(j) Total performance of the human mind may be estimated by the diagram shown in Figure 4, where the Z-axis represents the sum of the population having average error X.

Considering Equation (4), and assuming as threshold limits X_L and X_R, which are the separating boundaries between correct and error as shown at (i) above, then Equation (4) on these two boundary limits must give the same value for X and Y (Hatzopoulos 2008 pp. 247), or X = Y, therefore, Equation (4) becomes:

$$X = 1/X \text{ or } X^2 = 1 \text{ and thus } X = \pm 1 \qquad (5)$$

Or,

$$X_L = -1 \text{ και } X_R = +1 \qquad (6)$$

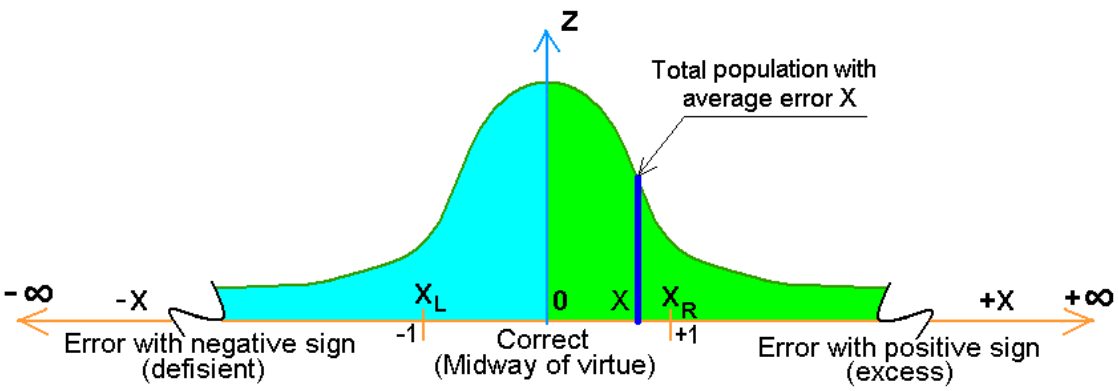


Figure 4. The error diagram of the ideal society showing the human error in the X – axis and corresponding total population averaging such error in the Z –axis.

Assuming that the distribution of human mind performance follows the standard normal distribution, then as shown in Figure 4, the 68.26% of total population must be within correct limits of 1-σ, where σ = ± 1. Also, 99.73% of the total population are within the limits of 3-σ, which is an error of small significance like illegal parking, or overworking, etc. Outside of 3-σ limits is the area of *the destructive power of human mind* and if this is not used for self defense, then it is a bias, or deception. The total destructive power of a group of people is shown in Figure 5, is the product of the number of people in the group E_i, by its bias of the group μ_i.

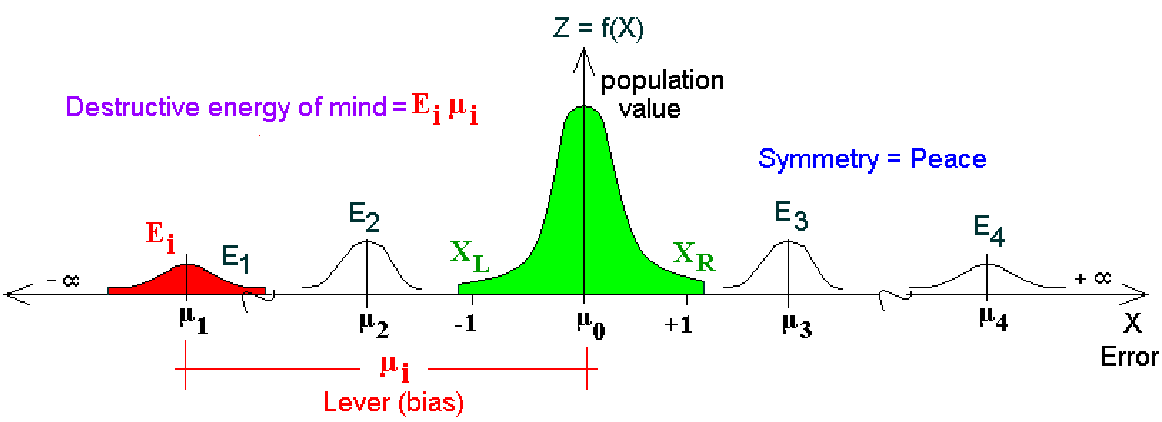


Figure 5. The situation of the real world with groups of people with biases $\mu_1, \mu_2, \ldots, \mu_n$

