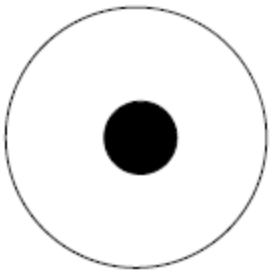

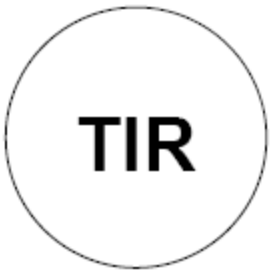

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Table of Contents:

Pearls of Wisdom by the Honorary Doctor of Belgrade University:

Interview
Fujii, Hironori 2

Space Experiment of Bare Tape-Tether Technology on the Sounding Rocket S520 the 25th
Fujii, Hironori 4

Invited Papers:

The Xmath ODE Algorithm
Bringslid, Odd 6

Information Content of Process Signals in Quality Control
Jović, Franjo; Krmpotić, Darko; Jović, Alan; Hocenski, Verica; Slavek, Ninoslav 10

Upgrading Generator Scripting Model by Object Model Properties
Radošević, Danijel; Kliček, Božidar; Kozina, Melita 17

How to Ruin the Career of a Ph.D. Student in Computer Science and Engineering: Precise Guidelines
Milutinović, Veljko; Tomažič, Sašo 24

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Department of Computer Engineering **IPSI BgD Internet Research Society** **University of Belgrade** **POB 35-54** **Belgrade, Serbia** **Tel: (381) 64-1389281**	**Department of Computer Engineering** **IPSI BgD Internet Research Society** **University of Belgrade** **POB 35-54** **Belgrade, Serbia** **Tel: (381) 64-2956756**
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Interview: "Human Activities in Space"

Fujii, Hironori

1. *What is the essence of the contribution for which you received the Prize in Belgrade?*

The essence of the contribution is feeding engineering realization for human activities in space around 2040. Space tether technology is being studied including space rocket experiment through international campaigns.

2. *What are the impacts of this contribution?*

The contribution will give engineering vilification for the vision including the space solar power satellite (SSPS) with dimension of several km and the space elevator (SE) with length 100,000km.

3. *What are the applications of your contribution that may change the everyday life?*

The SSPS will be beneficial to the all creatures including human on the earth and the space elevator SE will provide a facility to utilize a convenient method of space exploitation.

4. *Can you shed more light on the last answer?*

We can save the earth environment by using perpetual natural solar energy employing SSPS and we can easily construct such big space structures as SSPS by employing SE and thus without using chemical rocket. These facilities in space will bring us a plenty of benefits of space.

5. *We learned a lot from your lectures in L Aquila. Can you tell us, what are the issues that we have to teach our kids, so they become creative when they finish studies?*

Thank you. Space has been always the object of human dream every day/night when we look up at the sky and a lot of imaginations has introduced to every person including young and old in every nation. Applications of these technologies will also serve them to make true of their adventurous dream.

6. *What are the major things to keep in mind, when you form a team for a scientific experiment, or similar?*

Strong motivation is necessary to be consistent with much expectation for good future. It is a principle to have one character in every team of project to include one person who is not serious even in the worst case, i.e., to keep humor in mind every time is necessary.

7. *What are the people to avoid, when trying to generate a break-through achievement?*

To lose poem in mind.

8. *What is your opinion about the impact of math?*

Math is going to be very easy as the result of great advance in computer technology but we must be patient to study it although growing too much to study.

9. *When targeting a major breakthrough, how sensitive one has to be about the direct interests of tax-payers?*

Old days King was one and now every people is a king.

10. *What is the major driving force that motivates a person like you to continue to create and generate results after he-she receives such a big prize?*

Respect to nature.

11. *For small nations like Serbian, what is your advice, which road to take, when it comes to science?*

I believe Serbian people as any other nationality can sustain abilities to be patient in studying basic elemental scientific effort. There contribution will be much important to take advantage of smart brains in communication with other nations sustaining advanced hard-ware and systems.

12. *What road to take, when it comes to its general future development plans?*

International friendship to take advantage of ones abilities with help of others for disadvantages.

13. *Major impression about Serbian scientists that you met abroad?*

Smart and friendly atmospheres which are most important to achieve big jobs.

14. *Major impressions from your visits to Serbia?*

Expectation for future contribution with excellent historical accumulations.

15. *Major impression about the University of Belgrade?*

Excellency in preserving the academic traditional…

Space Experiment of Bare Tape-Tether Technology on the Sounding Rocket S520 the 25th

By Hironori A. FUJII[1),2)], Takeo WATANABE[3)], Tairo KUSAGAYA[2)], Hirohisa KOJIMA[3)], Koh-Ichiro OYAMA[4)], Susumu SASAKI[4)], Kohji TANAKA[4)], Takumi Abe[4)], Manabu SHIMOYAMA[4)], Yoshiki YAMAGIWA[5)], Hirotaka OHTSU[5)], Mengu CHO[6)], Koki KASHIHARA[6)], Toru HADA[7)], Juan R. Sanmartin[8)], M. Charro[8)], Alain Hilgers[9)], Jean-Pierre Lebreton[9)], Erick J. van der Heide[10)], Michiel Kruijff[10)], Fabio De Pascale[10)], John Williams[11)], Binyamin Rubin[11)], Charles Les Johnson[12)], George V. Khazanov[12)], and Pavel M. Trivailo[13)]

Keywords - *Sounding Rocket, Tether technology, Space experiment, Hollow cathode*

Two projects are introduced to verify the performance of space tether technology. The sounding rocket S520 the 25th will be launched on the summer of 2009 to deploy a bare electro-dynamic tape tether with length 300m. The other project to verify the space tether technology is a small satellite to deploy bare electro-dynamic tape tether with 25km in length and is expected to be launched on 2013. These verifications of tether technology will lead a large numbers of applications of space tether technology. The space tether technology is indispensable in constructing and also maintaining large space structures, which are designed for future space development including the solar power satellite and deep space exploitation.

A verification of tether technology will be conducted on a sounding rocket, S520-25 to be launched on August of 2009 by ISAS/JAXA. The object of the projects is to verify the bare electro-dynamic space tether technology, which is believed to be useful in our future space development from both of the scientific and engineering aspects. The tether will be deployed in its length through 300m in a few minutes (Fig.1).

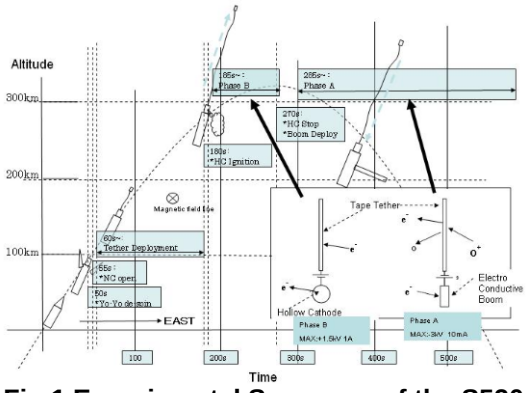


Fig.1 Experimental Sequence of the S520-25

[1)]*Kanagawa Institute of Technology/Nihon University, Japan,* [2)]*TMIT & Co., Ltd, Japan;* [3)]*Tokyo Metropolitan University, Japan;* [4)] *ISAS/JAXA, Japan,* [5)] *Shizuoka University, Japan;* [6)]*Kyusyu Institute of Technology, Japan;* [7)]*Kyusyu University, Japan;* [8)]*Unversidad Politecnica de Madrid;* [9)]*ESA, Europe;* [10)]*Dealta-Utec,SRC, Netherlands;* [11)]*Cololado State University, USA;* [12)]*NASA/MSFC, USA,* [13)]*Royal Melbourne Institute of Technology, Australia.*

The two object studied in this proposal are apparently two major indispensable technologies both in the scientific and engineering aspects and will play important roles in the course of the space development. The present proposal is to verify the fundamental technology for such important tether technology as deployment and use of bare conductive tether in space. The other of the two objectives of the present proposal is the scientific study to incorporate the conductive tether by employing an Aluminum bare tape tether. A conductive tether opens unique opportunities for science that are not limited to testing OML collection under orbital conditions and generating convenient electron beams. The project is a European/ American/ Australian/ Japanese International Sun-Tower Campaign.

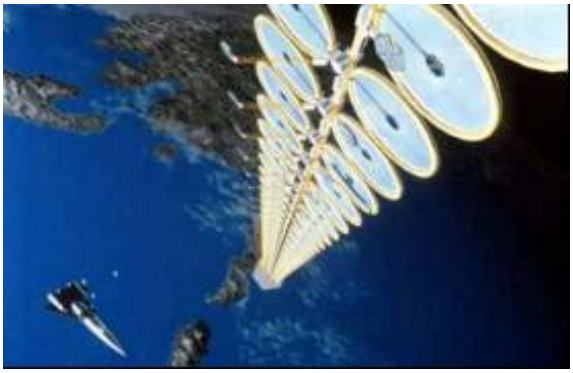


Fig.2 Solar power satellite

The sounding rocket experiment could be extended to a low cost LEO mission of a small satellite with an electro-dynamic tether. These demonstrations will extend many useful methods of employment of the bare electro-dynamic tether including engine to increase/decrease orbit, supplier of electricity, spring-shot, and lifter for payloads. The objective is to verify the two fundamental and important aspects of the tether technology: One is the orbit elevation without using fuel, and the other is the Alfven wave experiment. A tether could generate controllable nonlinear Alfven wave fronts in space that are of interest as regards fronts of the solar wind with Earth, Jupiter, or comets. In the engineering mission, thrust or drag could be applied by the electro-dynamic tether on space structures without using fuel mass and the orbit elevation without any fuel is an object of interest for persons in the space Institutions.

