Mihai Nadin On Anticipatory Systems

What is the difference between a falling stone and a falling cat?

Mihai Nadin, who directs the newly established Institute for Research in Anticipatory Systems at the University of Texas at Dallas, holds a Ph.D. degree in aesthetics from the University of Bucharest and a post-doctoral degree in philosophy, logic and theory of science from Ludwig Maximilian University in Munich, West Germany. He earned an M.S. degree in electronics and computer science from the Polytechnic Institute of Bucharest and an M.A. degree in philosophy from the University of Bucharest. He has authored 23 books, including "The Civilization of Illiteracy," "Mind: Anticipation and Chaos," and "Anticipation: The End is Where We Start From."

UBIQUITY: Your work is at the intersection of the arts, computer science, and cognitive science, correct?

NADIN: Yes. But please add semiotics and design to the list. Especially design, the most pervasive form of human activity: from product and interior design to landscape and urban design, from visual communication to visualization, from engineering to designing new materials. And let's not forget computational design.

UBIQUITY: Is there any way that you could explain the essential nature of the connection between those ways of thinking?

NADIN: There is really no way of defining it, if by "connection" you mean a shared body of knowledge. What interests me in each of these areas is the implicit theme of underlying creativity. How in the world are people creative? And why? That's the connection I look for.

UBIQUITY: How does your work in anticipatory systems relate to that interest? Tell us about anticipatory systems.

NADIN: We learned from Descartes to look at the world only as the physical reality that he described. That perspective is his contribution to the world. Part of his method was to reduce everything that's very complex to one or more simpler things

that you can understand. Just as he reduced geometry to numbers -- and he has gone down in history for developing what we call the Cartesian coordinate system -- he operated in the same spirit, as he looked for regularities in the physical world. Based on his reductionism, we learned how to find answers to the questions from the perspective of the cause-and-effect sequence. This model works beautifully when it comes to technology. We apply it when we build and drive cars, or launch satellites, or develop computers. However, the model implies that everything can be reduced to the physical, and therefore be explained in the language of physics. Moreover, it implies that the living is nothing more than a machine that embodies determinism. Yet it's becoming ever more clear, as science discovers new facts about how the living functions, that the living cannot be reduced to the physical. My main point is that what distinguishes the living from the physical is the property, or characteristic, called anticipation.

UBIQUITY: Give us an example.

NADIN: If I drop a stone, I can calculate its position, velocity, acceleration, and everything else involved in the stone falling from position A down to position B. But if I drop a cat, I am no longer able to provide such a description, although the cat is also made of matter. In contrast to the stone -- which will fall the same way -- the cat will never fall the same way. But it will fall the right way, that is, it will not get hurt. So the cat has a characteristic in its dynamics that the stone doesn't have -- that is, anticipation.

UBIQUITY: Who's doing the anticipation there? The cat?

NADIN: Anticipation shouldn't be seen as a voluntary action, such as "I'm going to laugh before you even touch me since you are about to tickle me." Laughing before being tickled! To ask the question "Who is doing the anticipation?" would imply that there is an agent that does the anticipation, and that anticipation related to a human being has something to do with the brain. Along this line of reasoning, some look at neurons, and say that they are doing the anticipation. So it all looks like computation. But that approach is as deterministic as Descartes' explanation of the physical world, and his reduction of the living to a machine. Anticipation is the result

of many processes. Some are inherent in the system, and others are developed through learning, or through experience, or through training.

So back to your question: "Who is doing the anticipation?" In the cat, there are long-term mechanisms, which we associate with evolution, that eventually became "hardwired" in whatever the particular living being is -- whether a cat, a human being, or a monocell. But there are also processes that unfold in each new context. Evolution accounts for the past, anticipation for the present and future. This is why I call anticipation our sixth sense, the sense of context.

UBIQUITY: So what do you anticipate finding as you study anticipatory systems? Where is your research going, and how is it related to software? You want to embed the notion of anticipation in software, isn't that right?

NADIN: Yes, but first let us get our terminology straight. First of all, on the theoretical level, anticipation is complementary to reaction. Isaac Newton declared that "Actio es reactio," the reactive mode. I add, "Anticipo ergo sum," "I anticipate therefore I exist." "Anticipare" comes from "antecapere," "to understand before." That is, we exist to the extent that we also anticipate, not only react. We'll reap a very high reward in our general understanding of how things work if we realize the practical consequences of this description of the living. Now to your practical question: Where can our research go? It will contribute to the elimination of that limiting and dangerous understanding, almost universally accepted since Descartes, that the human being can be understood as a machine. Four hundred years of determinism left us with the inclination not to question it.