It is important to understand that the real world situation is as shown in Figure 5, with many social groups having biases indicated by their mean value of error performance μ_1, μ_2, …, μ_n. It is interesting that most groups of people advertize their biases, as, for example, political parties adopt official positions as left, center, or right and same thing happens with NGOs, etc. Therefore, education can help all such groups to maintain their cultural values and minimize their bias values. Since groups of people may have opposite biases, this may cause conflicts and wars among them and therefore *peace* is obtained if there is symmetry in Figure 5. Also *stable peace* is obtained if there is symmetry and the biases of groups of people are relatively small, otherwise *peace is unstable*. Peace must be one of the highest priorities in education and for this reason it is necessary to clearly understand the scientific bases that peace is found.

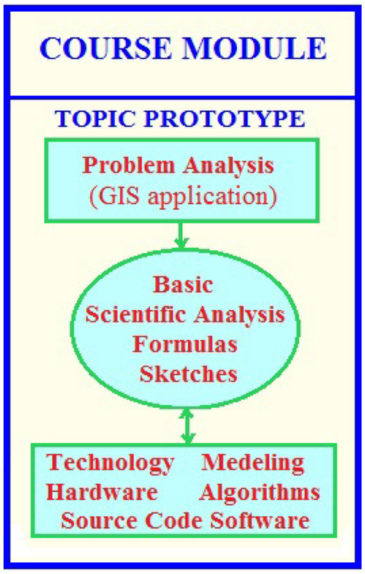
GIS education and curriculum development

The preceding analysis provides the philosophical bases of the engineering aspects of education in terms of modeling human error and its variance limits and paves the way to continue on the GIS engineering aspects of didactics in education.

There are several GIS applications related to teaching and research at the University of the Aegean Department of the Environment. Some of them are listed below:

1. Management of environmentally protected areas
2. Habitat management
3. Wetland management
4. Watershed and water resources management
5. Stream load
6. Air pollution management
7. Sea water quality
8. Land change and Land planning development
9. Regional planning and management
10. Urban development
11. Solid waste vehicle best route
12. Solid and liquid waste site selection
13. Solar energy planning and management
14. Wind mill energy planning and management
15. Oil fuel storage and oil energy plant management
16. Environmental risk assessment and management
17. Natural disasters monitoring and assessment
18. Environmental health spatial distribution
19. Earth science climate change
20. Global warming modeling

As stated in the Introduction the correct pedagogic process could adopt as an objective that *whoever is educated to use the computer as a tool, is always more intelligent than the machine*. Therefore, GIS mostly uses computer machines and software development is crucial for an efficient learning process.



As shown in Figure 6, a GIS application can be analyzed in its scientific bases, which lead to technology developments in terms of modeling, algorithm and software.

Since software is a time consuming process, then at undergraduate level software development may be left to be worked out by the instructor. However, at graduate level it is preferred that the students are the ones to develop the software. In either case software, especially in small independent modules, will validate the analysis of the scientific process by processing data and getting results. This advantage can be used to create motives without being necessary to go deeply into the scientific analysis, but provide just a summary with all kind of bibliographical and internet references, then run the software to validate the process and then go into more detail in the theory. This approach looks like a bottom up process and most of the time if motives are strong, it is not necessary to go back deeper into theory, instead, the students go themselves without asking them to do so and the lecture is occupied by questions and answers.

Figure 6. A course module of a GIS application to include topic prototype with problem scientific analysis and implementation through technology developments in terms of modeling, algorithm and software.

In Figure 7 shows the basic scientific process analysis, which is supported by the unlimited depth of existing knowledge. This knowledge is rather *static* based on math and physics and can be found in libraries of books and scientific articles and on-line internet support. In Figure 8 is shown the basic technological process to obtain modeling and an algorithm and transform the algorithm into the software. Technological process is a more dynamic process changing with time as the basic hardware and corresponding software is changing. Technological process is also based on the dynamic evolution of the scientific basis as they evolve through the research and development. In other words, scientific evolution depends on the technology evolution and vice versa technology evolution is based on scientific achievements.

