

Liberal arts writing and physics lab report writing in the context of kinematics thinking

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Abstract

Liberal arts writing are by definition sequential in that its appearance is manifested as successive paragraphs, while physics kinematics thinking involving the five variables of time, distance, initial velocity, final velocity and acceleration may be expressed in non- sequential diagrams that reflect spatial thinking. The non-sequential linkage concept among the variables in a diagram is straightforward, while the multiple linkages across the paragraphs in an essay are less obvious, especially to community college pre-engineering students studying kinematics. A pedagogy has been developed to emphasize the multi-linkages in liberal arts writing as it relates to kinematics thinking so as to improve physics lab report writing. The first- score and post- score upon receiving writing improvement recommendations have been used to assess the pedagogy effectiveness in terms of correlation and relative gain. The assessment result suggests that the modeling of liberal arts writing in the context of diagrammatic kinematics thinking would help students to improve on their physics lab report writing and undergraduate research paper writing.

I. Introduction

The City University of New York instituted a writing intensive component in its curriculum more than ten years ago. Queensborough Community College (QCC), being a junior college in the CUNY System, requires two writing intensive courses for graduation. Our Physics Department has designated Calculus Physics and Technology Physics classes as writing intensive classes where lab report writing is a substantial element ¹. A quick review of the 2014 high school SAT score shows that Engineering majors have higher critical reading scores when compared to English majors, while English majors have higher writing scores when compared to engineering majors ^{2,3}. The result would suggest that engineering majors could use their critical reading skill to help them improve their writing skill with writing improvement pedagogy. In addition, QCC is a minority serving institution and given that the SAT score shows that the Black group and Mexican American group are behind the White group by about a 100-points in each of the testing category, namely, reading, writing and math ⁴, it is of paramount importance that such writing improvement pedagogy could also improve critical reading and thus critical thinking.

II. Kinematics

A writing pedagogy based on kinematics critical thinking has been developed. In a kinematics equation, the left side unknown can be solved by knowing three variables values in the right side of a kinematics equation. There are five variables, namely, v_0 , v_f , x , a , and t .

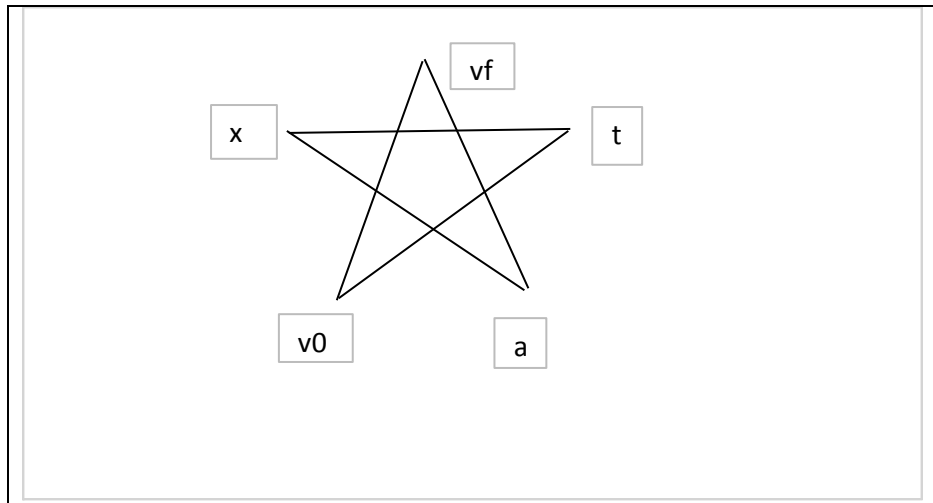


Figure 1: A diagrammatic representation of the five variables in kinematics. The v_0 as initial velocity, a as acceleration, t as elapsed time, v_f as final velocity, and x as distance or displacement are inter-connected in various pathways.

The simple cases when one of the variable values = 0, at a high school physics level, are described below.

Variable initial velocity $v_0 =$ zero, initially at rest;

Variable final velocity $v_f =$ zero, stopped finally;

Variable distance or displacement $x =$ zero, round trip, or initial position, etc.;

Variable acceleration $a =$ zero, constant velocity;

Variable elapsed time $t =$ zero, no motion.

The complex cases, in college physics, are described below.

