Interdisciplinarity in Engineering education: Trends and Concepts

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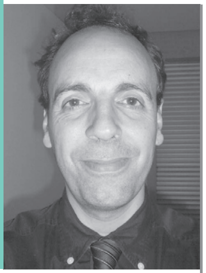
Interdisciplinarity in engineering is a topic whose potential is not always matched by actual success. A perspective is presented here on when interdisciplinarity is capable of being helpful to success. Different examples of interdisciplinarity are presented in fields like neuroscience, films, computer games, gene development, and power grids. The role of interdisciplinary complexity in defining both the wealth of a nation and the value of universitary education are also discussed.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INTERDISCIPLINARITY ISSUES

The topic of interdisciplinarity is one that any university must address in order to be successful in a world where technological integration is a major source of technological development. But there are correct and incorrect approaches to intedisciplinarity. What interdisciplinarity should not be is: i) a group of people each an expert on everything; ii) putting people from different expertise in the same place and hoping interdisciplinary stuff happens; iii) creating the tools for everything that is needed in all fields. What interdisciplinarity should be is: i) establishment of communications that enable idea-filtering; ii) idea-filtering creating information that is useful; iii) allowing that useful information to become institutional knowledge, which for Eric Beinhocker in his Origin of Wealth book is the true wealth of any institution [1].

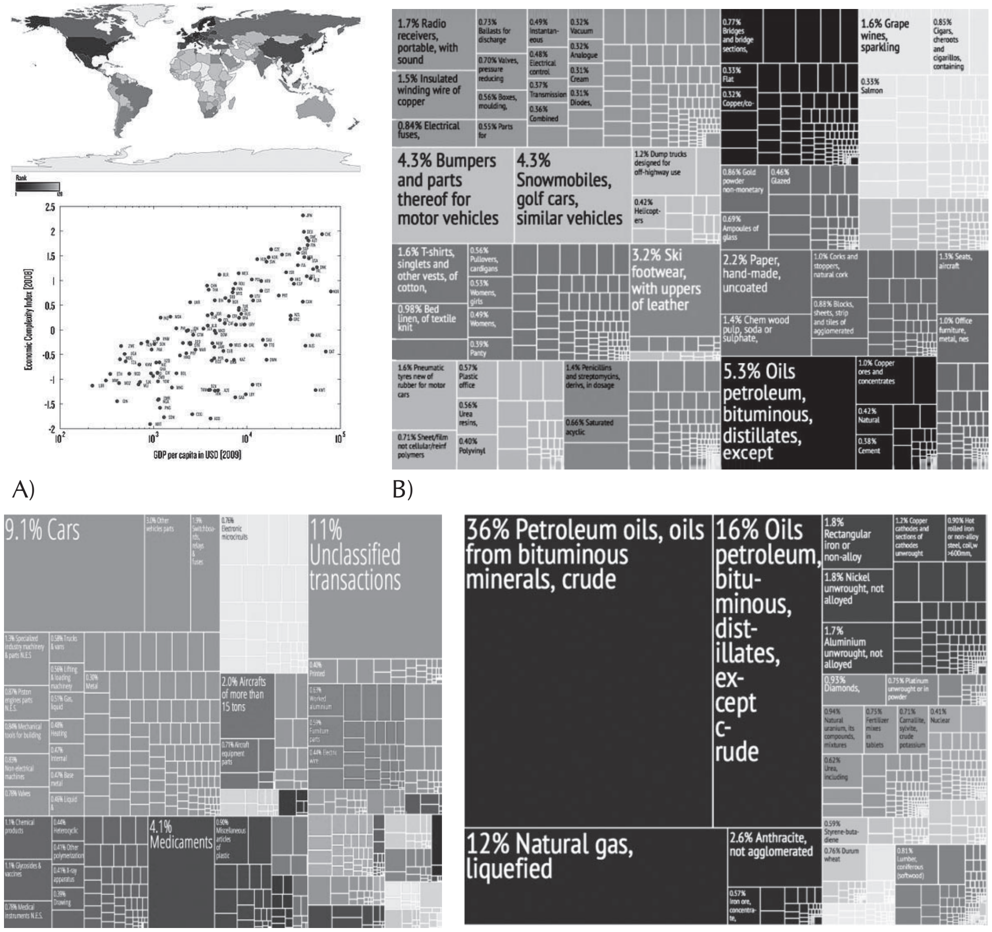
Interdisciplinarity correctly done can thus be a source of wealth. A university interested in exploring the major advantages of interdisciplinarity should do the following: i) degrees based on topics rather than fields, e.g. a degree on solar panel construction rather than a course on mechanical engineering which can be applied to a lot of things but cannot make anything with it; ii) have language classes integrated within the degrees based on what are the countries with the most job offerings for that degree; iii) built the degree based on what employers are saying they are needing right now, and forecasting the job offerings of the future.