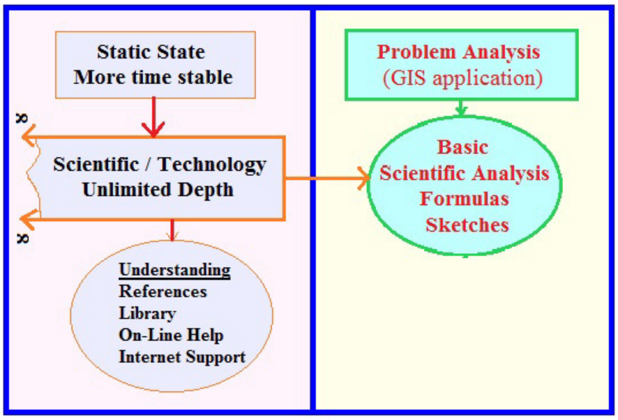


Figure 7. Basic scientific analysis process.

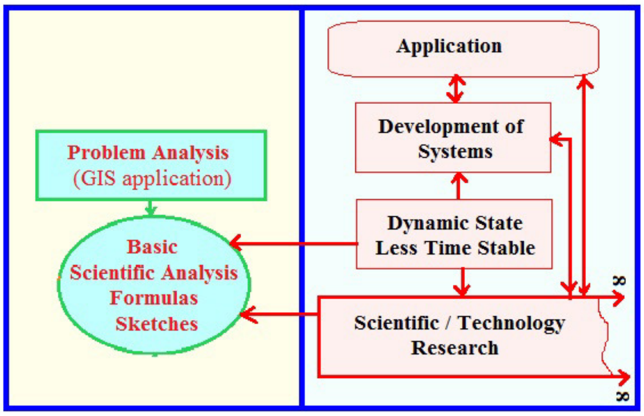


Figure 8. Basic technological analysis process

In Figure 9 shows the time and the learning diagram for educated students and professionals, where learning starts with detail explanation about education based on the mind models developed in this work, with emphasis on the Aristotelian midway of virtue and Plato's balancing state. Then didactics are applied as analyzed in Figures 6, 7, 8 using presentation material, lab assignments and appropriate testing.

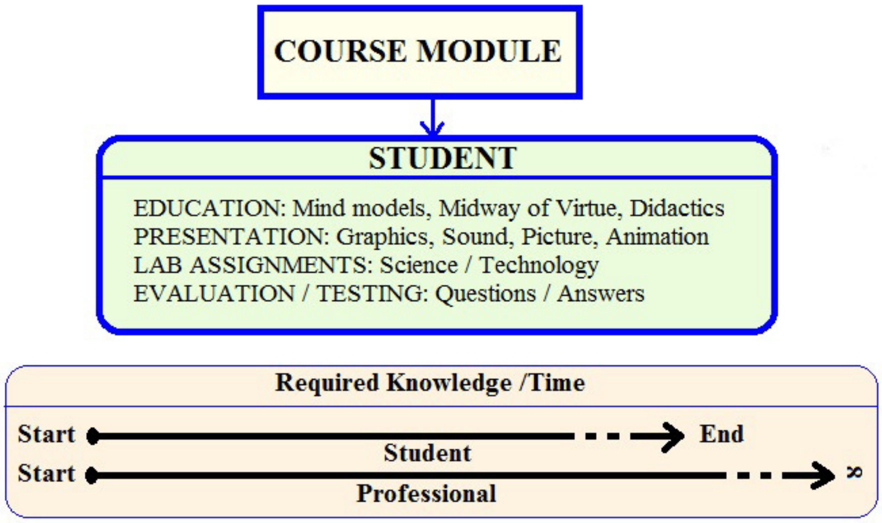


Figure 9. Time and learning diagram for educated students and professionals.

As shown in Figure 9, a student and a professional start the learning process about the same time, the difference being the time ending process which for the student is over at the end of the course, while for the professional it never ends.