There are 2 objects/masses having two motions that could be related by time, that is, the sharing of elapsed time as the common variable;

There are 2 stages of a single object motion that are related by time continuity such that final velocity at the end of stage-1 is the initial velocity in stage-2.

The use of simulation to generate values for one of the three variables is a simple technique. Examples include simulation in elapsed time to find the motion path or flight trajectory; simulation in launching angle to find the range value possibility like basketball throwing, etc.;

the use of calculus to find an algebra expression for the answer instead of numerical simulation at arithmetic level.

III. Writing Pedagogy and Assessment

An essay writing thinking analogy with kinematics thinking for lab report writing has been developed with the examples listed below.

The linking of two concepts in a sentence such as subject and an adjective (car/blue) would have an analogy in kinematics thinking when one of the three kinematics values is zero. This writing structure could be classified as elementary school writing.

The linking of three concepts in a sentence (subject/object/verb sharing) would have an analogy in kinematics when three variables values are known on the right side of a kinematics equation. The kinematics case of two masses sharing time as the common variable would have an analogy in sentence structure: "Henry seeing Sally".

The kinematics simulation would have a writing structure analogy. The sentence structures such as "Henry walking with Sally", "Henry running with Sally", "Henry seeing Sally", "Henry caring for Sally", "Henry staying in contact with Sally", etc. are illustrating linkage at different depths, with analogies of simulation of angles in ball throwing for example.

The continuity transitions between paragraphs where the last sentence in the previous paragraph echoes the beginning sentence of the next paragraph would have an analogy with the case where final velocity at the end of stage-1 is the initial velocity in stage-2 in kinematics thinking.

The overall essay containing non-sequential inter-relationship between paragraphs would bear similarity to the relationship depicted in Figure 1. In a lab report, the theory section has a non-sequential relationship to discussion with procedure/analysis in between.

It has been asserted that poetry conveys feelings, thoughts and ideas by accentuating metric constraints, rhyme and alliteration⁵. A lab report has the format constraint: the science favor of objectivity without subjective and psychology wordings like "I feel that the data collection was...", and a central theme written as the lab objective/purpose. The English majors hold the champion of poetry rhyme which has the analogy with objectivity in science writing. The strengthening of objectivity has effects on the critical thinking of relative velocity and frame of reference physics. The liberal arts writing style in rhyme with analogy to objectivity would enhance the understanding of examples such as a spaceship gaining kinetic energy in a slingshot motion around a planet. Furthermore the "I" correction in a submitted lab report by an instructor is not merely a grammar change but a conceptual change to embrace objectivity. Similarly a recommended verb change by an instructor is not just a grammar change, but a linkage depth expression in terms of diction and effectiveness.

A writing with logical consistency is a necessity at college level. The deduction logic of “If proposition, then conclusion” should be at mastery level. The generalization or induction thinking in “If conclusion, then proposition” should be explained as well. A 2013 open access article in Bloomberg.com published a tool for helping students to do the SAT logic questions ⁶. An excerpt is included below for easy reference.

(Start quotation ⁶)

“The SAT at its core is a test of reasoning, not a test of knowledge. Reasoning is technique that people use to create conclusions from premises or evidence or determine whether a conclusion is valid or invalid, based on premises. The most fundamental building blocks of reasoning come from logic, the formal study of valid reasoning....

Statement—If A, then B

Contrapositive—If not B, then not A

Converse—If B, then A

Inverse—If not A, then not B

If the statement is true, then the contrapositive must also be true—and vice-versa.

If the converse is true, then the inverse must also be true—and vice-versa.

Let’s look at an example in practice:

Statement—“If I studied for the SAT, I will get a high score.”

Contrapositive—“If I did not get a high score, I did not study for the SAT.”

Converse— “If I get a high score, I studied for the SAT.”

Inverse—“If I did not study for the SAT, I will not get a high score.”

(End quotation)

In a study of the standard basketball throwing question where the initial angle and the displacement are given, the speed value can be found by simulation. An example of a basketball thrown with unknown speed at 45 degrees with known range can be found on page 73 of Physics Fundamentals, Vincent Coletta, Second Edition, 2010, Physic Curriculum & Instruction Inc. A basketball with unknown speed thrown at 45 degree going from (0, 2m) to (6m, 3m) is listed and the book method contains algebra steps to solve for initial speed by eliminating time variable, with the answer = 8.4 m/s.

