Small Systems

Dirk Siefkes

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For two years now, besides my regular work in Theoretical Computer Science in Berlin, I have given seminars to Computer Science students on "The Literature of Small Systems". Together we read books like "Walden" by Thoreau, "Small Is Beautiful" by Schumacher, "Zen and the Art of Motorcycle Maintenance" by Pirsig. I drew on those experiences in discussing the question: What differentiates a big environment from a small one? How does the difference influence our interactions in each?

Not only the means and rules of a system determine it, but also my knowing of how it works, my willing to act in it, and the values I attach to it. I call a system 'small' if it is appropriate in these five respects, neither excessive nor defective. Since extremes impair the interactions, we interact more intensely in a small system than in a big one. Generally one describes and controls computer-aided and other technical systems through their means and rules alone. Thereby one reduces the systems to the first two respects; they become big. This observation holds for any kind of scientific work. A scientist who confines himself to work with small systems, could work with an ecological conscience.
1. Introduction

In 1845 Henry David Thoreau built a small cabin in the woods near his hometown, and lived there on his own for some time. From his journals he formed a book, "Walden" (References part 1), which explains (p. 172): "I went to the woods because I wished to live deliberately, to front only the essential facts of life, and see if I could not learn what it had to teach, and not, when I came to die, discover that I had not lived". In the chapter on "Economy" he states that "the swiftest traveler is he that goes afoot" (p. 144); because if you want to go by train, you have to earn the money first, whereas Thoreau as a walker can start right away; "and as for seeing the country and getting experience of that kind, I should have cut your acquaintance altogether" (p. 145). By his staying in the woods Thoreau wanted to prove, at least to himself, that a simple life is more beautiful and more efficient than a life which, as is common, requires substantial support from the big system around it. Can I, as a scientist, live as Thoreau did? This would be a threefold task: "Simplify" my teaching and my research; work towards a "small-scale science" this way; make my job and my every-day life consistent.

The other day I got two letters, both addressing me "Dear Dirk", type-written, signed in blue ink. One of them was by a friend, I read it twice, and answered it right away. The other was by an insurance company, offering me
incredible savings if I cared to read through; which I did not. It had been done on a computer, trying to make a personal connection to a million people at the same time. Why was I so disgusted? Mainly because I felt helpless: I could not talk back to the man who had written me; I could not reach him, since he disdained me as a human being, taking interest in me only as a potential customer. And second, because he had abused the powers of the very field I work in.

Last summer, I was assigned a course on "Mathematics for Computer Scientists" with 400 students. There was a big lecture, and small sections tutored by graduated students. Actually many students knew better, and did not come to the lecture after the first week, preferring to work in small groups. And were they not right? Was I not doing the same to them as the insurance salesman did to me? I know well that teaching and learning can be extremely boring in a small group as well, and also that one can excite a mass of students by a stimulating talk. Above all, how can one deal efficiently with 400 students other than through a big lecture? But disdain blocks off any communication; so actually a big lecture is extremely inefficient. But what is 'big' for a lecture? Or 'small' for a science?

In Mathematics one distinguishes between 'finite' and 'infinite', but one cannot between 'big' and 'small'. "We would need a number theory where the numbers above a certain
limit fade away as the tones do in the gamut", Paul Bernays once remarked in a discussion on finite arithmetic. (See the papers by Esenin-Volpin and by Ehrenfeucht, References part 5.) The Ramsey numbers might provide such limits; but, measuring only the mathematical complexity of a structure, they are so immensely big that they are practically useless. (See the paper by P.P. Ramsey, References part 5.) In Complexity Theory one distinguishes between "feasible" and "non-feasible" algorithms, the former ones being of polynomial cost. Again, feasible algorithms form an infinitely ascending chain, leaving no clue for a borderline between 'big' and 'small'.

During two sabbaticals at Purdue University my wife and I studied the Literature of Ecology with Jan Wojcik of the English Department. We read among other books "Walden" by Henry David Thoreau, "The Wilderness World of John Muir" edited by Teale, "A Sand County Almanac" by Aldo Leopold, and "Pilgrim at Tinker Creek" by Annie Dillard, and kept a journal on a dreary lot in the University's Horticultural Park (see References part 1). Both the reading and the writing were exercises in seeing. We saw that the many branches of a hemlock tree form a unity - the hemlock - in a way quite different from how the many uniformly planted trees form the woodlot.