In the perspective of complexity economics proposed by Eric Beinhocker [1], wealth is useful information institutionally implemented, meaning information that can be used to build things by that institution (an institution can be as small as a single person). Information is directly related to entropy, in that entropy equals the total amount of information in a system. In complexity economics, the economical environment is represented as a system of interacting atoms, except that now the atoms can make elaborate decisions. In a system of freely moving interacting atoms, like in a liquid, the atoms undergo Brownian motions which can be approximated by random walks. Random walks in Chaitin's Meta Math! [2] are described as general purpose tools which can describe Darwinian evolution. Likewise in complexity economics, the

Fig. 1. Differences Between Standard Economics and the Complexity Economics.

	Traditional economics	Economy as Complex Adaptive System
Dynamics	Economies are closed, static, linear systems in equilibrium	Economies are open, dynamic, non-linear systems far from equilibrium
Agents (human behaviour)	Spock-like. Only use rational deduction. Have perfect information and infinite computational power. No errors, biases and hence no learning needed.	More like Bart Simpson. Mix deductive/inductive decision-making, i.e., rules of thumb. Imperfect information and finite computing power. Makes mistakes, learns and adapts over time.
Networks / institutions	Assumes people only interact indirectly through market mechanisms. Information is adequately conveyed by prices and quantity.	Explicitly accounts for network structure of interactions and institutions.
Linergence	Macro patterns are the linear adding up of micro behaviours. Agents are homogenous and representative.	Macro patterns emerge non-linearly from micro behaviours and interactions.
Evolution	Contains no endogenous mechanism for creating novelty, or growth in order and complexity.	Evolutionary process creates novelty and growing order and complexity over time.

Fig. 2. The economic complexity index (ECI) [3, 4] is a measure defined at the Harvard-MIT Observatory of Economic Complexity) of the production characteristics of large economic systems, usually whole countries. A) Global ECI levels. B) ECI components for Portugal; C) ECI components for Germany; D) ECI components for Russia.



A)

B)

C)

D)

economical systems evolve in a landscape of all possible economical systems. Evolution is an all-purpose formula for innovation, a formula that, through its special brand of trial and error, creates new designs and solves difficult problems. Evolution can perform its tricks not just in the "substrate" of DNA, but in any system that has the right information-processing and information-storage characteristics, e.g. the business plan of a company.

Evolution's simple recipe of "differentiate, select, and amplify" is a type of computer program. It can do its order-creating work in realms ranging from computer software to the mind, to human culture, and to the economy [2].

But a more complex economy is likely to require changes in social interaction. In the work by Oishi and Kesebit [5] it is analyzed what is the optimal social networking depending on the surrounding economical conditions. Let's say we have a population of 1,000 people with 10 friends each and no "random" friends. That is, everyone's friends are drawn only from a strictly defined social circle [family and neighbors]. In that case, the average degree of separation is 50; in other words, on average it will take 50 hops to get from one randomly selected person to another. But if we now say that 25% of everyone's friends are random [not family or neighbors], that is, drawn from outside their normal social circle, then the average degree of separation drops dramatically to 3.6.

In an extreme narrow [deep ties] social network, there are no random friends. In a extreme broad [weak ties] all the friends are "random". The obtained results [5] indicate that narrow [deep ties] are only economically favorable in low mobility high crisis probability situations, and on low residential mobility low median income situations; for all other situations brad [weak ties] are better.