The simulation results can be categorized in the following format for the illustration of deduction thinking and induction thinking:

Science Deduction1 (Statement)

If speed was 8.4 m/s, then ball entered basket.

Science Deduction2 (Contrapositive)

If ball did not enter basket, then ball was not thrown at 8.4 m/s

If Deduction1 is true, then Deduction2 must be true (due to logic)

Science Induction1 or Generalization Thinking1 (Converse)

If ball entered basket, then it was thrown at 8.4 m/s

Science Induction2 or Generalization Thinking2 (Inverse)

If ball did not enter basket, then the ball was not thrown at 8.4 m/s
If Induction1/Generalization1 is correct, then Induction2/Generalization2 must be true (due to logic).

The explicit use of deduction and induction would help a student to sort through these logical condition situations and eliminate logical inconsistency in writing.

It has been said that “Education Is What Remains After You Have Forgotten Everything You Learned In School.” Although the origin of the above statement is unclear, the Quoteinvestigation.com has published references to support its conclusion that “Albert Einstein, B. F. Skinner, Agnes F. Perkins, E. F. L. Wood, James Bryant Conant and others have used expressions in this family but none of them claimed authorship.”⁷. The evidence for James Bryant Conant, President of Harvard University in 1943, carries the most resemblance to a liberal arts origin⁸. That is “A general education is something apart from a specialized vocational or professional training. It is, if you will, education for citizenship or education of the whole man as distinct from the development of certain skills or the acquirement of certain knowledge. It concerns “that which is left after all that has been learned has been forgotten”⁸. Such an education perspective is consistent with the pedagogy of relating kinematics training to liberal arts writing. The conceptual diagram in Figure 1 is simple for a student to remember.

The first -score and post- score upon receiving writing improvement recommendation have been used to assess the pedagogy effectiveness in terms of correlation and relative gain. A correlation graph with post-score as the y-axis and first score (or pre-score) as the x-axis would demonstrate any gain as a result of the kinematics thinking driven writing pedagogy. The ratio of post-score / pre-score is related to the relative gain by a subtraction of 1. In other words, the slope of the post-score versus pre-score minus one would be a measure of the relative gain using the (post-pre)/pre concept.

The learning assessment rubric of Highly Competent, Competent, and Needs Improvement versus Participant Deliverables was used. An improvement was observed in the grades of discussion sections of lab reports. The student relative gain was about 0.2 (N = 22 and N = 20, two classes) in the assessment model using highly competent =1, competent = 0.8 and needs improvement = 0.6). The rubric guideline is displayed in Table 1.

The assessment result suggests that the modeling of liberal arts writing in the context of diagrammatic kinematics thinking would help students to improve on their physics lab report writing.

Participant Deliverable	Highly Competent	Competent	Needs Improvement
Linking three concepts in a sentence (20%)	Wrote a sentence clearly and concisely that involved three concepts. More than 3 sentences in report.	Wrote a sentence clearly and concisely that involved three concepts. Only 2 such sentences in report.	Wrote one sentence that involved three concepts.
Linkage at two different depths (20%)	Provided at least two examples on concept linkage at two different depths.	Provided one example on concept linkage at two different depths.	Provided no example on concept linkage at two different depths.
Continuity transitions between paragraphs (20%)	Provided at least two examples on continuity transitions between paragraphs.	Provided one example on continuity transitions between paragraphs.	Provided no example on continuity transitions between paragraphs.
Non-sequential inter-relationship between paragraphs (20%)	Provided at least two non-sequential inter-relationships between paragraphs' examples.	Provided one non-sequential inter-relationship between paragraphs' example.	Provided zero non-sequential inter-relationship between paragraphs' example.
Objectivity science favor (20%)	Provided at least three examples on objectivity with consistent logic.	Provided two examples on objectivity with consistent logic.	Provided no example on objectivity.

Table 1: Kinematics thinking driven writing assessment rubric. The participants are students. Scoring could be performed when assigning Highly Competent = 1, Competent = 0.8 and Needs Improvement = 0.6.