UBIQUITY: What was the impulse behind that conviction?

NADIN: It was a useful conviction, up to a point. Complexity was too difficult to handle, so he believed it was possible to reduce the whole to its constituent parts. And since we human beings embody the physical, as well as anticipation, the understanding of the physical entailed a certain efficiency. It points to a way we can optimize our physical efforts, including the use of tools and machines...

The description of the being as a machine is one possible description, and thus a source of knowledge. It is another thing to believe that since this description is useful, we should apply it across the board, and treat human beings as if they were machines. If it didn't work to a certain extent, this perspective would not have shaped Western civilization to the extent it has. For example, how to turn human beings into a machine to fight battles, or to produce material goods. Remember Charlie Chaplin in "Modern Times." In medicine, every individual is treated in the same way, as though we were factory-made cars with a malfunction. Turning humans into machines is tantamount to turning them into idiots, and I find the implications of this attitude profoundly disturbing.

But now to your question of whether I intend to embed anticipation into software: my answer is yes and no. In reality, every program we write is also a machine -- a digital machine. It operates on a digital representation: high precision, low (almost zero) expressive power. My focus is on a different computation: anticipatory computation. Feynman had this revolutionary thought: In order to address complex phenomena, we would need to compute in the medium that interests us. Given his interest and competence in quantum mechanics, he suggested quantum computation. Well, it's important to understand that alternative forms of computation cannot be reduced to digital computation. So if we're able to start thinking of software as a living entity, then yes, I want to embed anticipatory characteristics in software. I see this possible as a hybrid implementation: the living interacting with the program. The resulting dynamics derives from learning.

UBIQUITY: What would be a good example of that?

NADIN: My work on hybrid control mechanisms. I was the one who introduced to industry the notion of what I called "the aging car" -- by which I meant not that your car would rust a little faster or fall apart sooner, but that as you continued to drive, it would "learn" your driving habits and also take the driver's age into account. So the aging car is the car that "realizes" that your reflexes are no longer the same as when you were 20 or 30 or 40. It will not prevent you driving wherever you want to, but it will try to assist you: what is the best time of day for you to drive, now that your vision and hearing are not what they used to be. The car starts adapting to your characteristics. Adaptations result from hybrid anticipatory control mechanisms at

work. They will eventually prove to be much more interesting than the deterministic control mechanisms applied to date.

UBIQUITY: You've done some work along these lines with what Audi and Daimler-Chrysler, is that right?

NADIN: Yes, that's correct, and it was a big challenge because car manufacturers have one main thing in mind: how to sell more cars. The "aging car" would remain with one owner longer than the industry desires. But my feeling is that the automobile industry would be better off if it saw itself less in the business of selling cars and more in the business of mobility. If I need to get from A to B, my car is not just a heavy steel object, it's an instrument of my purpose. It should know who I am (my characteristics), where I am, and where I want to go, and it should help me get there. This is what motivated me in advancing a similar anticipatory idea: "How much car does a person need?" If we conceive the engine and transmission as "driving software," we could have a standard, very efficient, low-power car for most of the time, and download the "extra power" -- the software controlling the engine and transmission, when we drive the car up a steep hill, or when the load requires it. This can all be beautifully automated -- a car is a machine. And not unlike paying only for the software we use — an idea grounded in anticipation, in which I invested lots of time and energy — we would pay only for the "amount of car" we really need. Think about the task, a real technical challenge, and the benefits for the environment.

UBIQUITY: As you've talked to different groups, what have you found to be the hardest thing for people to understand about what you're saying?

NADIN: What makes my life difficult is the appearance that I'm arguing against things that seem to be working fine. The modus operandi in the USA, but not only in the USA, is, "If it ain't broke, don't fix it." Most of the time, the work people carry out within the machine model is all right. What needs to be addressed is the long-term perspective. Consider it this way. I was conditioned -- just as you were, and as everyone was -- by an education founded on cause-and-effect. So the first reaction of most people to what I try to tell them is always, "We don't need to learn about anticipation in order to accomplish what we're already doing." Let's face it, people

who have invested their lives in a way of looking at things that is not only the dominant way of looking at things but in fact the *exclusive* perspective of the day, will find it very hard to come to grips with any other kinds of thinking. When it comes to things they cannot accomplish through the model they are captive to, the answer is: Not yet. But physics has all the answers.

