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George Klir and the Great Chain of Ideas

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Abstract

Earlier this year, I received sad news that my good friend and dear colleague George Klir is no more. George was a great scientist – and, in my opinion, a greatly underestimated one. I therefore believe that it will be beneficial to explain his true role in science.

Great chain of ideas. To better explain the contributions to George Klir to science, it helps to first recall, in detail how scientific contributions are made in general.

Readers of popular science article and books and viewers of popular movies sometimes get an impression that scientific theories emerge ready from the heads of the genius scientists – like the Greek Goddess Athena who appeared from Zeus's hear fully grown and even in armor. Einstein starts thinking – and suddenly equations of relativity theory appear on board.

We scientists know better. Yes, there are geniuses, and yes, without them, we would not have had these ideas – but it is usually a long and painful way from these ideas to the final equations. Special relativity is a good example. Its main idea is *relativity principle* – that there is no way to distinguish between rest and motion with a constant velocity. Contrary to some of the popular articles and books, Einstein did not invent this principle – it was already explicitly formulated by Galileo a few centuries earlier. What Einstein did was was transformed this principle from its philosophical form to a practical tool that helped him solve the problems of space-time.

But special relativity as we know it now did not stop with Einstein's ideas. Einstein was definitely a genius, and to solve several different problems, he used a lot of physical ingenuity, with creative thought experiments. But Einstein did not leave us with a general way of solving all related problems, he used a different trick every time. Modern textbooks do not use all of these tricks, they use general mathematical formalism of 4-dimensional space-time – a formalism that was developed not by Einstein himself, but a few years later by Hermann Minkoswki.

This is how every idea evolves in science. It starts with a vague, somewhat philosophical idea, an idea which is far away from practical applications. This idea then get transformed into something more practical – but still require a lot of thoughts and developments to be applied. And finally, the originally vague idea is transformed into precise mathematical form – and then a computationally efficient mathematical form, thus enabling people to use it without much intellectual effort – like even a freshman engineering student can use calculus to find the optimal values of corresponding parameters.

Just like medieval people envisioned the world as the Great Chain of Being, form un-animated matter to animal to humans to angels and finally to God, so do ideas of science evolve, following a similar great chain of ideas.

So who is the author? So who is the author of special relativity? The answer may depend on who you ask.

To some philosophers, it is undoubtedly Galileo, he had the main idea. What Einstein and Minkowski did was icing on the cake.

To some mathematicians, it is undoubtedly Minkowski, he was the first to come up with the mathematics of 4-D space-time. Einstein had vague ideas, but it was Minkowski who made these vague ideas into a precise mathematical theory.

To most people, it is Einstein. Yes, Galileo had a vague idea, and Minkowski added some math to it, but most physical real-life applications come from Einstein.

And, of course, in reality, all three geniuses were needed. Without any of them, the chain would collapse.

George Klir and fuzzy logic. Let us now go back to George Klir and his contributions to science. George contributed to many research areas. I would to start with a research area in which I am most familiar with his research contributions: the area of fuzzy logic.

Fuzzy logic started in 1965, with the groundbreaking ideas of Lotfi Zadeh. At first, these ideas were mainly on the general-idea, kind of philosophical level, until Ebrahim Mamdani helped transform it into an engineering tool – in particular, control tool – that is so widely used today. But from the mathematical viewpoint, fuzzy logic remained a mystery. It was not formulated as a mathematical theory; moreover, several fuzzy researchers expressed a belief that fuzzy theory cannot be adequately described in mathematical terms – unless some completely new mathematics is developed. Mathematicians did not like this mysticism, they know that however weird new ideas may seem – be it quantum physics or cosmology with its black holes – good old mathematics is always an important part of a recipe to success.

The story was even more complicated, since it turned out that, from the mathematical viewpoint, a similar logic with similar "and"- and "or"-operations have been proposed in the 1920s by a Polish mathematician Jan Lukaciewicz. So, from the viewpoint of these mathematicians, Zadeh's new theory was simply philosophical discussions of Lukaciwecz's logic – and success of Mamdani-type

fuzzy control was somewhat irrational, similar to the sometime success of voodoo healers.