An example from the Laboratory of Remote Sensing and GIS at the University of the Aegean.

There will be developed just one topic from a course named *Topographic Mapping and GIS* and from a part of the course called *Digital Elevation Models* (Hatzopoulos J. N. 2008).

The topic involves the interpolation process to produce elevations inside a grid cell using the bilinear function, which is defined by the elevations at the four nodes of the cell.

(a) Mathematical analysis (time stable math analysis)

A bilinear function is completely defined by knowing the elevations at the four nodes of a grid cell and is in effect only inside this cell. Let us assume a grid cell as shown in Figure 10 and Z(i, j), Z(i, j+1), Z(i+1, j), Z(i+1, j+1) are the elevations at corresponding four grid nodes that define this cell, then the elevation Z of point (u, v) found within the cell is given by the bilinear Equation (8) which is derived from Equation (7) as shown bellow. Notice that a local (within the cell) coordinate system (u, v) is established with origin the lower left cell node.

The bilinear function is given by the following relation:

$$Z(u,v) = \begin{bmatrix} 1 & u \end{bmatrix} . \begin{bmatrix} a_{00} & a_{01} \\ a_{10} & a_{11} \end{bmatrix} . \begin{bmatrix} 1 \\ v \end{bmatrix} \quad (7)$$

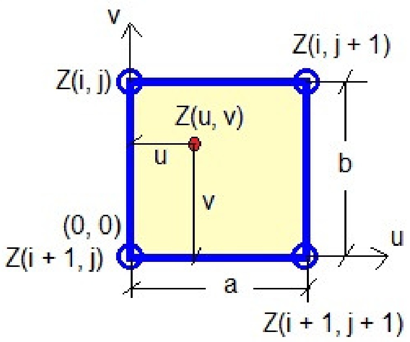


Figure 10. A rectangular cell represented by a bilinear interpolation function defined from the four elevations at corresponding cell nodes.

Based on Figure 10, the coefficients a_{00}, a_{10}, a_{01}, a_{11} are computed in the following steps:

The Equation (7) is developed as: $Z(u, v) = a_{00} + a_{10}.u + a_{01}.v + a_{11}.u.v$

Substituting $u = v = 0$ for node $(i + 1, j)$, then $a_{00} = Z_{(i+1, j)}$,

Substituting $u = a, v = 0$ for node $(i + 1, j + 1)$, then $a_{00} + a_{10}.u = Z_{(i+1, j+1)}$ and a_{10} is computed

Substituting $u = 0, v = b$ for node (i, j), then $a_{00} + a_{01}.v = Z_{(i, j)}$ and a_{01} is computed

Substituting $u = a, v = b$ for the node $(i, j+1)$, then a_{11} is computed

Therefore, the analytical form of the bilinear equation is given bellow:

$$Z(u,v) = \left(1 - \frac{u}{a} - \frac{v}{b} + \frac{u.v}{a.b}\right).Z_{(i+1,j)} + \left(\frac{u}{a} - \frac{u.v}{a.b}\right).Z_{(i+1,j+1)} + \left(\frac{v}{b} - \frac{u.v}{a.b}\right).Z_{(i,j)} + \left(\frac{u.v}{a.b}\right).Z_{(i,j+1)} \quad (8)$$

(b) Technological process and resulting algorithm (less time stable process)

Consider the following chain of numbers, which represent the grid form of a DEM. The first line is a header composed of three pairs of elements with very important information. The first pair indicates the rows and columns of the DEM, 27- rows, 31- columns. The second pair indicates the coordinates X, Y of the North West node of the DEM (the first node), $X_{NW} = 1025$, $Y_{NW} = 1185$. The last pair indicates the grid dimensions, a = 10, b = 10.

Following the header are the elevations at the grid nodes, 31 such elevations for each grid line. Therefore, there are 27x31 = 837 elevations in the list.

27,31,1025,1185,10,10
158.4 156.0 155.0 153.0 151.8 147.0 142.3 138.0 133.8 129.0 125.0 124.1 123.0 122.0 120.0 119.0 119.0 119.0 118.0 117.0 116.0 115.0 114.0 113.0 112.5 112.0 111.5 111.0 110.5 110.0 110.0 162.5 161.9 160.8 159.8 157.0 153.5 148.5 144.0 140.5 135.0 129.2 **125.5** 124.0 122.5 121.0 120.0, …
……………………………………………………….