UBIQUITY: Does it help to give them examples from different domains?

NADIN: Absolutely. Inventions take place in anticipation and not in reaction to reality. Science is always anticipatory. And when we are not anticipatory we end up facing difficulties. For example, the health system. Health was the subject of the art of healing. Now, after the industrial age, physicians are trained to look at human health entirely from the perspective of determinism. They become engineers, and fix the machine as it breaks down. In reality, health has much more to do with anticipation than with cause-and-effect.

This inevitably makes the discussion tremendously difficult at the beginning. But once they start comparing the deterministic and the anticipatory perspectives, then people's positions soften. To make progress along these lines, they simply have to come to understand that you can get only so far by applying the deterministic method, no matter how good that is, but that you can get much further if you start adopting an anticipatory perspective. The same thing applies to work and the future of work. Let's face it, at first, companies work hard to turn workers into parts of the working machine. Once the job is describable through regular patterns, the machine can take over. The jobs that involve anticipation are the jobs that machines cannot take over. And are difficult to outsource. Creativity cannot be outsourced.

UBIQUITY: Let's assume, then, that as they obtain insight at some point, do they then still have trouble figuring out what to do with that insight in the creation of practical systems?

NADIN: Yes. There are many difficulties in this respect. We all expect, we were all taught to expect, that if you solve a problem you thereby solve a whole family of problems. In the world of physics, we are dealing with homogeneous entities that are supposed to behave the same way under the same circumstances. The living does

not do that. The living is infinitely diverse, and different, and by definition, creative -- in the sense that a living being is not a copy of a past state. It's always in the new state. Accordingly, anticipation addresses things not repetitive in nature.

UBIQUITY: What does that mean, then, for the scientist?

NADIN: It means that traditional validation techniques, as applied today, don't apply. You won't be able to reproduce your results and test them and repeat that process forever; so-called scientific proof of valid scientific propositions does not apply to anticipation. Anticipation deals with singularity. The fact that we've eliminated singularity from our thinking over the last 400 years has a major effect on us. Everyone now is specialized. We have more and more experts who know everything about something limited, but repetitive. Today, very few scientists are able to look at the relation among these specializations and extract useful knowledge from these relations.

UBIQUITY: You don't consider the ability to look among specializations as actually a kind of generalization?

NADIN: No, I really don't. Again, terminology is important. To generalize is a defining characteristic of the human being. To generalize is to leave out the richness of the concrete. Anticipations are always in the act. There is no efficient distinction between the perceived and what is acted upon. Vittorio Gallese and his colleagues made this point quite well. Accordingly, to expect experts obsessed with generality and abstraction to "see the world anew" is almost like inviting them to give up their identity. The study of anticipation is an investment of the only thing that a scientist, like any other human being, will get only once -- part of his life. It costs part of somebody's life.

UBIQUITY: Do the difficulties leave you feeling a bit pessimistic?

NADIN: Not at all. I'm an optimist, because I don't think that life deserves to be lived other than in a spirit of optimism. But in respect to our topic, which is a tough issue, remember that Descartes himself had a very, very hard time 400 years ago. I'm by no means comparing myself to Decartes, but simply making the point that

obstacles are an inevitable component of all new scientific approaches. Descartes had it very difficult with other scientists because in his time the dominant viewpoint of the Church made it impossible for him even to address the issues that he had identified. He knew the Catholic Church would come after him if he said all he thought about humans as machines. So he had a tough time in many ways.

UBIQUITY: And today?

NADIN: We have a tough time today because the easy way is the one that brings immediate results, even if some are mediocre. The holy church of Saint Cause-and-Effect is as dogmatic as any church. The mechanisms in place (grants, prizes, recognition) are part of this church, of the machine designed to dispense public money for research. But computation, broadly understood, offers a tremendous chance for profound beneficial change. It brought about a new civilization, and new expectations. Of course, there is also tremendous danger associated with computation. Because of the digital computer, which we understand quite well, we are very close to reducing human beings to mere segments in the digital data processing. Look at the huge amount of mediocrity that is generated with the help of these immensely productive machines called digital computers. In our progress as a species, we're going to find out very, very soon that we put ourselves in a position that cannot be defended: we lose the perspective of belonging to a greater image, to the whole, in which the human being is only one part. Our interaction with the rest of life is probably more interesting than interaction with digital computers. But very little of this living interaction is effectively pursued.