IV. Discussion

The kinematics critical thinking driven writing pedagogy yielded about a 20% relative gain in our assessment data. A course outcome of meeting the College Writing Intensive requirement for graduation is important for students' learning and graduation statistics. Our College Writing Intensive Guidelines requires the following: "The students' written work is an integral part of the

course grade. When combined with short-answer and multiple-choice tests and other forms of assessing student mastery of material, writing assignments should figure significantly (for example 30%) in the overall assessment”¹. A 20% relative gain in our assessment data suggests that the pedagogy is helping students to meet the writing intensive component of the course outcomes in terms of writing better in the deliverables.

The low gain could mean that there is a threshold in writing. The SAT writing score for Technology majors (475 in 2014 SAT) is about the same as the Education majors (482 in 2014 SAT). A comparison of writing from Education majors, taking our department PH101 course titled “The Principles of Physics”, showed that the objectivity is also a difficult concept to master in PH101 lab report writing. Students in liberal arts taking our introductory astronomy lab course usually have the writing style of Who, What, Where, When, Why and How in command without much grammar difficulty while arithmetic operations such as fraction computation remain as a challenge⁹. It is interesting to note that event-related potential (ERP) measurement has been used for orthographic analysis of word recognition, and recently it was reported that ERP data can predict reading skill improvement one year before^{10, 11}. Whether the writing would be heavily influenced by word recognition speed is an interesting question. For better writing beyond objectivity, the style of a writing could also be analyzed with arithmetic, according to a recent summary in Scientific American¹². Our fractal analysis of musical singing aesthetics reported earlier could be used to quantify the rhyming in a lab report discussion for correlation with kinematics thinking in future studies¹³; consistent with numerical analysis reports on writing style in terms of fractal dimension and trend calculations in English Literature and Chinese Literature^{14, 15, 16}.

It is possible that the working rubric described in Table 1 is not of the best design¹⁷, and that an assessment should have been conducted at Physics II course on those students learning the kinematics critical thinking driven writing pedagogy. The PNAS paper of Reference 17 used writing that contains Chi-square information as a rubric for physics lab assessment at Stanford University, which is different from the Table 1 rubric focusing on liberal arts writing elements. Instead of Chi-square information, we at a community college setting ask students for discussion of uncertainty. The lab report writing of the obtained uncertainty values in the measured physical quantities with reference to the theoretical uncertainty formulas based on calculus consideration would give justification to the phrase “human error” beyond psychology. The concept of “One could be wrong” would promote intellectual humility¹⁸, which together with intellectual confidence for exploring with aspiration and intellectual ethics for fighting plagiarism will form a practical triad to describe intellectual energy from a liberal art perspective. The failing rate of about 35% in our Physics I lecture section certainly would not have helped writing pedagogy success in the lab section since critical thinking at the algebra level would be in question, let alone thinking in terms of the inter-relationship as illustrated in Figure 1. The commercial web sites such as preschlar.com on “How to improve writing” could

be of help ¹⁹, but such activity would belong more to the tutoring centers in a college setting. It should be noted that socioeconomic differences in vocabulary, evident at 18 months and 7 months with female infants ^{20, 21}, could have an impact on the relative gain assessed in this project conducted in a minority serving community college. While a path analysis had indicated that “language comprehension is more critical for later word-problem (math) solving than pre-algebraic knowledge ²², this kinematics thinking driven writing pedagogy project could just be a “second best” approach to improve lab report writing. However, this project is still of value in our community college setting with many homework practices, based on recent neuroscience results that learning would depend on epigenetics and memory would depend on neuro network oscillation ^{23, 24}.

When a student is engaged in a discovery lab, aligned with learning-cycle theory pioneered by Karplus in the 70s and further championed by others^{25, 26, 27}, the assessment rubrics would include a deliverable in the area of literature survey. A paragraph using a student’s own writing, instead of “copy and paste” from a textbook, would reflect the understanding. An extension of the assessment rubrics listed in Table 1 would be useful for a student to do self-assessment on his/her undergraduate research project and paper writing. Such an assessment rubrics for undergraduate research paper writing has been used by us. The research paper writing assessment rubrics, Table 2, provides the criterion used in each deliverable. Assessment of the improvement in research paper writing, which is part of the course outcomes in our independent study research course, showed a relative gain of about 50% with a small database (N = 5). The continued implementation of the writing strategy in Physics II using cause and effect critical thinking could be of interest in a following up project. Whether the “Effective Verbal Persuasion” technique reported recently can be adapted to become convincing writing style would be an important future investigation ²⁸.