But this was an opinion of those mathematicians – unfortunately, there were and there still are many of them – who under-appreciated informal ideas, who did not fully understand that precise ideas do not come out of nowhere, they have to be nurtured out of imprecise ones. George Klir was one of the few mathematicians who well understood this. He appreciated the ideas, he appreciated the practical successes, and he did not believe in semi-mystical impossibility to mathematize. And so he started mathematizing.

He was not the only one, there were many talented mathematicians who succeeded in formalizing different aspects of fuzzy logic and fuzzy control. However, the first one who came up with a convincing mathematized description of fuzzy logic and fuzzy control was George Klir, and he presented all this, in a traditional-in-mathematics definition-theorem style, in the 1988 book that he wrote with Tina Folfer and than in the 1995 book that he wrote with his then student Bo Yuan. This book became very popular, it was extremely well cited – and it, in effect, ended philosophical discussions about the impossibility to describe fuzzy logic in precise mathematical form. This was George Klir's touch of genius.

Not only the original fuzzy logic, but also all its modifications – interval-valued, type-2, etc. – were presented in precise mathematical form.

Not only fuzzy logic. Fuzzy logic was not the only area in which George Klir contributed his genius to translating informal ideas into precise terms. Another such important area was systems theory. Before George, systems theory and systems approach were – as often happens – a mixture of philosophical ideas, practical recipes, and some precise mathematical techniques, with a strong emphasis on imprecise philosophy. I remember how at one of the fuzzy conferences, when George was presenting possible applications and advantages of systems approach, a projector suddenly stopped working, and Lotfi Zadeh jokingly suggested "Use system approach". This was the attitude back then.

And how different it is now, after George Klir and other researchers made most of these ideas precise. To see the difference, one can simply look at the latest issues of the International Journal of General Systems – the journal that George founded and whose Editor in Chief he remained almost until his last days – yes, there are still interesting philosophical papers, but most of what is published is solid math, with good applications.

Another area which he helped mathematize is information theory. Claude Shannon, the genius author of the original paper on information theory, formulated it in a very engineering way, without a mathematical justification for all his formulas. Shannon's original formulas were originally formalized, but many reasonable – and practically successful – generalizations of these formulas remains purely heuristic. In his book on uncertainty and information, George Klir provides a convincing mathematical explanation for all these formulas.

So, George' contribution to the great chain of ideas covered three important research areas: fuzzy logic, systems approach, and information theory. I hope I

explained why I consider him under-appreciated.

What George Klir upset that he was under-appreciated? Now ay, he was always happy, he was always happily promoting both his own ideas and good ideas of his colleagues and his students – what was important for him was science, not personal recognition.

And since I mentioned students, I would like to take about another related aspect of George: a teacher and a nurturer.

George Klir as a nurturer. George Klir got interesting results. Did he do it all his own, in the movie style of a lone genius? Of course not, he always had many students and collaborators working with him, he nurtured his students, he nurtured his colleagues. For example, as the Editor-in-Chief of the International Journal of General Systems, he encouraged all his editors to submit at least one survey paper a year, and personally took care of processing these papers, all the way to helping himself. He supported the authors often against ideological objections of respected people in the community – if he felt that the resulting direction is worth pursuing. Some of the resulting surveys – on topics carefully vetted by him – because among the most high cited and highly praised papers published in this journal.

I am definitely not the only one who feels this way. After George's passing, mailing lists were filled with emails from former students and colleagues who praises as a scientist, of course, but also as a nurturer and teacher.

So what can we conclude from all this? When I lived in Russia, we had a very popular song, both sad and uplifting, devoted the memory of a mountain climber who died in a climbing accident. Its last verse starts with a question: "So what we conclude from all this?" ("Chto zhe iz etogo sleduet?"), and the answer that follows is simple: "That we should continue living" ("Sleduet zhit'!").

What can we conclude from the story of George Klir and his contributions to the great chain of ideas? That we should continue what he started, that all of us should do our best in our own place in this chain, and we should teach others to do our best. Let each of find what he or she does best: coming with us with new ideas, transforming raw ideas into practical applications, coming us with mathematical foundations for successful heuristic methods. And together, let us continue expanding the great chain of ideas, so that we should eventually be able to understand more and more about the world, predict more and more about the world, to get higher and higher in the great chain of being.

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