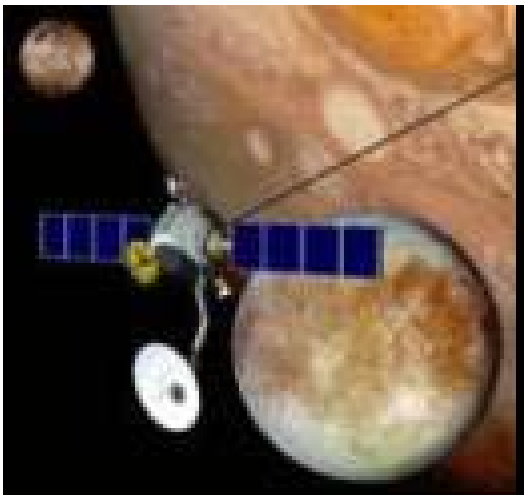


Fig.3 lunch free tour satellites

The drivers for the electro-dynamic tether underlie in the low cost, simple mission concept, and fast realization possibility. The application includes a number of interesting and useful operation of space tether technology including, elevation of orbit of the International Space Station without consuming fuel and the solar power satellite (Fig.2). The demonstration will also be very effective to examine the possibility of the rotating electro-dynamic tether to Jupiter mission application to enable simple entry into the atmosphere of the Jupiter, or lunch free tour to Saturn satellites (Fig.3). It may be noted that de-orbiting of defunct satellites is indispensable for our future space to reduce the numbers of debris indicating one of the commercial applications. These demonstrations will extend many useful employment of the bare electro-dynamic tether. The success of two international campaigns by Europe, United States, Australia and Japan on space tether experimental projects presented will bring new era of the electro-dynamic tether technology to a number of useful space applications in our near future.

The Xmath ODE algorithm

Bringslid, Odd

Abstract—*The Xmath eBook is being developed and algorithms into a wide range of undergraduate mathematical issues embeded in Mathematica packages are available on the web using the system webMathematica. The main purpose is to visualize mathematics in the same way as would a professor do it on the blackboard stating all intermediate steps for user defined input and then presenting solutions being easily recognized by the undegraduate student which may not always be the case using the Mathematica system directly. In this way the student may work more on a personal basis, viewing one step at a time in the solving process and then being less dependent of the professors. In this paper the Xmath algorithms for solving Ordinary Differential Equations step-by-step are presented (ODE Steplet).*

Index Terms— *Ordinary Differential Equation (ODE), Steplet, Mathematica packages, Online calculations, Pedagogical value*

1. INTRODCTION

The use of *Mathematica* [1] in education is one of the most important areas of application. The problem however is that in education we are focusing on how problems are solved perhaps more than on the final result. Since *Mathematica* only gives the final result it will be necessary to build an application on top of *Mathematica* giving intermediate results using the methods of solving given by mathematical textbooks. It is necessary to analyze the equations in depth, Xmath then using the *Mathematica* object TreeForm to be able to extract the information needed at each level of the solution process. The algorithm is different from the algorithm used by the developers of the *Mathematica* System (DSolve).

The Xmath algorithm will solve problems typical in mathematical teaching. Linear first and second order ODE, separable equations and suitable substitutions are implemented to make some equations important in education separable, the reduction to linear form for non-linear 1st order ODE is implemented and of course exact differential equations. The main purpose is not to do the algorithm as general as possible like DSolve but to track the solving process in detail to be easily recognized by the students for most problems in particular undergraduate education.

Manuscript received March 17, 2009. Author, assoc. prof. Odd Bringslid is with the Institute of technology, Buskerud University College, Norway

2. PEDAGOGICAL VALUE

The pedagogical value of the Xmath algorithms lies in the fact that a student may simulate solving by changing parameters and type of equation. In my own class last year the students had to solve linear second order ODE with constant coefficients for different values of parameters. This was a success. The important thing is that Xmath solves the equations as would a professor do it on the blackboard then easily being recognized by the students which is not the case using the *Mathematica* system directly [2].

3. ORDINARY DIFFERENTIAL EQUATIONS (ODE)

ODE's are differential equations in one free variable not including partial derivatives [3]. Given the differential equation

$$(1) \quad y''+3y'=3\cosh(x)$$

The equation may be solved by *Mathematica* using the built in objects DSolve and FullSimplify, the ouput being visually different from the output given by the Xmath algorithm. Xmath will also give all intermediate solutions and the methods for finding them. The Xmath algorithm will give an answer more in line with standard textbooks and blackboard teaching easily recognizing the homogenous and particular parts. Solution given by Xmath:

$$(2) \quad y(x)=c_1+c_2e^{-3x}-\frac{1}{2}xe^{-3x}+\frac{1}{12}e^{3x}$$

4. SECOND ORDER LINEAR ODE WITH CONSTANT COEFFICIENTS

Second order equations with constant coefficients are given in the general form [4]

$$(3) \quad ay''+by'+cy=f(x)$$

The eqaution is broken down for analyzing by using the *Mathematica* object TreeForm with 3 levels. The *Mathematica* object FreeQ is used to verify independence of the free variable and this gives the pseudocode for the homogenous part y_H.

```
k=Reverse[Level[TreeForm[ay''+by'+cy==0],3]];
a=k[[4]]/y'';b=k[[5]]/y';c=k[[6]]/y;
If [FreeQ[a,x]&&FreeQ[b,x]&&FreeQ[c,x],
        solvlist=Solve[c+bλ+aλ^2==0];
        (* 4 cases*)
        Which[a===0,yH=C[1] E^(λx),
                b^2-4ac>0, yH=C[1]*E^(λ1x)+C[2]*E^(λ2 x),
                b^2-4ac<0,
yH=E^(Re[λx](C[1]Sin[Im[λ]x]+C[2]Cos[Im[λ]x])
        (*end Which*)]
] (*end If*)
```

Figure 1 PseudoCode Homogenous part

The particular solution y_P of (3) is found by choosing a trial solution in accordance with the right hand side f(x). The built in *Mathematica* Object PolynomialQ is used and further the Xmath Objects ExpQ , ExpPolyQ , TrigQ, TrigPolyQ, TrigExpQ and TrigExpPolyQ . The trial solution will be multiplied with x or x^2 if parts of y_P are common with parts of the homogenous solution y_H. The algorithm for finding y_P is also using the *Mathematica* objects AppendTo, Expand , CoefficientList and the general method Undetermined Coefficients developed in Xmath. The built in *Mathematica* object ReplaceAll (/.) is also used.

```
k=Reverse[Level[TreeForm[ay''+by'+cy==f[x]],3]];
If[Different,kP={function1,function2,..},kP={rhs}];
(*Different gives TRUE for a sum of different kinds of functions
composing rhs, right hand side*)
yPtotal=0;
Do[
        Which[PolynomialQ[kP[[i]],x],yP=∑x^i Ai,
                ExpQ[kP[[i]],x],yP=E^(αx)A[1],
                ExpPolyQ[kP[[i]],x],yP=E^(αx)∑ x^i Ai,
                TrigQ[kP[[i]],x],yP=A[1]Sin[βx]+A[2]Cos[βx],
                TrigPolyQ[kP[[i]],x],yP=Sin[βx] ∑ x^i Ai
+Cos[βx] ∑x^i Bi,
                TrigExpPolyQ[kP[[i]],x],yP= E^(αx) Sin[βx] ∑
x^i Ai +
                        E^(αx) Cos[βx] ∑x^i Bi,
                Head[rhs]==Sec, Using variation of
parameters,
                (* Csc,,Tan and Cot accordingly*)
        (*end Which*) ]
(*using undetermined coefficients  to determine A[i]*)
unknowns=A[i]; SortyP=0;eqnList={};
eq=eq/.{y''->D[D[yP,x],x],y'->D[yP,x],y->yP};
Do[AppendTo[eqnlist,CoefficientList[eq[[j]]==0];
          SortYp≡0;          (*identical powers of x*)
          solvlist=Solve[eqnlist,unknowns];
          yP=Expand[yP/.solvlist;
          yPtotal=yPtotal+yP,{I,1,Length[kP]}] (*end Do*)
y[x]=yH+Yptotal;
```

Figure 2 PseudoCode Particular part

5. SEPARABLE EQUATIONS

A general first order equation is given as

$$(4) \quad h(y, y', x) = 0$$

Xmath solves first order separable equations [5] which might be written in the form

$$(5) \quad y' = \frac{g(x)}{f(y)}$$

Some equations which are not separable may be transformed to a separable equation by using a suitable substitution. These kinds of equations are in Xmath called pseudo separable equations and the substitution implemented is y→xy giving

$$(6) \quad h(y, y', x) = 0 /. \{y \to xy, y' \to y + xy'\}$$

Using the built in *Mathematica* object Integrate and the Xmath object xSeparate we may solve equation (5).

```
solvlist=Solve[h[y.y',x]==0,{y'}]; (*y'→p[x,y]*)
(*separating x and y expressions*)
g[x]=xSeparate[p[x,y],x]; f[y]=1/xSeparate[p[x,y],y];
If[p[x,y]===g[x]/f[y],
          y[x]=Solve[Integrate[f[y],y]==Integrate[g[x],x],y];
          If[substitution,y→xy,y], Not separable
] (*end If*)
```

Figure 3 PseudoCode Separable equation

6. INTEGRATING FACTOR

This method applies to linear 1st order equations but the coefficients need not to be constants [6]. The eqautions is given as

$$(7) \quad y \cdot p(x) + y' = r(x)$$

If p(x)=0 or r(x)=0 the equation is separabel. Xmath will reorganize (7) as ay'+by+c=0 and TreeForm is used to break the equation down.
The method for solving (7) defines a new function v(x) by

$$(8) \quad y(x) = e^{-\int p(x)dx} v(x)$$

The solution is given by

$$(9\ ) \quad y(x) = e^{-\int p(x)dx} \int e^{\int p(x)dx} r(x)dx$$

```
k=Reverse[Level[TreeForm[ay'+by+c==0],3]];
a=k[[4]]/y'; b=k[[5]]/y;c=k[[6]];
p[x]=b/a;r[x]=-c/a;
IntFactor=Integrate[E^(-p[x])],x;
Solve[IntFactor*v'[x]==r[x],v'[x]];
v[x]=Integrate[v'[x],x];
y[x]=Intfactor*v[x];
```

Figure 4 PseudoCode Integrating factor

7. REDUCTION TO LINEAR FORM

Given a non-linear equation of the form, a any real number

$$(10) \quad y \cdot P(x) + y' = y^a Q(x)$$

The equation is called a Bernoulli equation [7] and may be reduced to linear form by using the substitution $u=y^{1-a}$, effectively

$$(11) \quad y \to y^{\frac{1}{1-a}},\ y' \to \frac{y^{\frac{1}{1-a}-1} y'}{1-a}$$