Considering that all above numbers, compose a continuous chain in a file stored on a computer disk, the software to be developed must be able to locate the coordinates and the elevation of a node given its row and column. For example the elevation of the second row and 12th column is 125.5, its location in the file is 6 + 31 + 12 = 49 and it is called *offset* computed as:

$$offset = h + (m - 1).i + j \qquad (9)$$

where h is the number of header elements, m is the total number of columns in the grid, i is the row of the grid node and j is the column of the grid node. Therefore the coordinates of node (i, j) are computed as follows:

$$X_{i,j} = X_0 + (j - 1).a$$
$$Y_{i,j} = Y_0 - (i - 1).b \qquad (10)$$

Where i is the row number of the grid node, j is the column number of the grid node, a is the grid cell dimension in X-direction, b is the grid cell dimension in Y-direction, $X_{i,j}$ is the X-coordinate of node (i, j), $Y_{i,j}$ is the Y-coordinate of node (i, j), X_o is the X-coordinate of node (1, 1), Y_o is the Y-coordinate of node (1, 1).

According to Equations (10) the coordinates of node (2,12) are:
X=1025+(12–1)x10=1135, Y=1185-(2-1)x10=1175

If it is given the cell row and column (I, j) and the coordinates (u, v) inside the cell, then the elevation value within this grid cell can be interpolated. As shown in Figure 10 and according to Equations (9) and (10), the (X, Y, Z) coordinates of the four grid nodes can be determined. Also, the elevation at the (u, v) location inside the cell can be interpolated using Equation (8) and therefore, the (X, Y, Z) coordinates at any point within a grid cell are determined.

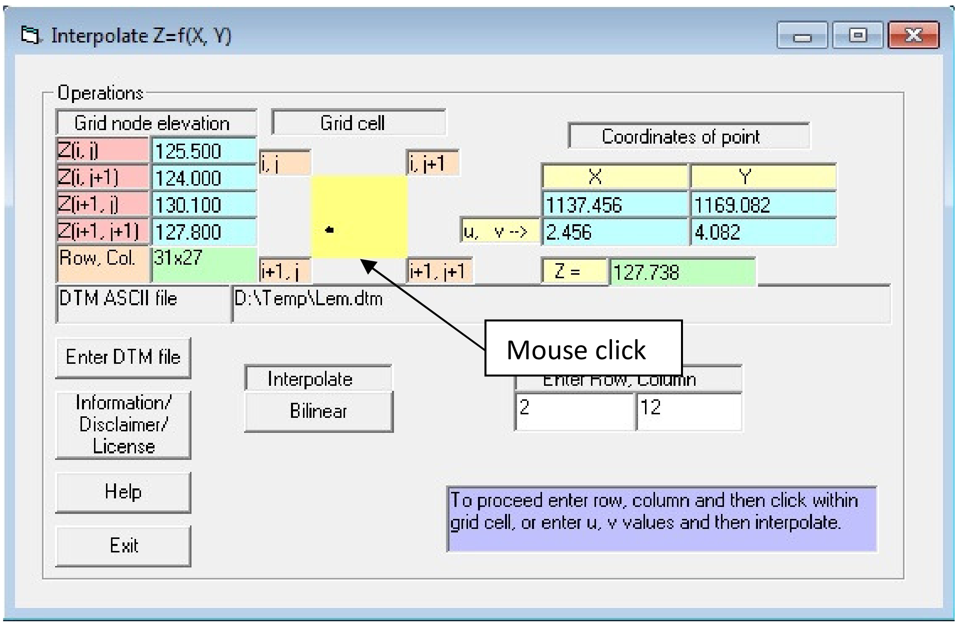


Figure 11. A mouse click within the yellow box will provide the X, Y, Z and u, v coordinates

The algorithm described above, was converted into an educational computer program named *ZeqFxy_Jnh.exe* and can be downloaded from the link:

http://www.env.aegean.gr/labs/Remote_sensing/EnglishBlock/Software/ZeqFxy_Jnh.rar

The form layout of this program is given in Figure 11, where a DEM (DTM) filename must be entered first, then the row and column of any desirable node in the DEM must be entered. If entering u, v values of corresponding spaces, then by pressing the button "Bilinear" the bilinear interpolation is activated and the elevation at location u, v is computed.