UBIQUITY: You used the word "mediocrity." When you look at what is done in software -- and in design and architecture, music, and everything else, music -- do you find mostly mediocrity? Or do you think things are better than that?

NADIN: To address the first part of your question: Fundamentally, the artifacts that result from the digital data processing model as we apply it in art, architecture, even music, etc. etc., are mediocre. Why? Because we take a machine (which can be driven by a very sophisticated software program, but which in the end is a machine) and we tell the machine, "Do it according to the rules embodied in your functioning!"

In other words: "Here are my rules. Here is my understanding" -- of what the building is, or of what the piece of music is, or of what an image is.

And this will be reproduced by the machine. When a creative person designs a building, or writes a piece of music, or paints an image, basically he or she looks back at the rules that dictated how we historically built homes, or how we made music, only as a stimulus to creativity. But does not repeat it. The individual involved in the act of creation is not an historian or an archaeologist recreating the past, but someone who is questioning it. The individual is in the process of discovering, whereas a digital computer program is not in the business of discovery at all, but in confirming past knowledge. It's in the business of performance. Unless and until we are able to introduce into computing -- understood above and beyond the digital -- the notion of discovery in its deep meaning, we will not have anything but mediocre products; nothing but canned experiences.

Now to the second part of your question: Do I find everything mediocre? On the contrary. In many cases, very important architects -- and for personal reasons, I want to mention Gehry, but there are others less famous who work in the same spirit -- or musicians, or artists have been able to use the digital computer almost in the way they would use a pencil, or another form of technology. In other words, they learned to control it, or have computer experts help them, and take advantage of what it can perform. They themselves remain dedicated to the actual creative work. The computer executes tedious routine assignments and supports the generation of alternatives, but the creative genius, the aesthetic choice, remains with the human being. The notion, advanced by Minsky and others, that the digital machine, well programmed, will evolve to the level of genius and experience emotions is simply ridiculous.

The digital machine as we know it came to existence in order to automate the mathematics of artillery essential to the persecution of war. That was the first computer. The second computer automated mathematics at a higher level, the third at an even higher level, and so on. But this advance was always based on the previous understanding of mathematics, not on the discovery of a whole new form of mathematics. That is the machine's implicit limitation. The second, let me repeat, results from the form of representation, and the associated logic, chosen. Cooking

might be describable in the language of zeros and ones, but not creative cuisine; neither is writing poetry (with or without rhyme and rhythm, even though computers generate all kinds of poems), nor dancing, nor the selection of a typeface, nor the design of an event.

UBIQUITY: What would people who are in, let's say, the software business do differently with this insight?

NADIN: They will eventually realize that you can not produce one piece of software that will fit everyone! Even now, within the digital computation model practiced, they should allow for as much individualization of the program as possible. "Proprietary" is not conducive to creative use. They should start writing programs that are basically interactive environments, in which the user -- challenged to be creative -- is able to individualize the program as much possible. This approach must be reflected not only in the user interface, where many things can be done better than they are done today, but reflected throughout the structure of the program. We are still writing programs that are by definition deterministic machines. We need to get past that and allow programs to open up to the larger world, to have dynamic properties.

UBIQUITY: Speaking of the larger world, you've suggested elsewhere that your approach would have an important impact on other fields, such as health systems, politics, and so forth. Is that right?

NADIN: That is correct. But in order to avoid inflationary promises, we must again adhere to strict terminology; otherwise we end up in demagoguery. Let's take politics as an example. Today, states are machines that create rules on whose basis people are supposed to function in a given society. States evolved into this machine condition as society entered the Industrial Age. Now, circumstances are fundamentally different, and the machine-model state breaks down. Within the scale of industrial society, states tried to function like deterministic machines, and encoded industry’s rules into their laws. At today’s new scale, the "machine" behaves erratically, fixing the cascading number of problems more by luck than political skill and responsibility. Its guardians (the lawyers) and its agents (the police, the military, security forces) and its many components (social services, education, commerce, etc.) face new issues, but are supposed to work with the "mechanics" of

the past. The rules pertain to the past, to the "machine" that we call "property rights," which commands that people are not allowed to exchange musical files on the Web, just to give the most ridiculous example. In general, these rules interfere with the creative impetus of the new generation. Innovators make new things possible; lawyers rush to regulate them. We have to free ourselves of their ruling. The almost sanctified Constitution -- a remarkable political document, exceptionally adequate for the time in which it was formulated -- corresponds to a State of limited dynamics. At the time of its writing, the Constitution projected an image of the future, it expressed anticipation. Today, by golly, this is not the case. We are forced to react to the Constitution. And the unprecedented power of practicing lawyers, who regulate even politics, places us all in the past, which for all practical purposes, "We the people" have successfully transcended through our own creativity.