This will give the linear equation

$$(12) \quad (1-a) \cdot y \cdot P(x) + y' = (1-a)Q(x)$$

Equation (12) is of the form (7) and may be solved using integrating factor, substituting back

$$(13) \quad y = y /. \{y \to y^{\frac{1}{1-a}}\}$$

8. EXACT DIFFERENTIAL EQUATIONS

This method applies to equations of the form [8]

$$(14) \quad M(x,y) + N(x,y) \cdot y' = 0$$

The exact (total) differential of a function u(x,y) is given by

$$(15) \quad du = \frac{\partial u}{\partial x} dx + \frac{\partial u}{\partial y} dy$$

Applying (14) this gives

$$(16) \quad du = M(x,y)dx + N(x,y)dy = 0$$

The implicit solution of (16) is u(x,y)=constant and the problem will then be to find u(x,y). We then have

$$(17) \quad \frac{\partial^2 u}{\partial x \partial y} = \frac{\partial^2 u}{\partial y \partial x} \Rightarrow \frac{\partial M}{\partial y} = \frac{\partial N}{\partial x}$$

```
k=Reverse[Level[TreeForm[M(x,y)+N(x,y)*y'==0],3]];
M[x,y]=k[[5]]; N[x,y]=k[[4]]/y';
If [        D[M[x,y],y]===D[N[x,y],x],
            u[x,y]=Integrate[M[x,y],x]+f[y] (*integration constant*)
            f ' [y]=Solve[D[u[x,y],y]==N[x,y],f'[y]];
            f[y]=Integrate[f ' [y],y];
            (*u[x,y]=c, constant,du=0*)
            y[x]=Solve[u[x,y]==c,y],
            (*else*) "Not exact"
] (*end If*)
```

Figure 5 PseudoCode Exact Equations

9. VARIATION OF PARAMETERS

The method variation of parameters [9] applies to liner second order equations and the coefficients need not to be constant. Xmath however will only solve equations with constant coefficients and use variation of parameters in the case where no trial solution is available, f.x in (3), f(x) = sec(x). For solving using variation of parameters, (3) has to be rewritten

$$(18) \quad \frac{cy}{a} + \frac{by}{a} + y'' = \frac{f(x)}{a} = r(x)$$

The homogenous solution is given by $y_H = c_1 y_1 + c_2 y_2$ and we define the Wronskian as $W = -y_2 y_1' + y_1 y_2'$ giving the particular solution

$$(19) \quad y_p = \int \frac{y_1 r(x)}{W} dx \cdot y_2 - \int \frac{y_2 r(x)}{W} dx \cdot y_1$$

The integrations may give complicated results or no results at all especially when the coefficients are not constants (not implemented in Xmath). Equations which theoretically may be solved by this method will often have to be solved using numerical methods implemented in the *Mathematica* object NDSolve.

```
y[1]=yH[1]/.C[1]->1;
y[2]=yH[2]/.C[2]->1;
W=-y[2]*y[1]'+y[1]*y[2]';
r[x]=rhs/a;
yP=-y[1]*Integrate[y[2]*r[x]/W,x]+
y[2]*Integrate[y[1]r[x]/W,x]//Simplify;
y[x]=yH+yP;
```

Figure 6 PseudoCode Variation of Parameters

10. ODE INITIAL VALUE PROBELMS

For second order equations we need to know the values of y(x) and y'(x) for a given value of x (x0). The constants C[i] may then be found. For 1st order the value of y(x) at a given value of x is sufficient. If infinite values appear or if C[i] cannot be found for other reasons a meassage is given and the initial values have to be changed.

11. EXAMPLE

The Xmath algorithms may solve an arbitary ODE problem in the areas implemented or give a message that Xmath cannot solve the problem in question. In this case calling for the *Mathematica* solution based on generic kinds of algorithms only giving the final answer.

Solve the equation

$$x^3+3y^2x+(y^3+3x^2y)\cdot y'=0$$

Task 1

Type of equation

First order, includes y'(x) as highest derivative
Substitution: y→x y gives separable equation
This gives: y'→(xy)' = y+xy'
May be written in the form f(y) dy = g(x) dx
Finding y(x) by integrating: ∫f(y)dy=∫g(x)dx

Task 2

Finding y'(x)

Given: $x^3+3y^2x+(y^3+3x^2y)\cdot y'=0$
Not separable
Substitution y→x y gives

$$x^3(y^4+6y^2+x(y^2+3)y'y+1)=0$$

$$y'=\frac{dy}{dx}=\frac{-y^4-6y^2-1}{xy(y^2+3)}$$

Task 3

Separating variables

$$\frac{dy}{dx}=\frac{-y^4-6y^2-1}{xy(y^2+3)}$$

$$\frac{y(y^2+3)}{-y^4-6y^2-1}\frac{dy}{dx}=\frac{1}{x}$$

$$\frac{y(y^2+3)}{-y^4-6y^2-1}dy=\frac{1}{x}dx$$

Task 4

Integrating the equation

$$\int\frac{y(y^2+3)}{-y^4-6y^2-1}dy=\int\frac{1}{x}dx$$

$$-\frac{1}{4}\log(y^4+6y^2+1)=c+\log(x)$$

Task 5

Solving for y(x)

Real parts:

$$\{y\to-\sqrt{\frac{c\sqrt{x^8+x^4}}{x^4}-3},\ y\to\sqrt{\frac{c\sqrt{x^8+x^4}}{x^4}-3}\}$$

Substituting back: y→x·y

$$y_1(x)=-\sqrt{\sqrt{8x^4+c}-3x^2}\ ,\ y_2(x)=\sqrt{\sqrt{8x^4+c}-3x^2}$$

Task 6

Implementing initial values

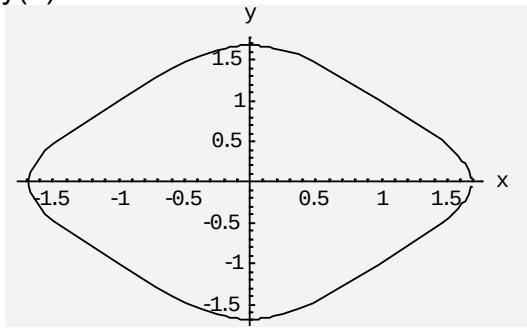
y(0)=1
Solving for c: {c→1}

$$y_1(x)=-\sqrt{\sqrt{8x^4+1}-3x^2}\ ,\ y_2(x)=\sqrt{\sqrt{8x^4+1}-3x^2}$$

Task 7

Graphics

y(0)=1



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Odd Bringslid
Assoc. Professor at The Institute of Technology, Buskerud University College, Norway. Project coordinator of EU Leonardo project dMath [1], EU Minerva project Xmath [4] and a former third party program designer for HP calculators. Officially appointed as Project leader of Educational Government Projects. Partner in the JEM project. Conference leader of several European Conferences into eLearning. Guest Editor of the Journal of Computers in Mathematics and Science Teaching. Research into mathematical eLearning and Computer Algebra and proposed Member of the OpenMath Society.

Information Content of Process Signals in Quality Control

Jović, L., Franjo; Krmpotić, Darko; Jović, Alan; Hocenski, Verica; and Slavek, Ninoslav

Abstract—***Role of quality control in industry, software engineering and government. Control schemes: measurement and actuator signals. Process time constants: material balance control, production control, quality control. The concept of quality assurance and quality culture. Control system as a simple teleonomic, purposeful, system. Kolmogorov definition of teleonomic entropy. Realization restrictions in Kolmogorov entropy calculation. Shannon entropy as system uncertainty measure. Carnap entropy measure by calculating Voronoi diagram of respective signal. Introducing one-dimensional Carnap entropy measure of quantitative signals. Pragmatic question in calculating Shannon entropy: lack of data in some data classes. Problems of Carnap 2D entropy: multiple data points, split-down of signal space, data resolution and calculation duration, interpretation of obtained results. Pragmatic questions in calculating one-dimensional Carnap entropy of control signals: equivalency of entropy measures for slightly different signal shapes, cases of short decision intervals. Delta modulated 1D Carnap entropy. Calculation of measurement and actuator signal entropies of a two-stage laboratory heat exchanger. Entropy contents of quality control signals in highly automated ceramic tile plant.***

Index Terms—***one-dimensional Carnap entropy, process control, signal entropy, tile production quality***

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Franjo L. Jović is with the Faculty of Electrical Engineering, University of Osijek, Croatia (e-mail: jovic@etfos.hr, corresponding author)

Darko Krmpotić is with KIO-Keramika, d.o.o. Orahovica, Croatia (e-mail: dkrmpotic@kio.hr).

Alan Jović is with the Department of Electronics, Microelectronics, Computer and Intelligent Systems, Faculty of Electrical Engineering and Computing, University of Zagreb, Croatia (e-mail: alan.jovic@fer.hr)

Verica Hocenski is with is with KIO-Keramika, d.o.o. Orahovica, Croatia (e-mail: vhocenski@kio.hr).

Ninoslav Slavek is with the Faculty of Electrical Engineering, University of Osijek, Croatia (e-mail: ninoslav.slavek@etfos.hr)

1. Introduction

Quality of products is of primary interest to industrial producers. Basic quality control actions in plants nowadays take place in well-defined structure known as quality evaluation system [1]. In order to ensure adequate decisions in functioning of quality control system, the most appropriate signal processing with respect to resulting quality should be installed.

There are two main obstacles in this system thinking: nature of the signal and signal-to-quality relation. According to the signal nature there are quantitative or qualitative (mark) signals, and relating signal-to-quality attributes there exist more direct or more remote connections between signal and searched quality mark of the product. The development of quality inspection must take all these aspects into account.

The development of specific quality control schemes in ceramic tiles production includes overall inspection of basic process parameters such as: grinding materials for ceramic body, milling, spray-drying, pressing-drying, glazing and decoration, firing, as well as quality control of suppliers. Some automatic devices have been developed for final inspection of ceramic tiles, but the final quality decision is still on the side of skilled workers [2, 3].

Nevertheless, nowadays ceramic tiles plants are highly automated and robotized processes. The more automated the process the more the final quality depends on quality of respective work power. Thus there exists an overall quality control scheme as depicted in Fig. 1 [4]. It can be observed from Fig. 1 that there is an opposite flow of material and control signals. While the flow of material is to the right side of the scheme, the quality corrections are towards the left side of the scheme. The role of a worker is to interact as soon as possible with the production process, changing actual control signals and implemented actions as indicated by the measurement quality signal from the plant.