Another way to get the elevation inside the cell is by clicking the left mouse button inside the yellow colored cell area, then the X, Y, Z and u, v coordinates are displayed. In the upper left area of the form are also displayed the elevations at the four nodes in the cell together with the total DEM rows and columns.

Math, software and technology issues

Most GIS applications use math and software and it is necessary to talk about the difficulties most people are facing and how to help to overcome it. Problems in math and software have to do with inadequate background in these areas. On the other hand, these are areas with many supporting tutoring works and facilities, but most important is the attitude of the teacher and consequently the student. Excellent mathematicians are usually bad teachers because their attitude about math is that it is *an entity with extraordinary attributes*, so they go deeply into theory, which is good for doing research to advance mathematical science, but most students are lost. This happens because good mathematicians usually like theory and they do not like practical applications. The proper didactics in mathematics, as stated by Noss R., & C. Hoyles 2007, must involve practical applications of everyday examples. In addition, the attitude of the instructor and consequently of the student must be that "*mathematics is the best tool of mind to solve complicated problems*". It must be clear by the instructor that complicated problems are not directly understood by the human mind, therefore, mathematics are used as a tool to analyze into simple understandable elements using proper symbology and formulation to obtain solution. However, to do this it is necessary to have case studies of many examples and GIS applications have many of them.

Software development has a common feature with the math, that is, the analysis of a problem into simple steps understandable by the machine and again complicated processes can be analyzed into simple steps and programmed into computers. Computer programming therefore, could facilitate to run complicated problems and as stated earlier, could create motives for further studying math and science and implement such studies by developing simple software to prove that problem solution works. This is actually the proper effort to develop the attitude that the educated one is smarter than the machine.

Another important issue about software is the increased use of open source GIS systems and related programming languages which usually are platform independent. This fact is an additional supporting argument to help people as early as possible to learn developing software. The open source programming has the great advantage of using unlimited number of software libraries, or improving existent ones, or creating new ones, which provides availability for all kinds of functions.

The inadequacy problem in math and software developments must be partially transferred into the junior/senior high school level and part in the general education courses at the college level.

Conclusions

Education is quite different than didactics and knowledge, it is the effort to maintain human mind performance within specified error limits as defined by Aristotle's midway of virtue, it is the effort to develop a balanced mind so that its logic part maintains a balance between the other two parts namely the desire and anger. The absolute such balance together with a variance factor establish the specification limits for the engineering of GIS education. In this respect, educators must be at first palace philosophers using math and science to work out philosophical structures and on a second place to apply such philosophy on research and teaching GIS applications.

GIS education involves computer systems of hardware and software under constant development with hardware going into the recycling process over a relatively short period of time, while the software is always there as an immortal entity in a latent state and therefore, it is gradually built up improving itself by implementing science and technology, information and knowledge. The engineering aspects of proper GIS education involve specifications to implement application modules using educational software developed by the instructor and the students, necessary to help creating an attitude where most people involved in the process has become smarter than the machine. This process creates motives to better understand science and go deeper into the theoretical aspects of GIS applications.

Information science and mathematics provide the necessary tools to improve didactics, for this reason general education starting from high school must provide the necessary background so that at the college level are used efficiently to improve didactics. Therefore, math instructors must develop application case studies of related problems (GIS) to create motives and teach mathematics, thus avoiding direct abstract theories, but creating though motives to support the scientific theoretical background. The same process is appropriate for GIS education, especially by giving emphasis on software development, which also prepares the next generation to have more active participation in the open source application developed.

Since technology evolves at high speeds, instructors must be standing up, if possible, at the edge of such developments and use them to increase research and teaching efficiency. Most people in the applications who are using GIS sometimes face the problem that students are more advanced concerning technology issues. In such a case the ones they are following technology developments must provide all kinds of options such as Internet tutorials, webinars, seminars and other facilities to help these people.

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