In recent months, many, many people --in the USA and abroad -- asked me whom was I going to vote for: Bush or Kerry. I answered that both are irrelevant, the Presidency is irrelevant. The dynamics of the world today is such that no person, be it Bush, Kerry or both together, would ever be able to steer such a system. It's as though someone placed you on a rocket and said, "Would you please, when you see my house, go a little slower so I can wave at you and you take a picture of my swimming pool?" These are systems that can no longer be driven the way we are used to driving a car, or to running a piece of software. They reached a scale at which the dynamics is such that only by taking an anticipatory perspective can we start coping with whatever change such systems bring upon us. The consequence is that we must start focusing on self-organizing nuclei, allow for greater degrees of freedom, establish correlations, form networks of reciprocal interest and responsibility. These are more effective control mechanisms than regulation driven by interest groups watching the road through the rear-view mirror.

UBIQUITY: To take another example, what are the prospects of changing health systems?

NADIN: In respect to medicine: we buy aspirin under the common, but false, belief that aspirin is good for everyone, no matter what. Medical advances based on the deterministic model of the machine have brought us to a crisis. We look for a medicine similar to how we practice engineering, a medicine of spare parts, artificial

or natural, to repair the body. Not for self-repair mechanisms, which are anticipatory. Not for our own responsibility for our well-being. Spectacular science has made possible surgery that only years ago looked like science fiction. However, it is expensive and intrinsically dangerous. The living is not a machine, and things go wrong. The lawsuits that follow are just as spectacular. And they cannot be regulated because life is the most precious thing each has. There is something more to human health than the machine perspective allows. And there are some people in the medical field, people who know much more than I about it, who are looking at alternatives. A person's protein profile is a very individual image of the body's dynamics. It indicates a possible path of our health, and in this respect it invites a very individualized consideration. Physicians who look at the whole, not just the parts, don't immediately plug you into the diagnostic machine and order a dozen of X rays and MRIs.

UBIQUITY: What's wrong with that?

NADIN: If you go to a doctor's office, they will immediately draw your blood and perform the other tests -- in order to find out whether you function like the machine that they compare you to. And you're supposed function like a machine. If you don't, they will give you what it takes to make this happen. If the insurance you carry provides for it.

UBIQUITY: Then we'll never see a machine that can be used to anticipate a patient's reaction to a drug received for the first time?

NADIN: I would not use the word "anticipation" in this case. I would use the word prediction, or forecast, for there's a distinction between prediction and anticipation. Prediction is based on previous observations, probabilistic models, and statistics. Anticipation integrates both possibilities—the possibility that something might or might not affect you—and probabilities. In general, we have a problem in dealing with possibilities. We are very good in dealing with probability and statistics, but possibility is not something to which we've paid enough attention. I've often said that Zadeh’s genius was not only in inventing fuzzy sets, but in making the first attempt to give a rational foundation for a theory of possibility. Not too much happened with his attempt. In the years ahead, people will focus on possibility.

There is a possibility that a drug might affect the same person in different ways over the course of his life, and might change fundamentally in a different biological context. Doctors will always face the problem of looking for a common denominator (some still believe that aspirin is good for everyone's headache) versus treating the individual irreducible to any other. Human beings change. But physicians don't realize anymore that these changes are even more profound than suggested by the old categories—infant, child, mature, aged—which are coarse time distinctions that define medical fields (from pediatrics to geriatric medicine). Health is dependent on much, much finer distinctions. The grain of distinction counts here. After all, anticipation means that we acknowledge time distinctions: the pre-, or ante- of a process.

UBIQUITY: Let's move from medicine to education. How do anticipatory notions impact that area?

NADIN: Education became the meat processing machine through which we send our kids, like you send meat through a salami factory. At the end of the process, you put the grades A, B, C (no factory would admit it sends out D or E grades of meat) on the various types of salami the factory produces. Graduates get these certifications, along with the degree of incompetence -- BA, MA, Ph.D., or post-doctoral. Anticipation is actually a fundamental implicit characteristic of every act of learning, yet we removed anticipation from our education system. We are making education an institution that *reacts* to reality, not one that prepares for future, changing, possible realities. Not to be visionary, not to be in the forefront of creativity, not to question, but to service, to satisfy requirements -- we need so many accountants, so many teachers, so many hotel managers, etc.