2. Signals and Control Schemes in Ceramic Tile Quality Control

Classical quality control scheme for blending can be applied to, spray-drying, glazing and decoration, and glazing preparing, in ceramic tile production. Quality process on press depends on input material and many press parameters:

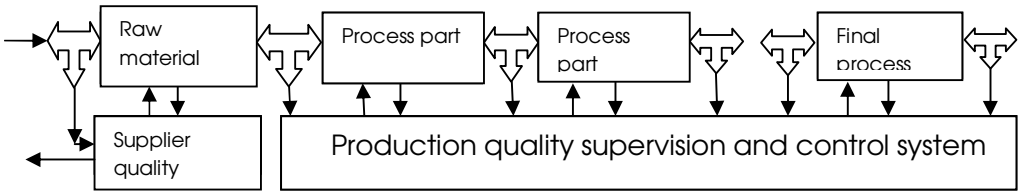


Fig. 1. Overall quality control scheme of the production plant. Measurement and control signals are indicated with arrows from and to the processing parts.

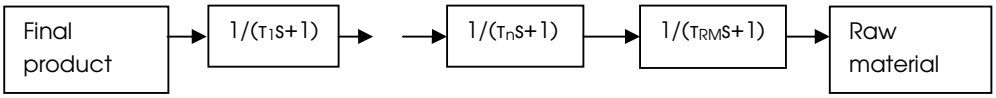


Fig. 2. Signal flow diagram for Fig. 1.

temperature of press tools, dimension of press tiles, power pressure, etc.

Quality of firing process depends on complex interaction of temperature profiles and materials for glazing and decoration. General strategy of process quality control demands as many controls as possible before material processing takes part. With blending the control has to be performed after each processing stage, thus pointing to the signal flow diagram as presented in Fig. 2.

Signal processing time constants $\tau_1,\cdots,\tau_{RM}$ are specific for each quality control part. Integrating control signal flow with time constant τ_s after each quality control step that possesses signal process time constant τ_p enables better quality than in the case of only each consecutive quality control step with approximated improvement factor B equal to $B = {}^{\tau_s}/_{\tau_p}$ [5]. Time constant of the quality control signal τ_p should be set to at least five to ten times as large as the largest time constant in the dynamics of the measurement and control equipment [5]. Time constant of the quality control signal τ_p should be set to at least five to ten times as large as the largest time constant in the dynamics of the measurement and control equipment [5]. Thus integration quality scheme as for instance given in Fig. 3 used for spray-drying, glazing and decoration, firing, should be preferred.

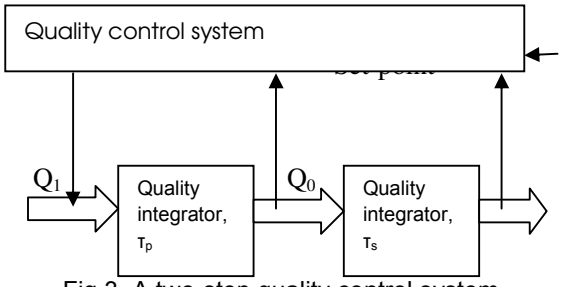


Fig.3. A two-step quality control system

3. INFORMATION MEASURE IN THE QUALITY CONTROL SYSTEM

Quality control system of the ceramic tile plant produces signals that are of quantitative, measurable form, stemming from various plant process parts. They are mostly manually collected by QC crew on the daily bases. The information content of such a measurement points to the actual state of the product quality, because any deviation from the required quality can result in production losses.

Hence, not only overall signal information content but also its required value is of importance to process control. Unfortunately, Shannon's information measure cannot cover such a case because of its insensitivity to signal shape and also to the lack of information measure for data missing cases of the entropy distribution classes [6]. Therefore, Carnap entropy concept [7] has been proposed.

3.1 SIGNAL INFORMATION MEASURE OF BASIC 1D CARNAP-TYPE DISTRIBUTIONS

As a zero-type of Kolmogorov entropy [8] there exist several different topological entropies. Rudolf Carnap (1956) introduced an *n*-dimensional system space using its *n* system variables within their theoretic limits R^{μ}, μ being at maximum equal to *n* [7]. Each system variable u_i is given within its minimum and maximum values of its space Φ_i.

A two, three, or more – dimensional spaces are produced with respective Voronoi diagrams [7]. The relevant occupation space e_j is defined for each measurement point $b_j\,(u_{i1}, u_{i2})$ according to minimum distance criterion from neighboring points. Because of the possibility to relate the relative ratio of each occupation space and theoretic limit, the dual logarithm of the relation is named Carnap entropy:

$$I_C = -\sum_j \frac{e_j}{R^{\mu}}\, ld\, \frac{e_j}{R^{\mu}} \quad \text{(bit/volume)} \quad (1).$$

The time-space trajectory of the system produces a dynamic Voronoi diagram that can be traced and compared to the desired, teleonomic system trajectory. Thus Carnap entropy can measure system entropy of dynamic teleonomic systems.

A problem not specified in the Carnap concept is the case of equal measurement points and the case of extreme reduction of the dimensions to only one. One-dimensionality of the Carnap

entropy is forced whenever overall plant data are examined whose mutual difference values do not indicate any system dynamics or just do not carry explainable information content. According to the above premises the following theorems can be set:

Theorem [6]: Carnap-based entropy is invariant to event occurrence instant.

Proof: The change of element ordering in the relation (1) does not produce any change in the sum value.

Corrolary: One-dimensional Carnap entropy as stated in relation (1) is applicable also to time-independent data series.

Periodic scanning *N* times of a constant process value *L* should yield a negligible one-dimensional Carnap entropy H because the space that occupies first measurement is total space *L* with $H = \frac{L}{L} ld \frac{L}{L} = 0$ and all the other data occupy a negligible space with $H = \frac{0}{L} ld \frac{0}{L} = 0$. Space of equal measurement values should not be subdivided among equal measurement points. It should be taken as a unique, albeit small space e_j and its content multiplied by the number of equal measurements. This statement is valid for Carnap entropy of any dimension.

1D uniformly distributed Carnap entropy with *N* events in *k* classes of the total measuring span *L*, of the width Δ_i and starting from *x* to $x + 2\Delta y$, $\Delta_i = \frac{2\Delta y}{k}$, with $\frac{N}{k} = \lambda$, possesses entropy equal to [6]

$$C_U = -\lambda\left(\frac{x}{L} ld \frac{x}{L} + (k-1)\frac{\Delta_i}{L} ld \frac{\Delta_i}{L}\right),$$

(bit/measurement unit) (2).

Usually the number of classes *k* is approximated with $= \sqrt{N}$, and relation (2) depends dominantly on the value x.

Gaussian distributed 1D Carnap entropy involves measured values distributed into classes with different number of events with values distributed according to given parameters (μ, σ^2) of mean value and variance. With *Δ* as interval between measurements, *N* as total number of measurements, total occurrence space *L* is given by $L = \max_{\mu,\sigma}(N)$. Event occurrence classes are usually of the width $c \cong \frac{\sigma}{2}$. Left flank of the distribution can be calculated from the binominal distribution as [9]

$$f_{ti} = N\, p_i = 1 \quad (4),$$

where f_{ti} is the expectation of one event in the minimum value class. With N as known value, the correspondent deviation from mean value for unity normal distribution can be calculated from Gaussian unity distribution as $\varphi\left(\frac{1}{N}\right)$.

For $N = 100$ the distribution is between $(-3{,}54\sigma \; and \; 3{,}54\sigma)$ and data can be subdivided into 14 classes. Thus one-dimensional Carnap entropy of the Gaussian measurement starts from $\mu - \varphi\left(\frac{1}{N}\right)$. The number of classes is $k = \left|\frac{2c\varphi\left(\frac{1}{N}\right)}{\sigma}\right|$. Therefore total 1D Carnap entropy of the Gaussian distribution is

$$C_G = -\frac{f_{t1}(L-2\varphi\left(\frac{1}{N}\right))}{L} ld \frac{f_{t1}(L-2\varphi\left(\frac{1}{N}\right))}{L} - \sum_{i=2}^{k} \frac{f_{ti}c}{L} ld \frac{f_{ti}c}{L}$$

+err, (bit/measurement range) (5).

The error term has to be added because of volatility of distribution that can change upper and lower flank of the actual distribution. The inclusion of actual data for f_{ti} and with $f_{t1} = 1$ gives

$$C_G = -\frac{L-2\varphi\left(\frac{1}{N}\right)}{L} ld \frac{L-2\varphi\left(\frac{1}{N}\right)}{L} - \sum_{i=2}^{k} \frac{Nc^2\varphi(u_i)}{\sigma L} ld \frac{Nc^2\varphi(u_i)}{\sigma L}$$

+err, (bit/measurement range) (6).

3.2 Information content of the Δ -modulated process signal

Generally any measurement signal can be presented as a *Δ*-modulated signal, which is a signal composed from a series of unit step changes. This signal approximation can be used as a basic approximation of the quality control signal changes in the plant.

Let us suppose that quality control signal is of value *L* in the first observation cycle. If it remains constant then its Carnap 1D information content is zero. If it changes for a positive unit step *Δ* the information content is $I^{+} = I^{L+\Delta}(L + \Delta/2) + I^{L+\Delta}(\Delta/2)$, and for a negative unit step *Δ* the information content is $I^{-} = I^{L}(L - \Delta/2) + I^{L}(\Delta/2)$. Thus for two consecutive unit steps the information content will be

$$I^{++} = I^{L+2\Delta}(L + \Delta/2) + I^{L+2\Delta}(\Delta) + I^{L+2\Delta}(\Delta/2)$$

or $I^{+-} = I^{L+\Delta}(L + \Delta/2) + 2I^{L+\Delta}(\Delta/2)$

or $I^{-+} = I^{L}(L - \Delta/2) + I^{L}(\Delta/2)$

or $I^{--} = I^{L}(L - \Delta - \Delta/2) + I^{L}(\Delta) + I^{L}(\Delta/2)$, (7),

depending on the signal step sign sequence. Actual information calculation is performed using the formula

$$I^{x}(y) = \frac{y}{x} ld \frac{y}{x}, \text{ (bit/x)} \quad (8).$$

1D Carnap information measure of the Δ-modulated signal after three steps still possesses difference in the signal shape that is

$$I^{+++} \neq I^{++-} \neq I^{+-+} \neq I^{-++} \neq I^{--+} \neq I^{-+-} \neq I^{+--} \neq I^{---} \quad (9).$$

Nevertheless signal information measure after four steps is equal for two different cases

$$Case\ 1: I^{++--} = I^{+-++}, and\ Case\ 2: I^{-+--} = I^{--++} \quad (10),$$

as indicated by the signal spectra from which 1D Carnap entropy is calculated and which are given in Fig. 4 for both cases in expressions (10). Because of obvious entropy identity for two different event sequence there exists a problem of signal teleonomic measure. Generally the expansion of a signal results in entropy decrease and the contraction of a signal results in entropy increase. Thus for $L= 10$, $\Delta= 1$, $I^{++++} = 1{,}3024\ bit$ and $I^{----} = 1{,}617\ bit$.