This experience helped me to understand that in any situation the difference between 'small' and 'big' lies not
only in the size of the system but more in the kind of human involvement. To keep a system small we have not only to use simple means; we also have to enter with our free will, follow loose rules, develop an intimate knowledge, care for what we do. Only then we interact intensely. If we cut out the human values, everything becomes abstract, our partners fade away into purposes, the distances grow, the system becomes "big" in this very real sense, though not necessarily numerically. In a big system much of the attention and energy goes into the system instead of into the participants; which makes the system inefficient.

This analysis in turn helped me to understand my own likings and dislikings in the matter. I am not opposed to technology, or administration, or sciences; I am only very critical against their tendency towards big systems. As a scientist, living in a modern civilization, I have constantly to deal with big systems, and often I do not know how to do without them. I do not try to change them; this would be a big-systems-attitude in itself. But I try to create small systems around me as much as I can.

I have tried to write the paper in this spirit. I do not present a universally valid theory; rather I picture, as clearly as I can, what I know about small systems, and how I live and work with them.

In sect. 2 I develop the concept of a small system through the above example of lecturing. In sect. 3 I
introduce the terminology and the general definition of 'big system' and 'small system'. In sects. 4 and 5 I apply the definition to technical systems (esp. to automatization) and to science, resp., taking up the example of lecturing again in sect. 5. In sect. 7 I analyse my relation as a human to nature and to language, as I experience it through the literature of ecology. I include a fairly extensive, partially annotated list of books and papers for reference and further reading. A former version of this paper in German had three additional sections on properties of small systems, on peculiarities of the analysis presented, and on my own work at the university concerned with small systems. I refer them to a later publication.

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2. **Small and big lectures**

I approach the problem through the **Question**: How does the process of teaching and learning change with the number of people participating?

I choose this example because most of us are experienced with it in some way. I start with an analysis of the situation based on my own experiences as a teacher and as a student. I do not intend these observations to be a scientific investigation on class size. Quite in the contrary, I will use it as a model to shift the attention in the enquiry into the meanings of 'big' and 'small' away from numerical size towards other categories. I hope that I can make this shift transparent even to the reader who disagrees with me on the didactive observations.

**1st stage**: Up to about 5 participants in a learning situation communicate mainly by conversing or by doing things together. Only a few informal rules are necessary to regulate the process, like "No more than two people talking at the same time." A few simple means can be helpful, like books, and paper and pencil. Everybody can continuously and through direct contact communicate with everybody. Even if the participants vary widely in age or knowledge, everybody can learn through the communication. Teaching and learning are not distinct. Even a single person learning from direct experience, from a book, or from memory, still learns through communication though with invisible partners.
2nd stage: As more members join the group, the situation requires more structure and more auxiliary support. A single teacher, or several, emerges; the work has to be planned, prepared and done, evaluated and graded; the participants lecture on specified subjects; one needs blackboards, pin boards, exhibits; subgroups evolve which work before and after class. More and more, the participants learn outside of the assembled group, whereas the assigned hours serve rather to organize the process and keep it going.

3rd stage: As the group becomes still bigger, the process splits into lecturing and listening, imposing the fixed roles of teacher and students onto the participants. The subject matter tends to be distributed in class, to be digested later. This type of communication requires more rigid rules covering both teacher and students e.g. grading specifications, and expensive technical means like a lecture hall with audio-visual equipment. Since teaching and learning are divided, the teacher gets less feedback; thus he learns less from his students. With a real crowd in the lecture communication almost certainly becomes one-way, at the same time entertaining and tormenting both students and teacher.

To sum up: The more people there are in a learning group, the less they can communicate directly. Instead, they communicate through fixed channels which require more elaborate means and more rigid rules. This yields a fixed
situation; change, and thus learning occurs mainly outside the lecture.

Let us look closer now at this first picture of learning situations to see what really constitutes the differences between 'small' and 'big'.

First, more participants require more means and rules to keep the communication going, but the converse is not true. Namely, a small group, too, can employ complicated technical means like a learning machine, or strict rules like "No talking without being asked".