UBIQUITY: How could we then restore anticipation to its rightful place in education?

NADIN: In the first place, by giving up this very institutionalized hierarchical centralized model reminiscent of the military, of hospitals, and of prisons. We need open environments that allow for the individual's unfolding not based on rules that tell him and her that they have to be like everybody else. Engage the students through projects and not through the obsession with grades and credits. This is what "equality" turns out to be in education today. We should look at our educational

process as one that does no longer impose homogeneity, but allows for diversity, in the true sense, one that is driven by acknowledging and stimulating difference, innovation, and creativity.

UBIQUITY: You've had a great deal of experience, both as a student and as a professor, in European and American institutions of higher education. What comparisons could you make?

NADIN: The European system is still stuck in the Industrial Age (in some cases, in the Middle Ages). Many students sit mute in classes, if they show up at all. The professors are "lords" in their respective fiefdoms. Only the demands of rigor have been weakened, as in the USA. In West Europe, Germany, which once produced a highly educated populace, scores at the bottom third on European educational tests. There is an apathy to students more interested in receiving certificates than a challenging education. Some educators are looking at the models of the most successful American universities, including their obsession with finding rich people to fund programs, mainly because the state coffers are no longer full enough to support the many so-called social programs in place.

It was not always so. For instance, some of the most intriguing things happened in the post-World War II university generation in Eastern Europe. Out of desperation, I and others still knew enough about independence to pursue an education based on finding our way around the books we were forced to read -- the communist bibles by Stalin, Marx, and others -- and discovering those areas where we could express our highest creativity. That's why the East Europeans, and Russians, Uzbeks, Estonians, etc. of my generation became fabulous mathematicians, much better at that time than the mathematicians in Western Europe or the United States. Rigor was still demanded. But this has changed. The brain drain there and the brain hunger here helped us refresh the perspective. East European universities are becoming more market oriented. But in doing so, they will give up some part of their soul. The USA and Western Europe has profited from the situation. The list of Nobel laureates already has a new sound to it.

UBIQUITY: Is there anything in particular that you like about the American system?

NADIN: It is dynamic, even where it is mediocre. But I like two fundamental characteristics in particular. One, it is a place where you can definitely fight for your ideas, and have a very good opportunity to bring your ideas into the public domain. Two, the American university is still a competitive institution, whereas the European university is not. The European university -- which at this time is in the process of opposing the American university model, especially when it comes to tuition -- is the best place for people afraid to grow, for people who graduate but don't find employment and so stay on at the university and study for 10, 12, 15 years, at taxpayer expense, even after new measures taken to discourage "the eternal student" as he is known in Germany. You ask them what their profession is, and they answer, "I am a student." It's a sad situation. That's why not too many ideas have come out of those European universities, despite their strong tradition and generous public funding, in the last 15 to 20. A number of better ideas came out of the American universities. It is our chance that we can maintain the university as a creative context.

UBIQUITY: And you don't find that kind of fear among American students?

NADIN: No. And I refer to higher education in the Northeast, as well as to my new experience in Texas. My best experience was at Stanford. I had the chance to see a student in a seminar congratulated for developing a successful search engine and at the end of the semester congratulated again, at a brunch at Terry Winograd’s home, when that student -- a co-founder of Google -- became a multi-millionaire. It was beautiful because I could witness the unfolding of a young person who dared to do something, and did it in a context in which to have an idea is not a sin against society, or cause professors to suspect you of breaking eternal rules. In the USA, to be different is not seen as a handicap. That's a good aspect of the American university and American society. But if we are not vigilant, we might lose some, or a lot of this.

UBIQUITY: How would begin to think about the design of a perfect program for undergraduates?

NADIN: I tend to like a renaissance program in which the liberal component and the science component are completely integrated. I'm still dreaming and hoping that I

will find a university some place, even if it's on the moon, where people will notice that although we all have eyes, not everyone sees, and therefore it is time to provide for "visual education." Everyone in such a university who wants to become a doctor, or engineer, or even an accountant, would learn what it means to really see and what it means to express oneself visually. This will add a fundamental dimension to language and music education. The visual has been woefully neglected in our approach to education. That needs to be corrected, especially in the new age of visual acquisition of knowledge aided by computation. Some of our more interesting anticipations are definitely related to the visual.

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Prof. Dr. Mihai Nadin
Ashbel Smith University Professor
The University of Texas at Dallas
www.nadin.name

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