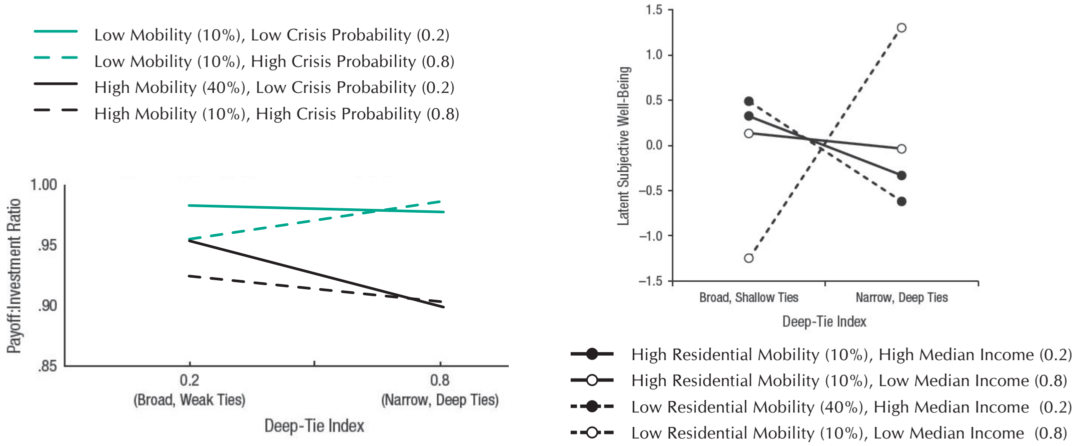
INTERDISCIPLINARITY EXAMPLES

As interdisciplinary examples, we will consider: i) Neuroscience; ii) Films & Games; iii) Gene Development; iiii) Contemporary National Grid. Each of these topics involves several presently-existing courses, but each of the examples only uses a part of those courses, so a possibility for a university would be to focus on the topic, so that someone with a degree in the topic could coordinate (and/or implement) the interactions between people with presently existing degrees.

DISCUSSION

We address the correct and incorrect approaches to interdisciplinarity in engineering. The reason for the correctness of an interdisciplinary approach is directly related to its capacity to address the major difficulty of interdisciplinar-

Fig. 3. Oishi and Kesebit's [5] results on what is the optimal social networking.



ity, the impossibility of being up-to-date in all the disciplines. It is hard enough keeping up-to-date in one discipline, keeping up-to-date with all the disciplines that interact in an interdisciplinary way is virtually impossible. That has always been the drawback of interdisciplinary approaches to engineering education, no matter how well prepared a student is by the university, without the permanent professor-induced and colleague-induced pressure to perform, the student loses contact with the relevant literature in a short amount of time. If that is relevant for standard degrees, it is even more so for interdisciplinary degrees.

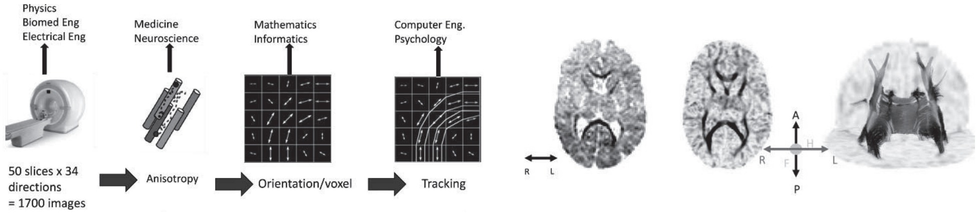
The remedy we propose is that the interdisciplinary degree focuses in production topics, meaning that the student has an interdisciplinary education focused around the generation of a certain type of product. The focus is not the area of knowledge, but the area of production. Focusing on the production is likely to increase the usefulness of the student in the job market, and if a certain form of production disappears, what appears after is likely to be an evolution of previously existing forms of production. So, all the ex-student will be asked to do after finishing the degree is to keep up with the evolution in the production techniques associated to the student's area of expertise.

Table 1. Relation Between Topcs and Presently Existing Universitary Courses.

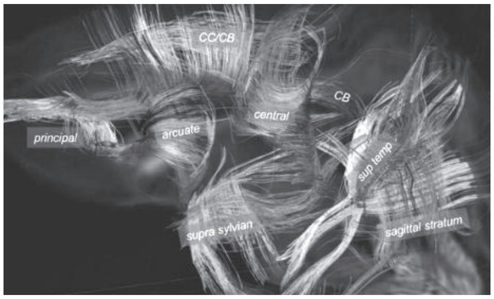
Topics	Presently Existing Courses
Neuroscience	Genetic Eng., Social Sciences, Biomedical Eng., Psychology, Physics
Films & Games	Marketing, Computer Eng., Literature, Management, Publicity
Gene Development	Bioinfomatics, Genetic Eng, Biomedical Eng., Physic, Computer Eng.
Contemporary Power Grid	Electrical Eng., Mechanical Eng., Informatics, Transportation Eng.

Figure 4. Examples of Interdisciplinary Areas.