Second, elaborate means and rigid rules as such, restrict the communication, independently of the group size. Namely the means disturb the direct contact between the participants, and the rules divert the communication into fixed channels.

Third, poor means (like language difficulties) and doubtful rules (as who is to speak) make the communication uncertain or impossible. Thus, we have the right communication only with appropriate means and rules; where appropriate means avoiding the extremes of 'too much' and 'not enough', keeping to simple means and loose rules.

Fourth, inappropriate means easily, but not necessarily, bring forth appropriate rules. For example, the use of expensive equipment makes strict scheduling necessary, and with everybody chattering, nobody can be understood.
Finally, appropriate means and rules make the right kind of communication possible, but they do not secure it. Indeed, the communication can break down in groups with appropriate means and rules, e.g. when one of the participants knows too much. Thus there must be other bearings of the communication which can go out of kilter. I will use bearings as a technical term for the aspects which determine the communication; I have investigated means and rules so far.

As a third bearing, I consider the knowledge about form and content of the communication. A small group can learn without anybody knowing exactly where and how to proceed. In a big lecture, however, as a teacher I have to know beforehand what I want to say and why; but while lecturing, I do not know what is going on within the students. As a student, on the other hand, I cannot anticipate the course of the lecture; but I will grow accustomed to the teacher's style.

Now I record observations analogous to the case of means and rules, to liberate us further from numerical size. First, more people in a learning group make a fixed knowledge necessary. Second, the fixed knowledge impedes communication, independent from the group size, because learning is not just an exchange of information, but requires both sides to change. Third, ignorance hinders communication as well, for this very reason; thus an inti-
mate, but exploratory knowledge is appropriate between the two extremes of 'fixed' and 'shaky'. Fourth, inappropriate knowledge tends to go with inappropriate means and rules. For example, when a learning situation involves more means and rules, I have to know about them, whether I am teacher or student; otherwise, I am likely to suffer from requirements I did not meet, or from a failure in the supporting system. Finally, even with these three bearings standing well, the communication can still suffer, for example, from a too dominant teacher.

Therefore, I consider next the will to communicate; and make the analogous five observations. In a small group, we can learn without much effort, whereas in a big lecture, student or teacher, I really have to put energy into the system of communication rather than on the message. Being overdetermined in this way, I communicate badly, independent of the group size, since I concentrate more on the system than on my partner. I communicate poorly also when I approach feebly; to change through learning, besides bringing joy, is painful; it will not happen without force from both sides, teacher and student. Only the free will of all participants, avoiding the extremes of 'determined' and 'feeble', is appropriate for learning. Either extreme is likely to go with extremes in the other bearings. For example, with a determined or feeble will, people will not become intimate. Still this is not the whole picture, since e.g. a presumptuous teacher can destroy everything, even if
the bearings we have considered are functioning well.

The missing part in the picture is the value which I attach to the situation. In a small group I can care for the others, respecting their needs and wishes. In a big lecture, we do not know each other; therefore, I can place a high value on the communication abstractly, or on the group collectively, but not on the single participants and their concerns. Very easily I become presumptuous, or submissive, or ruthless instead, overrating the value of the other person, or of myself, or of the communication; or I become indifferent, attaching no value at all, not even to the learning process. Either way I impair the communication, since the relations between the people involved, or between the people and their purpose, are out of balance. Only by caring and thus being helpful, I value the situation appropriately. Again, as a teacher or a student, I do not really care when I overdo or underdo in preparing the lecture (knowledge), in my wish to communicate (will), or in the organization (means and rules). Finally, I maintain that we have now collected the conditions for the right type of communication: simple means and loose values, an intimate knowledge of the people involved and the subject, and free will and helpful intention.
3. The Analysis

In the last section I suggested that in a lecture the number of participants determines the communication in five respects, which I call bearings. With too many participants the bearings go out of kilter, getting too tight or giving no support at all. But they may go into extremes in a small group as well. In any case the extremes do curtail the communication. We communicate well only if the bearings are right. The bearings influence each other: one extreme leads to the other. But they do not directly depend on each other.

I went through this rather detailed analysis of learning situations to shift the attention away from sheer numerical size, and then in the general analysis, which I start now, to define 'big' and 'small' referring to the bearings alone.