4. Information content of the fully-expanded Δ-modulation signal

The other approach to the problem of signal teleonomic measure is to perform a full expansion of the signal into a Δ-matrix, such as for a given signal data $(L_1, L_2, L_3, \ldots, L_k)$ the triangle matrix of data differences can be calculated among all set members, i.e. [10]

$$\begin{bmatrix} \Delta L_{1,2} & \cdots & \Delta L_{k-1,k} \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \Delta L_{1,k} \end{bmatrix} \quad (11).$$

Such matrices for Case 1 data from Fig. 4 exhibit the following results:

$$I^{M(++--)} = \begin{bmatrix} \Delta & \Delta & -\Delta & -\Delta \\ - & \Delta & 0 & -\Delta \\ - & - & \Delta & -\Delta \\ - & - & - & 0 \end{bmatrix}$$

$$I^{M(+-++)} = \begin{bmatrix} \Delta & -\Delta & \Delta & \Delta \\ - & 0 & 0 & \Delta \\ - & - & \Delta & \Delta \\ - & - & - & \Delta \end{bmatrix} \quad (12).$$

Taking each subsequent row of the matrix (12) as a new extension of the 1D Carnap information signal the extended graphs of Fig 4 can be obtained as given in Fig. 5.

5. Calculations of Shannon, 2D Carnap and 1D unexpanded Carnap entropy from the two-stage quality control model

A laboratory two-stage control system has been used as information source that models the two stage quality control process. It consists of heating and mixing unit that feed a larger container with warm water. Its conceptual structure is similar to the scheme in Fig. 3 except for two control signals that can improve final quality requirement of the unit. Two control and two measurement signals were used in the sequence of unit step temperature change of the container.

The total time span was 5000 seconds. Four 30-sample equidistant measurement data have been taken for the calculation of respective entropies. A data sample of the starting sample is given in Table 1. Obtained entropies of the Shannon, 2D Carnap and 1D unexpanded Carnap type are given in Table 2.

Entropy data on quality control signals in the two-stage kiln from the KIO Keramika d.o.o. plant in Orahovica are given in Table 3 [6].

Case 1: I^{++--} = L→Δ→Δ→-Δ→-Δ

I^{+-++} = L→Δ→-Δ→Δ→Δ

Spectrum: L*2,(L+Δ)*2, (L+2Δ)*1

Case 2: I^{+--} = L→-Δ→Δ→-Δ→-Δ

I^{--++} = L→-Δ→-Δ→Δ→Δ

Spectrum: (L-2Δ)*1,(L-Δ)*2,L*2

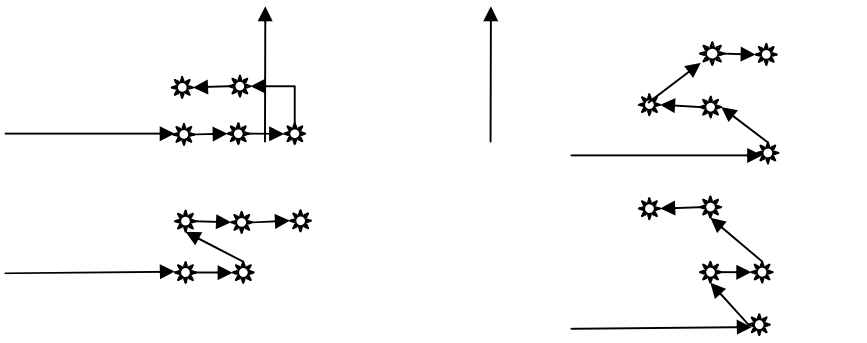
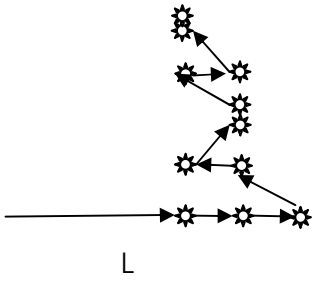


Fig. 4. Identical signal spectra for Case 1 and Case 2 from equation (10) in spite of different signal event flow

$I^{M(++--)}$:

L→Δ→Δ→-Δ→-Δ→Δ→0→-Δ→Δ→-Δ→0

Spectrum: L*5,(L+Δ)*5, (L+2Δ)*1.



$I^{M(+--+)}$:

L→Δ→-Δ→Δ→Δ→0→0→Δ→Δ→Δ→Δ

Spectrum: (L)*2,(L+Δ)*2,(L+2Δ)*3,

(L+3Δ)*1,(L+4Δ)*1,(L+5Δ)*1,(L+6Δ)*1.

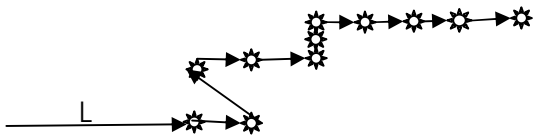


Fig. 5 Carnap 1D entropy of the full expanded *Δ*-modulated process signals from Case 1 as an example of signal teleonomic solution: there are visible essential signal path and entropy content differences

Table 1. Data set for the entropy analyses of the laboratory step quality change – initial observation after the set-point step change, uc - pump control signal, ug - heater control signal, umd – tank water temperature signal, umg – heater water temperature signal

t	uc	ug	umd	umg
0	0,00000	0,00000	19,50000	22,00000
4	0,40001	-0,00097	19,50000	21,99919
8	0,38208	-0,01397	19,50000	21,99616
12	0,44110	9,74745	19,50000	22,12211
16	0,45618	9,92590	19,50000	23,36624
20	0,46787	9,97358	19,50000	25,33188
24	0,44961	9,96402	19,50001	27,60515
28	0,46314	9,94945	19,50001	30,00832
32	0,47041	9,96284	19,50002	32,46636
36	0,46894	9,95965	19,50003	34,94855
40	0,47304	9,96373	19,50005	37,44115
44	0,47051	9,97195	19,50006	39,93704
48	0,46237	9,94937	19,50008	42,43520
52	0,47628	9,96171	19,50011	44,93371
56	0,46576	9,97690	19,50013	47,43147
60	0,48826	9,97856	19,50017	49,92741
64	0,48249	9,95944	19,50022	52,41624
68	0,45541	9,95758	19,50030	54,90607
72	0,46546	9,96551	19,50040	57,40015
76	0,45334	9,91252	19,50051	59,89777
80	0,45653	7,69572	19,50062	62,33556
84	0,45932	5,59170	19,50073	64,46369
88	0,45308	3,88978	19,50086	66,15638
92	0,44594	2,58772	19,50101	67,42535
96	0,44477	1,65228	19,50117	68,33156
100	0,45833	1,03354	19,50134	68,95203
104	0,45217	0,60127	19,50151	69,36033
108	0,48704	0,35816	19,50168	69,61718
112	0,43826	0,15675	19,50186	69,76960
116	0,44238	0,06975	19,50205	69,85784

6. DISCUSSION AND CONCLUSION

Quality control in all human activity requires correct data about the process. Although not easily acquired, data can be collected from process industrial production, software production facility or government office. They significantly differ in volume, content, and impact. The purposefulness of the data is relevant for system owner and user. Thus only teleonomic quality data can be finally regarded as completely socially useful.

Theoretical consideration of information content of signal data is covered by Kolmogorov concept of entropy. Information system theory as proposed by Vladimir S. Lerner [11] is conceived to build a bridge between the mathematical systemic formalism and information technologies dealing with transformation of information. The aim of such a procedure is to obtain system models that reveal information laws and specific object codes and patterns. General evaluation of informational aspect of stochastic data is enabled by application of Kolmogorov entropy that measures the extent of chaos in a system. According to Shannon's interpretation, system uncertainty is closely related to system information content we possess [12].

When applying Shannon's concept, two distinctive data manipulation problems appear: it cannot cover for deterministic data because of lacking data classes for entropy calculation as indicated in Tables 2 and 3, and it can operate strictly only on qualitatively enumerated data sets such as letters or signs. Quantitative data do not automatically apply for Shannon entropy calculation as indicated in Tables 2 and 3. Both conceptual features are inappropriate for quality control in industrial signal environment that is based on quantitative signals from measurement transducers and that possess a given stochastic component. In addition, Shannon's concept does not consider any system teleonomy at all.

Application of 2D Carnap entropy is favorable for quantitative data but it sometimes takes extreme calculation time for its Voronoi diagram calculations [6], as indicated in Table 2 as well.

Table 2. Shannon, 2D Carnap and 1D Carnap entropies calculated for four data series: 1-120, 120-240, 240-480 and 480-1120 seconds after step change of the set-point in the laboratory two-stage control system

Data Series	Entropy type	Pump control signal entropy, bit/unit	Heater control signal entropy, bit/unit	Tank water temperature entropy, bit/unit	Heater water temperature entropy, bit/unit
1	Shannon	None*	15,1826	18,2839	12,4693
	1D Carnap	2,2654	3,1688	4,5909	4,5257
	2D Carnap	2,2830	3,0209	4,1475	4,477
2	Shannon	None	14,6696	13,1876	13,0684
	1D Carnap	2,7049	1,5239	2,9164	2,9879
	2D Carnap	2,2896	Not calculable**	2,6843	Not calculable
3	Shannon	9,6729	None	5,0361	9,9045
	1D Carnap	4,6459	3,0487	4,8879	4,1634
	2D Carnap	4,5099	2,5943	4,8352	4,1209
4	Shannon	13,0747	7,7612	6,3382	9,9122
	1D Carnap	4,4152	4,5034	4,6746	3,5847
	2D Carnap	4,0905	4,1877	4,6299	3,8030

* - some data classes missing, ** - calculation on a quad-core Pentium IV machine greater than 4 hours

Table 3: Entropy calculations of 90-day temperature control profiles in the two-channel kiln in KIO KERAMIKA tile factory, Orahovica, Croatia

Control signal name	Temperature lower bound, ˚C	Temperature upper bound ,˚C	Shannon entropy, bit	1-D Carnap entropy, bit/unit	2-D Carnap entropy, bit/unit
Signal 44	1106	1166	None*	17,0464	5,82848
Signal 45	1119	1151	2,89715	20,4124	6,96516
Signal 46	1106	1166	None	16,8702	5,44023
Signal 47	1106	1166	2,9183	19,6232	6,66346
Signal 48	1107	1169	None	15,7453	5,5408
Signal 49	1114	1150	2,74091	18,5061	5,98589
Signal 50	1107	1170	None	16,0646	5,584
Signal 51	1114	1150	2,7879	18,7413	6,5268

* one or more empty data classes

It is also unresolved for multiple data points, in which case a reasonable improvement has been proposed in the form of multiple entropy impact [6]. Its teleonomy is obtainable only for final data point arrangement in the given Voronoi diagram, but the in-between step order teleonomy is completely disregarded.