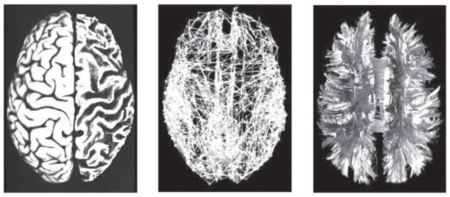
DIFFUSION MRI DATA PROCESSING IN NEUROSCIENE



DIFFUSION SPECTRUM IMAGING (DSI)
RESULT [6] USING DIFFUSION MRI



DIFFERENT BRAIN CONNECTION RESULTS
(E.G., DSI ON THE RIGHT) USING THE HUMAN
CONNECTOME CONCEPT [7]



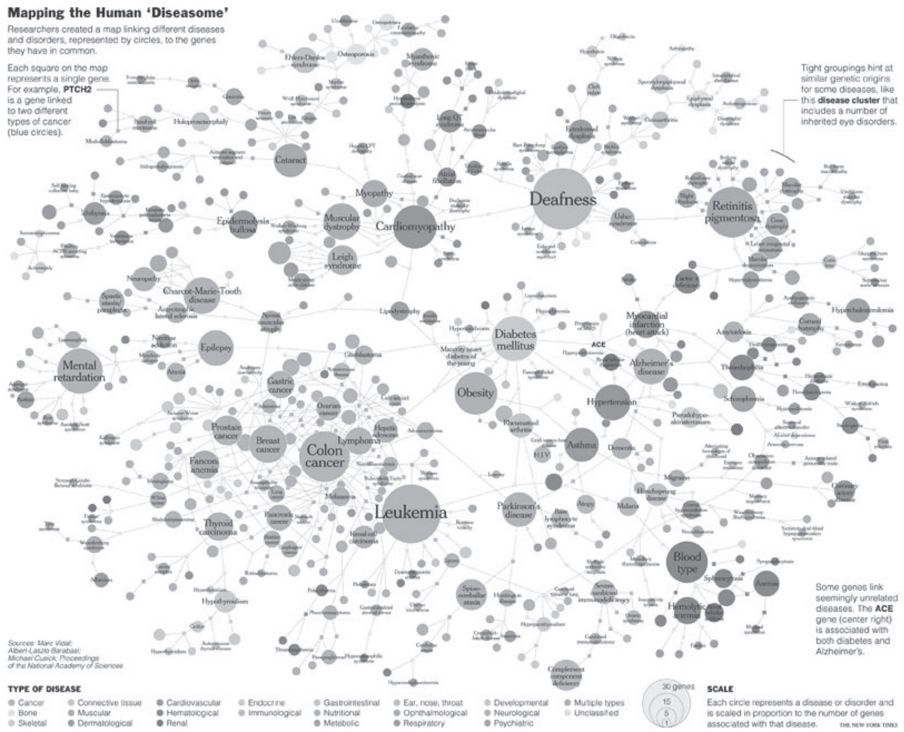
Anatomy
Klingler's method for fiber tract dissection uses freezing of brain matter to spread nerve fibers apart. Afterwards, tissue is carefully scratched away to reveal a relief-like surface in which the desired nerve tracts are naturally surrounded by their anatomical brain areas.

Connectome
Shown are the connections of brain regions together with "hubs" that connect signals among different brain areas and a central "core" or backbone of connections, which relays commands for our thoughts and behaviors.

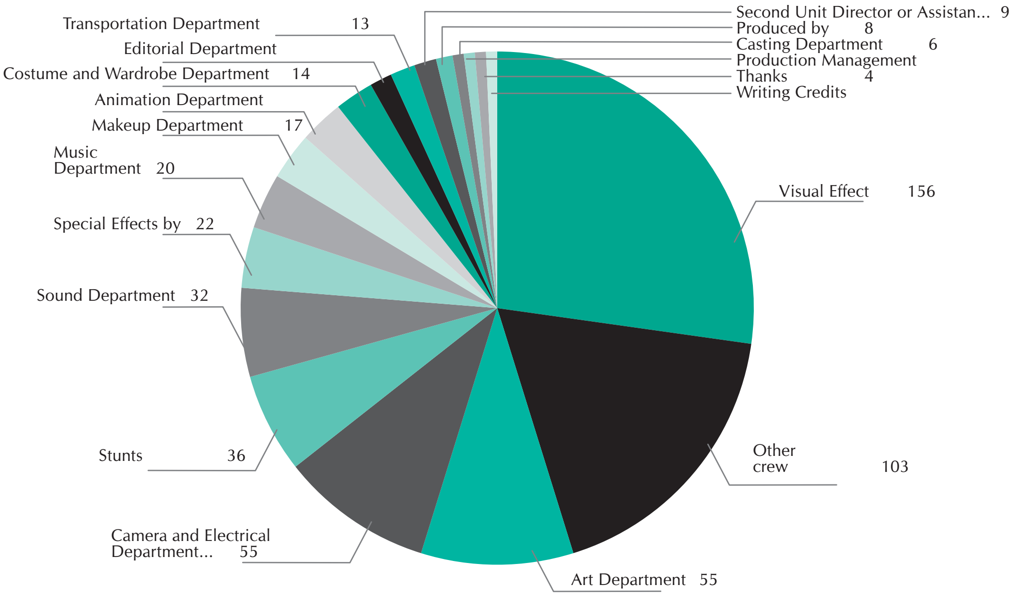
Neuronal Pathways
A new MRI technique called diffusion spectrum imaging (DSI) analyzes how water molecules move along nerve fibers. DSI can show a brain's major neuron pathways and will help neurolo-gists relate structure to function.