Participant Deliverable	Highly Competent	Competent	Needs Improvement
Introduction literature survey and hypothesis explanation (20%)	Using top-tier journals like Science, PNAS etc. in the writing (using “well known journal” as criterion).	Using non-top-tier journals in “well known” databases, Scopus, PubMed etc.	Using only online non-reviewed blog information.
Data integrity (20%)	Using data from Space Station, Fermi National Lab, Genbank, etc. (using “well known” database as criterion).	Using data from a professor’s lab.	Using only data from non-reviewed sources such as Youtube, etc. other than videos from NASA, universities, etc.
Data analysis method/tool (20%)	Using methods/tools published by “well known” journals and/or NIH, NASA, Fermi Lab, etc. (using “well known” as criterion).	Using only tools learned at college classes.	Using only tools at the high school level.
Discussion (20%)	Answering recent questions posed on “well known” journals (using “well known” as criterion).	Answering questions posed on graduate student unpublished theses.	Answering only questions posed on non-reviewed sources without any reference to a reviewed source.
Conclusions (20%)	Containing future study direction in a clear logical writing with relationship to the studied hypothesis (using logical thinking as criterion).	Containing future study direction in clear logical writing.	Containing illogical sentences.

Table 2: Assessment rubric for undergraduate research paper writing. The participants are students. Scoring could be performed when assigning Highly Competent = 1, Competent = 0.8 and Needs Improvement = 0.6.

V. Conclusions

We have reported our pedagogy of liberal arts writing in the context of kinematics thinking from SAT training to poetry writing. The feedback of writing onto kinematics thinking was highlighted with an example in logic. An assessment rubric was put forward for quantitative analysis with the use of statistics to measure the correlation and relative gain. Future studies

could include an examination of the effect of writing fluid intelligence on kinematics fluid intelligence building.

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VII. Bibliography

1. Queensborough Writing Intensive Policy. <http://www.qcc.cuny.edu/WIDWAC/wiGuidelines.html>
2. College Board SAT result statistics 2014
<https://research.collegeboard.org/programs/sat/data/archived/cb-seniors-2014>
3. SAT score result listed by majors
<http://www.businessinsider.com/heres-the-average-sat-score-for-every-college-major-2014-10>
4. SAT score result listed by race/ethnicity
<https://nces.ed.gov/fastfacts/display.asp?id=171>
5. Vaughan-Evans A, Trefor R, Jones L, Lynch P, Jones MW, Thierry G. Implicit Detection of Poetic Harmony by the Naive Brain. *Front Psychol.* 2016 Nov 25;7:1859. eCollection 2016.
<https://www.ncbi.nlm.nih.gov/pubmed/27933025>
6. Bloomberg.com Logic Questions on the SAT Math Section Dec 24 2013
<https://www.bloomberg.com/news/articles/2013-12-24/logic-questions-on-the-sat-math-section>
(Last accessed 3/7/2017)
7. Quoteinvestigation.com <http://quoteinvestigator.com/2014/09/07/forgotten/>
8. The 1943 February 21, New York Times, Section: New York Times Magazine, No Retreat for the Liberal Arts: Dr. Conant is confident that they will survive the war by James Bryant Conant (President of Harvard University) Start Page SM5, Quote Page SM37, New York. (ProQuest)
9. Le Watanabe Crockett. 2016. The critical thinking skills cheat sheet
<https://globaldigitalcitizen.org/critical-thinking-skills-cheatsheet-infographic>
10. Carreiras M, Armstrong BC, Perea M, Frost R. 2014. The what, when, where, and how of visual word recognition. *Trends Cogn Sci.* 2014 Feb;18(2):90-8.
<https://www.ncbi.nlm.nih.gov/pubmed/24373885>
11. Stites MC, Laszlo S. 2017. Time will tell: A longitudinal investigation of brain-behavior relationships during reading development. *Psychophysiology.* 2017 Feb 23.
<https://www.ncbi.nlm.nih.gov/pubmed/28229468>
12. Mark Fischetti. 2017. Great Literature Is Surprisingly Arithmetic.
<https://www.scientificamerican.com/article/great-literature-is-surprisingly-arithmetic/>
13. George Tremberger Jr, Sunil Dehipawala, David Lieberman and Tak Cheung 2016. Engineering Parameters of Musical Singing Aesthetics and Application to Affective Computing. EEECOS 2016 June 1-2 Conference Proceedings, SASI Institute of Technology & Engineering, pp 622-625.
<http://eeecos.org/papers/ES0331.pdf>