1D Carnap entropy as proposed in [6] is applicable for quantitative data. It possesses short calculation time but its teleonomy is like its 2D counterpart and only obtainable for final data point arrangement.

A modified 1D Carnap entropy, named *Δ*-modulated 1D Carnap entropy or *Δ*-Carnap entropy, is analysed in this paper as well and proposed for further investigation because of the teleonomy feature improvement over the other Carnap entropies. This entropy installs data differences among all signal data. Thus it promotes also the introduction of qualitative data into entropy calculation. Obtained information content as expressed in Table 2, that is very similar for different quality control sequences, requires such an approach.

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Authors are thankful to Prof. Davor Antonić for disposition of data from the laboratory control set-up and on text remarks.

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Upgrading Generator Scripting Model by Object Model Properties

Radošević, Danijel; Kliček, Božidar; Kozina, Melita

Abstract— *Generative Programming (GP) is a relatively new discipline of automatic programming, with the accent on program code optimization and flexibility in parallel development of generators and final applications. The Generator Scripting Model (GSM) is an aspect-based, graphic model of application generator. It is a static model based on higher level of scripts, called metascripts, unlike UML, which is based on classes and their processes. However, the basic concepts of object oriented programming, like encapsulation, inheritance, and polymorphism could be achieved in GSM. Benefits of introducing such concepts into GSM are: more precise application specification, more reusability of generator, simpler generator model and its easier implementation. The upgraded GSM is actually implemented in a form of a C++ library.*

Index Terms— *Generative Programming (GP), Generator Scripting Model (GSM), Object Oriented Programming (OOP), polymorphism, UML*

1. INTRODUCTION

GENERATIVE Programming (GP)[1] is a discipline of automatic programming which assumed that name in the late 1990's. According to the definition, GP represents "...designing and implementing software modules which can be combined to generate specialized and highly optimized systems fulfilling specific requirements" [2]. The main aspirations of GP are, in relation to other techniques of automatic programming, programming code optimization as well as making the process of building generators and final applications more flexible.

The Generator Scripting Model (GSM) was introduced by Radošević[8] and enables graphic way of modeling generators. GSM is oriented on modeling aspects i.e. features not strictly connected to individual program organizational units like functions or classes. Therefore, the model can appear within different application parts [6].

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D. Radosevic is with the Faculty of Organization and Informatics, University of Zagreb, Croatia

B. Klicek is with the Faculty of Organization and Informatics, University of Zagreb, Croatia

M. Kozina is with the Faculty of Organization and Informatics, University of Zagreb, Croatia

Concepts inherited from Object Oriented Programming (OOP) like encapsulation and inheritance are included in the basic GSM, which is now upgraded by concept of polymorphism. Inside GSM, polymorphism concerns late binding of metaprograms during the process of generation, depending on program specifications. Benefits of that concept should be: easier generator (because of lower number of generation levels), more precise application specification and more flexibility in generator development.

GSM (now including polymorphic features) is actually implemented in a form of C++ library [11]. Some older generators are written in Perl.

2. GP AS A POSSIBLE SUCCESSOR OF OBJECT ORIENTED PROGRAMMING

The idea of this paper is to offer GP as a possible successor of today's dominant programming paradigm - OOP. Some notion for it was given by Guerray, who marked Aspect Oriented Programming (AOP) as possible successor of object paradigm [3]. AOP is a discipline in base of GP, and there some aspect oriented varieties of standard programming languages, like AspectJ, AspectC++ etc.

To be a successor of OOP, GP should inherit the main concepts of OOP (encapsulation, inheritance and polymorphism) in a way the OOP inherits main concepts of structured programming (Figure 1).

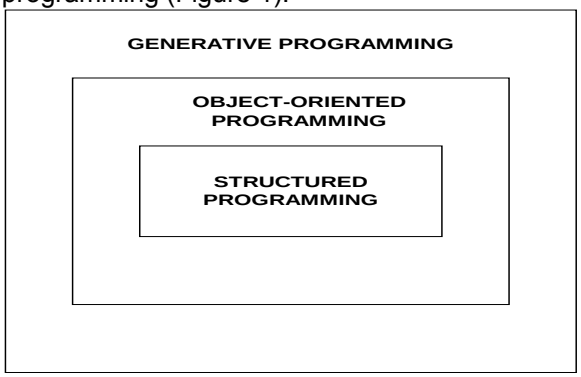


Figure 1: Relationship between structural programming, OOP and GP

GSM has been originally developed for the needs of GP based on scripting languages [10]. It's a connection model which defines the involvement of specific features (i.e. aspects) given inside program specification into programming code which should be generated. In terms of AOP, it is a type of a Join Point Model [4]. The specific difference to other Join Point Models is that the scripting model (similarly to scripting programming languages) is not based on types, i.e. it represents a type-free system. Thus, connecting points in the scripting model do not represent classes and their objects, only type-free connections between metaprograms and properties defined in program specification [10].

3. BASICS OF GSM

GSM is a graphic diagram which starts from the general (static) model of a generator (Figure 2), where that generator binds the program/component specification to metaprograms, producing final programming code, as described in [1].

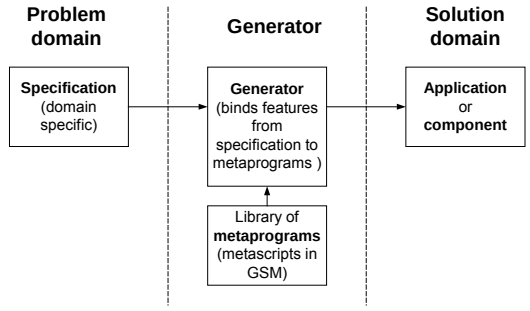


Figure 2: The general model of generator

GSM consists of two graphic diagrams:

- **The specification diagram** - defines the structure of application specification. Specification defines proposed properties (aspects) of the future application, which will be used in application generation.
- **The metascripts diagram** - defines distribution of specific properties, which are proposed by specification diagram, within application, and also their connecting to program code templates (called *metascripts inside GSM*).

The specification diagram is a hierarchic diagram defining proposed application features in a form of tree-like feature model, similar to the model given by Limbourg and Kochs [7]. Features are defined by attributes which are used for specifying application from the generator's domain. Attributes of specification have hierarchic structure, as shown on Figure 3.

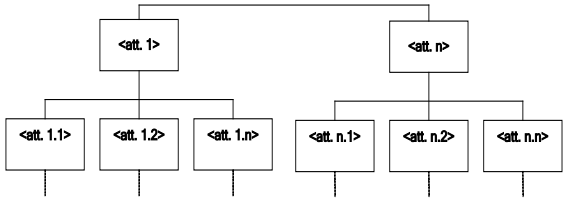


Figure 3: The specification diagram

The metascripts diagram defines distribution of specific properties proposed by the specification diagram within the application, and also their connection to program code templates (metascripts). It consists of three basic elements (Figure 4):

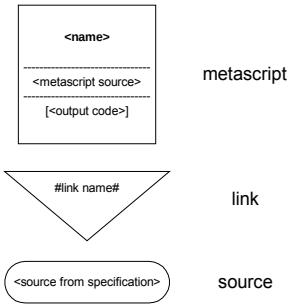


Figure 4: Elements of the metascripts diagram

Metascript is a template used in generation of its implementation - program code in target programming language, which is called *script*.

Link connects metascripts to property sources from application specification, and (optionally) to lower level metascripts.

Source represents a feature defined by appropriate attribute in the specification diagram. Sources can be defined as containers - in that case their further use must be defined on lower levels of the metascripts diagram.

Elements of the metascripts diagram are located in vertical columns. Each of the columns represents an appropriate level of metascripts, as shown on Figure 5:

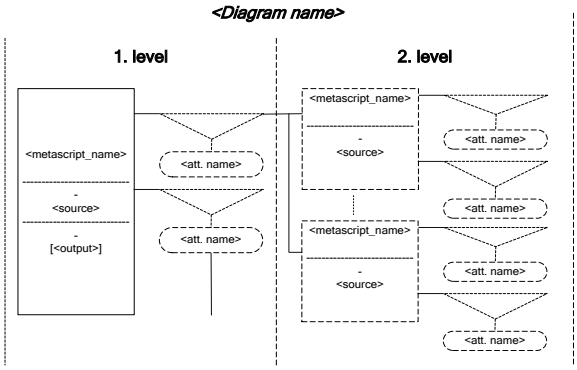


Figure 5: Arrangement of elements on the metascripts diagram

Number of levels in a metascripts diagram determines the level of the generator; therefore, the levels of generators in scripting model are:

- ***Single-level generator*** - simple generator consisting of only one metascript (its metascripts diagram has only one level; Figure 6) and

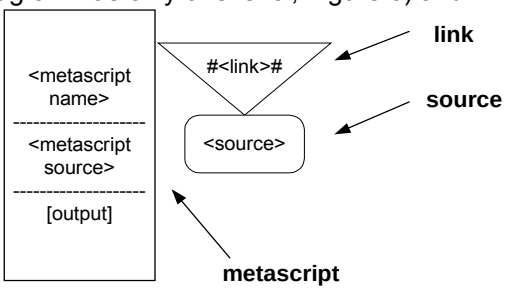


Figure 6: Single-level generator

- ***Multi-level generator*** - generator that includes more metascripts arranged on different levels (its metascripts diagram has more than one level). Each branch in the metascripts diagram defines the appropriate lower level generator. The lowermost level of each branch in the metascripts diagram defines one simple single-level generator. Multi-level generator is given by superposition of multiple one-level generators (Figure 7).