A system is composed of members which interact with each other to a certain purpose. The members can be men, animals, plants, or inanimate things like machines. By interacting I denote every conceivable way of getting into relation, as: the wolf eats the mouse; men operate a machine; a sunflower absorbs sunlight; the machine kills a man. 'Purpose' also is quite general, not just the profit or the immediate goal. We always act to a certain end, which unites us into a system. We will see later that this unity is stronger in small systems than in big ones.
Adapting this terminology I define: An interaction is appropriate if it is right in all five bearings, neither excessive nor defective. A system is small (or appropriate) if for all human members all interactions are small. If any human member goes into extremes in any respect, then the system becomes big (or excessive). And I maintain the thesis: In a small system the interactions are more intense than in a big system.

I emphasize that in distinguishing between small and big systems, I refer only to the human members. Especially, I do not investigate systems where no humans are present. I do not feel thus restricted: If a system without humans, say a technical system, concerns me at all, I become thus part of the system, if only as an observer. Similarly the interaction between non-human members of a system, say between machines, is important for a human member only if he is in any way occupied or concerned with it. Thus, I do not consider the relation "The birch hinders the pine from growing", but rather "It bothers the ranger that the birch hinders the pine from growing". (Compare the fine paragraph on biases entitled "Axe-in-Hand" in the November part of the "Sand County Almanac" by Aldo Leopold; References part 1.)

In the terminology I follow E.F. Schumacher. In his book "Small is Beautiful" he differentiates between "big companies" and "small companies" according to their size, i.e. the number of employees or the amount of production;
"small technology" however, means "appropriate" technology in the above sense. In his last book "Good Work" he uses the term 'appropriate technology' explicitly to help the reader break free from thinking in terms of sheer size or number. My analysis is not Schumacher's, but it is very much influenced by his way of thinking, especially by his third book "Guide for the Perplexed". (All three books in part 4 of the References.)

Now let us consider the thesis "The members of a small system interact more intensely than those of a big system". This seemed fairly obvious in the case of teaching and learning as investigated in the last section; and still is with the general situation governed by the above definition. With defective bearings, the interactions break down: they are impossible without enough support; their results are uncertain under doubtful rules; shaky knowledge as well makes them impossible or indeterminate; we cannot put them through feeble-mindedly; and we cannot endure with them if we value them indifferently. Excessive bearings restrict the forms of interactions: elaborate means block off the direct contact between the participants; rigid rules forbid spontaneous changes in the interactions; with a fixed knowledge I do not even consider changes; being determined to succeed, I easily overlooked many ways to success; and overvaluing either partner or the interaction, I make most interactions impossible. I summarize these observations into two statements: A system where the bearings are
defective falls apart; thus the participants disperse. The more excessive the bearings of a system are, the stronger grows the system, the less important are the members as such; thus the system puts itself in between its members. In either case, the distances between the members grow as the bearings go into extremes; the system becomes literally "big", only that I now measure the distances between the participants and not their number.

I condense the analysis into the following diagram in order to suggest, by their schematization, the abstract relationships between the concepts. I do so acknowledging that when one reinserts the terms into a rhetorical context, they trade logical precision for discursive suggestion.

<table>
<thead>
<tr>
<th>Bearings of interaction</th>
<th>big(excessive)</th>
<th>Form of interaction</th>
<th>small(appropriate)</th>
<th>big(defective)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Means</td>
<td>elaborate</td>
<td>simple</td>
<td>poor</td>
<td></td>
</tr>
<tr>
<td>Rules</td>
<td>rigid</td>
<td>loose</td>
<td>doubtful</td>
<td></td>
</tr>
<tr>
<td>Knowledge</td>
<td>fixed</td>
<td>intimate</td>
<td>shaky</td>
<td></td>
</tr>
<tr>
<td>Will</td>
<td>determined</td>
<td>free</td>
<td>feeble</td>
<td></td>
</tr>
<tr>
<td>Value</td>
<td>presumptuous</td>
<td>caring</td>
<td>indifferent</td>
<td></td>
</tr>
<tr>
<td></td>
<td>submissive</td>
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</tbody>
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In spite of the orderly representation one should not take the analysis as scientific in the traditional sense. Although I define terms and establish relations between them by referring to reality, I do not claim an objective truth. Rather, I try to explain my own experiences as clearly as I
can, thus to induce similar, or different, experiences in the reader. I use the analysis to understand the relations in which I find myself. Once and again, I am astonished how easily things fall into place when I translate a situation into the language of small systems. In this sense the analysis is important and very clear to me. I ask the reader to verify it in the small and big systems he is involved with; but not to translate it into a universal system like philosophy or science, because there it makes no sense. Especially, I put my very own values into the analysis: the attributes for small systems are positive, the others negative. "Small is beautiful". Although I do not build towards a scientific construction, I do not preach either, neither a new nor an old religion. Any religion, at least if crystallized into a church, is a big system: certain in its knowledge about God and the world, rigid in its rules, often too rich, determined to proselytize, valuing beliefs rather than people. (In Sect. 6 I will speak similarly, but with more care and detail about science.) If understood as a religious or an objective scientific statement the analysis will deteriorate into a big system. It shall entice you instead to live in small systems.