14. Andrew J. Reagan et al. 2016, "The Emotional Arcs of Stories Are Dominated by Six Basic Shapes," by EPJ Data Science, Vol. 5, No. 1, Article No. 31; December 2016
<https://arxiv.org/abs/1606.07772>
<http://link.springer.com/article/10.1140/epjds/s13688-016-0093-1>
15. Stanislaw Drozd et al. 2016, in "Quantifying Origin and Character of Long-Range Correlations in Narrative Texts," Information Sciences, Vol. 331; February 20, 2016
<http://www.sciencedirect.com/science/article/pii/S0020025515007513>
16. Yang T, Gu C, Yang H. 2016
 Long-Range Correlations in Sentence Series from A Story of the Stone.
 PLoS One. 2016 Sep 20;11(9):e0162423
<https://www.ncbi.nlm.nih.gov/pubmed/27648941>
17. N. G. Holmes, Carl E. Wieman, and D. A. Bonn. 2015. Teaching critical thinking. PNAS vol. 112 no. 36, 11199–11204 (2015 September).
<http://www.pnas.org/content/112/36/11199.short>
18. Mark R. Leary (2017) , Kate J. Diebels, Erin K. Davisson, Katrina P. Jongman-Sereno, Jennifer C. Isherwood, Kaitlin T. Raimi, Samantha A. Deffler, Rick H. Hoyle. Cognitive and Interpersonal Features of Intellectual Humility. Personality and Social Psychology Bulletin, Article first published online: March 17, 2017
 DOI: <https://doi.org/10.1177/0146167217697695>
19. ACT writing rubrics. 2015 August 22.
<http://blog.prepscholar.com/act-writing-rubric-analysis-essay-strategies>
20. Fernald A (2013), Marchman VA, Weisleder A. SES differences in language processing skill and vocabulary are evident at 18 months. Dev Sci. 2013 Mar;16(2):234-48. <https://www.ncbi.nlm.nih.gov/pubmed/23432833>
21. Betancourt LM (2015), Brodsky NL, Hurt H. Socioeconomic (SES) differences in language are evident in female infants at 7months of age. Early Hum Dev. 2015 Dec;91(12):719-24
<https://www.ncbi.nlm.nih.gov/pubmed/26371987>
22. Fuchs LS (2016), Gilbert JK, Powell SR, Cirino PT, Fuchs D, Hamlett CL, Seethaler PM, Tolar TD. The role of cognitive processes, foundational math skill, and calculation accuracy and fluency in word-problem solving versus prealgebraic knowledge. Dev Psychol. 2016 Dec;52(12):2085-2098.
<https://www.ncbi.nlm.nih.gov/pubmed/27786534>
23. Gene E. Robinson, Andrew B. Barron (2017). Epigenetics and the evolution of instincts. Science, Vol. 356, Issue 6333, pp. 26-27. <http://science.sciencemag.org/content/356/6333/26>
24. Nicolette Ognjanovski et al. (2017) Parvalbumin-expressing interneurons coordinate hippocampal network dynamics required for memory consolidation. Nature Communications 8, Article number: 15039 (2017)
<http://www.nature.com/articles/ncomms15039>
25. Karplus R. 1977. Science teaching and the development of reasoning. J Res Sci Teach. 1977;14:169.
26. Bergquist W. 1991. Role reversal: Laboratory before the lecture. Physics Teacher. 1991;29:75–76.
27. Stewart M, Stavrianeas S. 2008. Adapting the learning-cycle to enrich undergraduate neuroscience education for all students. J Undergrad Neurosci Educ. 2008 Spring;6(2):A74-7.
<https://www.ncbi.nlm.nih.gov/pubmed/23493626>
28. Hendel, RJ. Effective Verbal Persuasion in Prayer, Business, and Teaching
 WMSCI 2016 - 20th World Multi-Conference on Systemics, Cybernetics and Informatics, Proceedings, pp311-316
<http://www.iiis.org/CDs2016/CD2016Summer/papers/SA910GI.pdf>