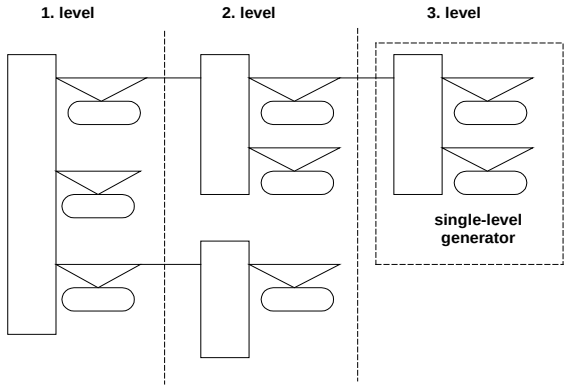


Figure 7. Multi-level generator is given by superposition of multiple one-level generators

4. MODELING LEVELS OF GSM IN RELATION TO UML

Architecture of software system development supported by UML diagram techniques is shown on Figure 8.

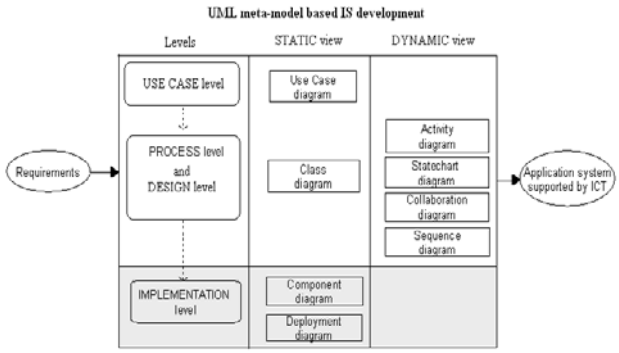


Figure 8: Architecture of software system development supported by UML diagram techniques [4]

According to this architecture, we recognize the following levels: the use case level; the processing level, the design level and the implementation level [4].

GSM defines only the static view, and includes two diagrams on two levels: the specification level and the processing level. The dynamic view is a part of programming code templates – (metascripts; Figure 9).

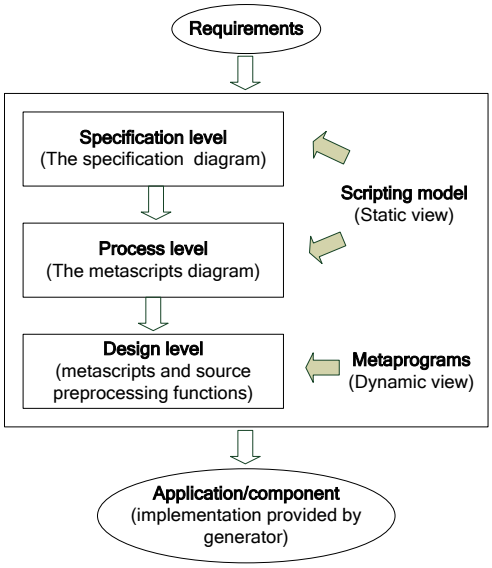


Figure 9: Levels of GSM architecture [9]

The paper especially emphasizes the defining of relationships between the generator scripting model and base levels of the UML model (Use Case and Process).

1. OBJECT MODEL PROPERTIES IN GSM

1.1. Encapsulation

Inside GSM, the basic encapsulated unit is the metascript. The metascript is, despite class, just a basic structure, which means that its instances (called *scripts*) share only the basic (higher level) structure, and could be of different sizes (Figure 10):

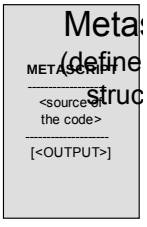


Figure 10: Metascript and instantiated scripts

1.2. Inheritance

Inheritance in the generator scripting model works in a way that base metascript inherits lower-level metascripts. Inheritance is selective and inclusion of a particular metascript depends on the existence of the appropriate program specification source (Figure 11):

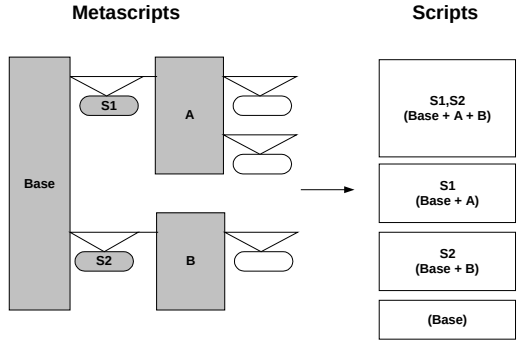


Figure 11: Inheritance in GSM

1.3. Polymorphism

Polymorphism inside generator scripting model is based on usage of *virtual metascripts*. Virtual metascripts are invoked by a mechanism of late binding during the process of program generation (according to program specification, as further described; Figure 12).

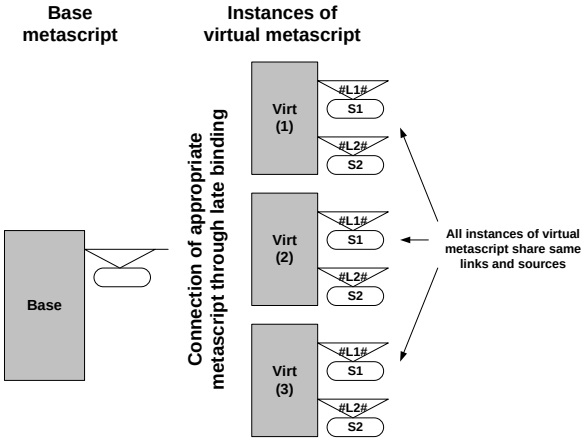
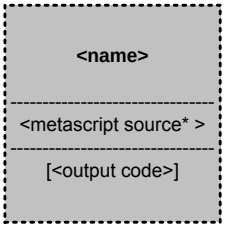


Figure 12. Instances of virtual metascript

As shown on Figure 12, all instances of virtual metascript share same links and connected sources, which is analogue to the object model, where subordinated classes share same virtual methods. Virtual metascript is represented by the dot line rectangle (Figure 13):



***** - contains variable part

Figure 13. Virtual metascript

Metascript source (usually a text file) contains a variable part marked by brackets (square or curly; depending on the type of invocation). This variable part is defined by appropriate specification source, as described below.

Invocation of virtual metascripts

Program specification consists of attribute-value pairs, meaning there are two invocation methods of virtual metascripts:

- By attribute and
- By value.

Invocation *'by attribute'* is marked by square brackets:

<prefix>[<attribute group>]<suffix>

For example (Figure 14), if metascript instance should be invoked according the attribute from the group *field_*, it should be specified as follows:

create_[field_].metascript

For the specification line

field_float:<some value>

which will produce the invocation of the metascript *create_field_float.metascript* .

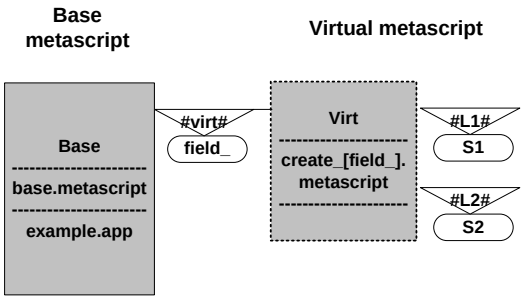


Figure 14. Example of invocation *by attribute*

The source *field_* is (on link *#virt#*) is a container source. The value inside the brackets has to be inside its source container.

Invocation *'by attribute*' is marked by curly brackets:

<prefix>{<attribute>}<suffix>

For example (Figure 15), if metascript instance should be invoked according the value of attribute *review*, it should be specified as follows:

show_{review}.metascript

For the specification line (specifies type of review)

review:combo

which produces the invocation of the metascript *show_combo.metascript* .

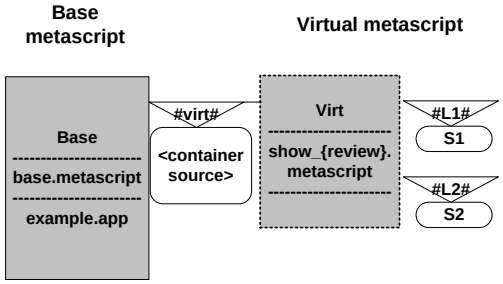


Figure 16. Example of invocation by value

Similar to previous type, the value inside brackets has to be inside its source container.

2. ILLUSTRATIVE EXAMPLE: THE SCRIPTING MODEL OF PHP WEB APPLICATION GENERATOR

Formation of a generator starts from the *application prototype*, i.e. from a possible application that could be made by the generator. Furthermore, the application specification should define all features differing the particular (generated) application from its prototype. This illustrative example contains a database table *students*, which should be managed by php scripts and html forms (Table 1).

Attributes	Data types
student_id (primary key)	integer
surname_name	varchar
year_of_study	integer
year_of_enrolment	integer

Table 1: Structure of prototype database table

According to Table 1, the specification of a prototype could look like this:

title:students
table:students
primary_key:student_id
field_char:surname_name
field_int:year_of_study
field_int:year_of_enrolment

Appropriate specification diagram is given in Figure 17:

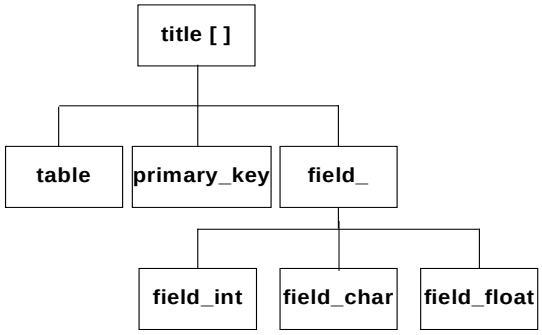


Figure 17: The specification diagram of the example generator

Features from the specification are dispersed through different parts of program code, enabling basic operations like data review (Figure 18) and existing record modification (Figure 19):

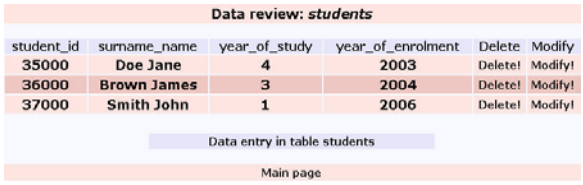


Figure 18: Data modification

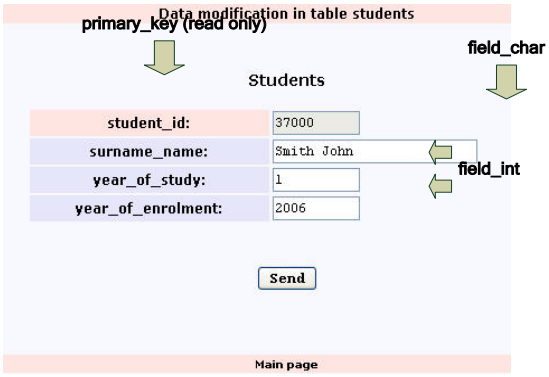


Figure 19: Existing record modification

As can be seen on Figure 18 and Figure 19, features from the specification are dispersed through different parts of the application, representing aspects. Those features are handled differently depending on metaprograms used, as defined in the metascripts diagram (Figure 20.).