The first misconception - which takes the analysis of small systems as secure and unbiased - goes together with a second one, which often comes up in discussions at this point. Namely, small systems be the golden mean, in the five bearings, between the extremes of excess and want.
With this conception one assumes that between extremes one should be in a stable balance:

But actually, when caught between any pair of extremes one is drawn towards either direction, depending on whether one values the bearing in question positively or negatively. Therefore, in a small system, I live in tension between both valuations, thus in unstable balance:

This means once more: the analysis does not describe a fixed state. Rather, it outlines a task. A joyful task, however. Unstable balance does not mean that one has to wander on a ridge between two abysses:

This implies, finally, that small systems do not exist. They are not out there like the big systems are, to be found, and to be looked at, and to be discussed. We have to create our small systems every moment out of the big systems which are around us. We cannot construct them at our discretion, however. There are always other people involved, and a natural surrounding. Thus our small systems exist in
our common responsibility. And then they are most real.

The reality of small systems is what Robert Pirsig calls 'Quality' in his book "Zen and the art of motorcycle maintenance" (References part 4). After developing the concept of Quality in the course of the book in a rather abstract and subjective (not to say egotistic) manner, the motorcycle driver realizes at the end of the journey that he can find Quality only with and through his son. The two start creating a small system!
4. Tools and machines

For a second example, I turn to technology and ask the question: Is technology possible in small systems? Technology deals with technical systems; which are systems made up from inanimate things. Such systems are determined solely by their means and rules. They enter our life in two different ways: First, as means to describe, and then to control or to simulate, animate systems. Second, man-machine systems, for example computer-aided systems, are normally treated as technical systems.

The first use is common in the biological, the economic and the social sciences, and even in the humanities. If one perceives an animate system as, or by means of, a technical system, either one translates the last three bearings (knowledge, will, and value) into the first two ones (means and rules), or one disregards them at all. In either case, one does not treat them as what they are, thus not appropriately, and this way the system becomes big. This type of reduction is well-known, although it may be described in different ways. Many scientists, among others, feel uncomfortable about it. In sect. 6 I will take up the general question whether science can be done in small systems.

The second use of technical systems, in technology, involves a similar reduction in a less outspoken way. In technology and in any Engineering science one is concerned solely with technical systems, so it seems. Obviously,
humans have to design, build, operate, use and service these systems. Nevertheless, the engineer admits them into the picture only abstractly - as designers, builders, operators, users and service-men, but not as living people - and only at specific points. In this way he tries to reduce the man-machine system as much as possible to a technical system. The knowledge of the user for example, enters into the system, if at all, only through the choice of the user/systems interface, which consists of the machine parts which serve, and the rules which govern, the interaction between user and machine. The German word 'Schnittstelle', 'cut point', is revealing here. The interface actually separates the two partners; neither can go through the other's face.

The situation is somewhat different with the people who actually build and run the system. Their knowledge, drive, and esteem are essential: if they do not know the machine, or do not like the job, or do not want to work, the system does not function properly. In spite of this fact the researchers and workers in Software Engineering or any science aiming at automatization try to reduce the knowledge, the will and the values of all humans in the system into rules and means as much as possible. I will not enter into the current discussion about the reasons for and the drawbacks and the advantages of this attitude. Analogously to the case of technical systems as models for animate systems, man-machine systems become big through the very reduction to
technical systems. Therefore, before I could discuss the problems of technology, I have to answer the opening question whether technology is possible in small systems. To do this I have to be more precise about automatization. (Here I learned particularly from discussions with Wolfgang Taube; see References part 5.)