Fig. 4. Examples of Interdisciplinary Areas.

MAP OF GENETIC RELATION BETWEEN DISEASES, THE DISEASOME [8]



DISTRIBUTION ACROSS EXPERTISE AREAS FOR AN AVERAGE FILM PRODUCTION BETWEEN 1994 AND 2013 (550 PEOPLE)



SUGGESTED READING

1. Damasio A. R. Looking for Spinoza: joy, sorrow, and the feeling brain / A. R. Damasio. – Orlando, Fla, 2003. – 365 p.
2. Organizational trust: a reader / R. M. Kramer, ed. – N. Y., 2006. – 496 p.
3. Panikkar R. The silence of God: The answer of the Buddha / R. Panikkar. – Maryknoll, N.Y., 1989. – 294 p.
4. Levine P. Waking the tiger: healing trauma / P. Levine, and A. Frederick. – Berkeley, Ca., 1997. – 274 p.
5. Cognitive and neural foundations of religious belief / D. Kapogiannis [et al.] // PNAS. – 2009. - Vol. 106, № 12. – P. 4876–4881.
6. Unequal chances: family background and economic success / ed. by S. Bowles, H. Gintis, and Osborne Groves M. – N. Y. ; Princeton, NJ, 2005. – 310 p.
7. Penn D. C. On the lack of evidence that chimpanzees possess anything remotely resembling a 'theory of mind' / D. C. Penn, and D. J. Povinelli // Philos. Trans. of the R. Soc. B : Biol. Sci. – 2007. – Vol. 362, № 1480. – P. 731–744.
8. Lori N. F. Matter and selfhood in Kant's physics: a contemporary reappraisal / N. .F Lori, P. Jesus. // Relations of the Self / E. B. Pires, B. Nonnenmacher, and S. Büttner von Stülpnagel (Eds.). – Coimbra, 2010. – P. 207–225.

REFERENCES

1. Beinhocker E. D. The origin of wealth: evolution, complexity, and the radical remaking of economics / E. D. Beinhocker. – Cambridge, MA, 2006. – 527 p.
2. Chaitin G. J. Meta Math! : the quest for omega / G. J. Chaitin. – N. Y., 2006. – 234 p.
3. Hidalgo C. A. The building blocks of economic complexity / C. A. Hidalgo, R. Hausmann // PNAS. – 2009. - Vol. 106, № 26. – P. 10570–10575.
4. The atlas of economic complexity mapping paths to prosperity / R. Hausmann, C.A. Hidalgo [et al.]. – New Hampshire, 2011. – 80 p.
5. Oishi S. Optimal social-networking strategy is a function of socioeconomic conditions / S. Oishi, S. Kesebir // Psychol. Sci. – 2012. – Vol. 23, № 12 (Dec.). – P. 1542–1548.
6. The geometric structure of the brain fiber pathways / V. J. Wedeen [et al.] // Science. – 2012. – Vol. 335, № 6076. – P. 1628–1634.
7. Sporns O. The human connectome [Electronic resource] : courtesy of Little, Brown and Company [published in 6th Iteration (2010): Science maps for scholars] / Olaf Sporns, and Patric Hagmann // Places & spaces: mapping science : [website] / ed. by K. Börner, and E. F. Hardy. – Bloomington, IN, [2006–2014]. – URL: http://scimaps.org/maps/map/the_human_connectome_115, free. – Tit. from the screen (usage date: 06.06.2014).
8. Biologie : l'ère numérique / sous la direction de M. Roux ; préface de P. Tambourin et F. Russo-Marie. – Paris, 2009. – 259 p.
9. Follows S. How many people work on a Hollywood film? [Electronic resource] // [Blog of Stephen Follows]. – [San Francisco,Ca.], © 200-2014 Stephen Follows. – URL: http://stephenfollows.com/how-many-people-work-on-a-hollywood-film/, free. – Tit. from the screen (usage date: 31.05.2014).