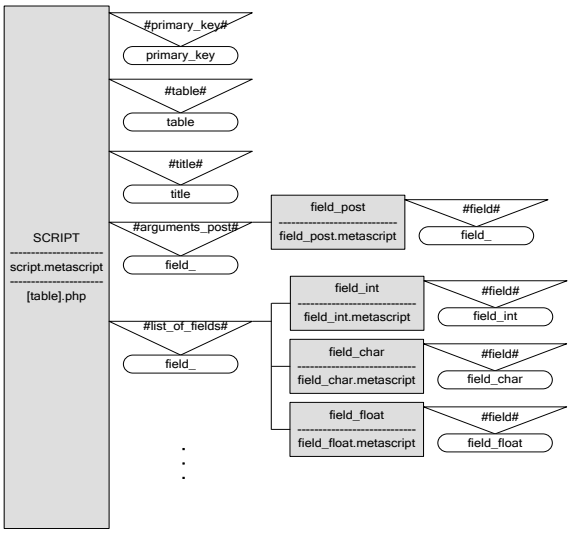


Figure 20: The metascript diagram of the example generator

3. CONCLUSION

GP, as a relatively new discipline of automatic programming, strives to make the application development process more flexible through the usage of generators as a knowledge base for development of new applications. GSM is a generative model that enables a graphic means of modeling generators, not particular applications, like UML. However, to be a successor of the currently dominant object

paradigm, GP should involve all basic concepts of OOP. Therefore, the paper examines the usage of basic object oriented concepts, encapsulation, inheritance and polymorphism on a level of modeling generators using GSM. Encapsulation and inheritance were present in the original GSM, while polymorphism was introduced recently. It has shown that benefits of introducing polymorphism into GSM are recognized in more precise application specification, more reusability of generator, simpler generator model (lover number of levels) and its easier implementation.

For now, the improved GSM is implemented in form of a C++ library and used mainly in development of web application generators. In our future projects, we plan to work on the development of new programming platforms and new tools for making generators, as well as on the improvements to the prototype reengineering process.

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How to Ruin the Career of a Ph.D. Student in Computer Science and Engineering: Precise Guidelines

Milutinović, Veljko; Tomažič, Sašo

In our profession, one widely utilized Ph.D. thesis structure implies the following elements[1]:

(1) Introduction: motivation and environment
(2) Problem statement and why it is important
(3) Existing solutions and their criticism
(4) Proposed solution that is both application and technology aware
(5) Details of the solutions to be compared
(6) Conditions and assumptions of the analyses to follow
(7) Mathematical analysis
(8) Simulation analysis to compare performance
(9) Implementation analysis to compare complexity
(10) Conclusion from the performance/complexity ratio point of view
(11) Acknowledgements
(12) References

In order to have these elements ready when writing the thesis and papers (after the research and development are completed), one has to perform specific work (before the research and development are completed). Working on each one of the above defined elements, Ph.D. advisors can and often do make errors that force students to undertake activities and create habits that could form irreversible damages to their research mentality and ruin forever the chances that they become real scientists in the future. The text to follow discusses the major pitfalls of each methodological element in the environment typical of Computer Science and Engineering (CSE), using the following template: (a) an advice leading to a pitfall (in italic), (b) a short explanation shedding an extra light, and (c) an illustrative example.

(1) *Tell the student that the Ph.D. thesis is the crown of a research career.*
Since things in CSE change so rapidly, the main motivation for a Ph.D. should not be to create her/his lifework; it should only be treated as a proof that she/he is able to solve scientific problems using scientific methodologies when the real research starts after the Ph.D. thesis is defended.
It is the fact that many Ph.D. research activities, for a variety of reasons, take too long; at some universities, especially in East Europe, in the past, some researchers would obtain the Ph.D. degree not long before they retire.

(2) *Tell the student to select the hardest problem and to go after the optimal solution.*
In computer engineering there are many unsolvable problems, however, the things still work; therefore, the candidates do not always need to find the optimal solution; a suboptimal solution that works is also good. The fact is that some problems have many elegant and easily understandable, but unfortunately wrong solutions; do not select such a problem for a Ph.D. research; also, do not choose a problem that is not important for the present day technology and applications (it is the responsibility of the Ph.D. thesis advisor that the student selects an important problem to work on, and the advisor, rather than a student, is to be blamed for missing directions).

[1] V. Milutinovic, "The Best Method for Presentation of Research Results," IEEE TCCA Newsletter, September 1997, pp. 1-6.

(3) *Tell the student that one has to master all existing solutions to the problem before one makes an attempt to create something novel.*
Knowing too much about existing solutions may mislead the student and will minimize the chances that she/he generates a breakthrough (it is good that in CSE people are less prone to following the opinions of recognized authorities); reading too much will definitely lock the student inside the avenues already taken by others.
A well known example is that Nobel Laureate Marconi discovered that short waves do bounce off the ionosphere, because he dared to do the related experiments in conditions when nobody else dared, because a guru of the field published a paper 'proofing' that something like that is not possible; in this case, the inventor did not know about all existing work in the field, and that certainly helped.

(4) *Tell the student that he, as a newcomer into the field, will never create good new ideas by herself/himself alone (without the help of the major professor); only experienced experts can create breakthrough ideas.*
Actually, the fact is that the accumulated knowledge (which may not be relevant any more) could create blocking obstacles in the process of our creative thinking and decision making; well educated newcomers into a field do not have this type of problem.
Fortunately, in CSE, things change rapidly, and it is not difficult to be a well educated newcomer, e.g., operating system Linux was created by a student and turbo codes were invented by a mechanical engineer

(5) *Tell the student that one should never share the details of an invention with others, because they will steal it and abuse it.*
Some researchers do not go to conferences (time waste), and publish their work only in journals (that brings the SCI credit, which is typically a formal requirement for oral defense); the fact is that one obtains the best ideas when trying to explain the initial ideas to others.
Fortunately, in CSE, people tend to be more open to sharing, which is clearly demonstrated by large open source and freeware communities.

(6) *Tell the student to keep simplifying the problem until it becomes tractable.*
It is the fact that narrowing the assumptions and conditions of the research increases the probability that one creates something novel, but narrowing beyond the absurd line turns the underlying assumptions into wrong assumptions, since the contact with reality gets lost; if one lives 24 hours with the Ph.D. thesis problem, and is obsessed with it, one will create original solutions without introducing any technology and application restrictions.
Researchers in CSE tend to oversimplify, especially when doing analytical work, since mathematical modeling works there not nearly as efficiently as in other fields, like physics or similar.

(7) *Tell the student to avoid any simplification of the problem*.
Do not be overambitious, since it is impossible to take all relevant details into account. Some simplification is necessary in order to arrive to a solution. What is important is to distinguish between important, not so important, and unimportant.
By being too ambitious, one typically creates a useless result, or does not create the result at all, as is still the case with the attempts to create artificial intelligence comparable to human intelligence.

(8) *Tell the student that one does not have necessarily to be a good programmer, if doing a Ph.D. in CSE; software tools will do the necessary job.*
Some researchers advocate that the purpose of Ph.D. research is to create ideas, not programs. The fact is, however, that one has to touch and feel the problem (e.g., by mastering the programming related details), before being able to create an effective simulation environment.
If one wants to find an efficient solution to a problem, she/he has to understand the essence and limitations of programs underlying the tools she/he uses.

(9) *Tell the student that she/he should produce an ideal implementation, since academic implementations (those including bugs, errors, and stupidities of the un-experienced) are worthless.*
Actually, PoC type (proof of concept)

implementations are the best enablers of extremely efficient market oriented industrial implementations. Trying is the best catalyst for breakthroughs.
PoCs are of special importance for CSE; some of the products of major software companies stay in the PoC phase throughout their lifetime cycle, until the new successful release comes (actually, the new release becomes successful only the concept was proved by previous versions).

(10) *Tell the student that price and performance are the only important criteria for evaluation of the novel ideas.*
Performance and complexity do not represent the full set of important issues; sometimes other issues like availability, reliability, and feasibility are of greater importance.
Researchers in CSE do not care enough for these other issues; they are often treated as of secondary importance. Actually, "abilities" are typically much more important in technology and application considerations, and notoriously omitted. Only holistic approaches and solutions they create will survive technology and application revolutions.

(11) *Tell the student that it is not recommended to apply for funds apart from doing it jointly with the major professor, since no funding agency would give the research money to a Ph.D. student alone; they will do it only if they see the major professor name on the application, too*.
It makes sense to give research money directly to PhD students (one can not teach an old dog new tricks). Also, Ph.D. students who rely on the excusive guidance from the advisor will never become creators of breakthroughs (note however that an advice from an old dog can be very useful, indeed). Since CSE is changing so rapidly, some computer research sponsoring agencies do recognize the importance of this issue.

(12) *Tell the students to include into the thesis text as many references as possible, and before completing the thesis, also to publish as many own papers as possible (for inclusion into the list of references and the CV).*
Knowing about all existing solutions takes lifetime and minimizes the chances to generate anything, while putting in more than one knows is dangerous. Quantity can never compensate for lack of quality; even worse, too much quantity can produce bad quality.
Actually, in some of the best universities of the World, researchers in computer area are judged for promotion based on only the best 3 papers: in such conditions, a researcher with 300 papers on the CV is judged based on only 3 she/he selects, and is obviously handicapped in comparison with another researcher who created only 3 papers using the same amount of time and creative energy (all of them superb, because she/he did not care to waste time on non-breakthrough ideas).

A general truth is that a fool would never agree to exchange his brain with the brain of a genius, since, fool as he is, he believes that his brain is more valuable. In computer engineering this non-trading might be a good decision to make, because things change so rapidly and one must be open minded (empty brain) to be able to accept and generate new ideas. Of course, this is an oversimplification to underline the fact that an unbiased mind is often times also a more effective mind, when it comes to computer engineering.

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