The process of automatization consists of analyzing the situation (specification of the requirements), postulating regularities (functional specification), translating into technically feasible terms (design), and finally carrying out the plan (implementation). The issue can thus be broken up into two phases: formalization and (actual) automatization, or analysis and synthesis. Together they lead from the initial situation, i.e. from reality, to the finished system, which is a model of reality:

"In reality" the two phases are not separated, but interleaved. (See e.g. the book by C.B. Jones on Software development; References part 5.) Thus analysis and synthesis should not be pictured as going strictly up and down, but rather as meandering in a semi-circle. More important though, the model is as much real as the initial situation; namely it contains and concerns human beings. The technical
itself is irrelevant, only as a man-machine system it serves its purpose. And only then it creates problems. The picture thus becomes:

We can make the picture even more fitting if we understand time cyclic instead of linear. (See e.g. Fritjof Capra "The Tao of Physics", and my note "Hessian Lake"; both part 4 of the References.) Then the half-circle becomes a circle, or rather a spiral. Once again we, designer and user, come back to where we started from, under changed conditions. In technical terms: the work is never done, we have to run through the circle over and over again. (See the paper by Floyd and Keil in part 5 of the References.)

Thus the errors in automatization result from its efforts to render man superfluous. Then one tries to reduce reality to a technical construct, maybe without realizing that one is changing a system which possibly has been small, into a big system. How can one automatize without loosing man in the process? There is only one way: all people involved in the system have to walk through the half-circle together; only then will the system possibly stay small.

In his paper "Social Choice in Machine Design" (Referen-
ences part 5) David F. Noble describes the method of record-playback used for the automatic control of machine tools. (Incidentally the method found its place in literature in Kurt Vonnegut's "Player Piano"; References part 3.) There one tapes all settings and movements of the machine when a worker produces a certain piece for the first time; thereafter the tape is used to control the machine to do the same piece automatically. The method did not spread widely, and was finally replaced by the method of numerical control, where the commands on the control tape are computed. Like any tool for automatization even record-playback eliminates monotonous work processes, and thereby (albeit monotonous) jobs. Record-playback, however, leaves at least some workers with at least some independent work where their knowledge, their wishes, and their likes may play a part. Compared to the method of numerical control, where one tries to transfer all initiative from the factory hall to the management, with record-playback the system can stay at least halfway small.

Through automatization, one tries to make systems bigger, not only numerically. As a process and in its results automatization is expensive, violent, and presumptuous, it requires rigid rules and fixed knowledge. Thus how can automatization be done in a small system? The above answer sounds self-contradictory and it is according to common understanding: when one promotes automation in a small system, then all people involved have to be involved all the
They have to be familiar with the system to be constructed and with each other; they must want the envisaged change; and they must rate positively what they are about to create and what will be done with it. Only then the automated system can be “cut-point-free” (see above). All these demands sound utopian, but they are not. They surely exclude any big technology; they characterize what Schumacher calls “small” or “appropriate technology” in “Small is Beautiful” and his other books (References part 4). Small technology is possible, and appropriate, in many situations, not just in developing countries. In its consequences for the people involved it surpasses any big technology. George McRobie, a coworker of Schumacher, reports on its realization in his book “Small is Possible” (References part 4).

Therefore the call for small systems is not a declaration of war against technology and industrialization, not even against the big companies per se. The Scott Under Commonwealth – an English firm producing plastics products on which Schumacher reports in the last chapter of his book “Small is Beautiful” – with nearly 400 participants surely is not a family company, but it functions as a small system, for example through common ownership of all workers. I understand “small systems” as an urgent invitation to deal with economics “as if people mattered” (which is the subtitle of Schumacher’s book). Everybody is invited, whether he heads a big company or handles his own business, whether he
is a manager or a worker on the assembly line. I am convinced that whenever people act accordingly to this invitation, a cut in size will follow, since in a large company it is always the company which matters, not the people - workers and customers. But this cut in numerical size is a consequence, not the first step.

An appropriate technology yields tools rather than machines. There I define the distinction between tool and machine not through properties of the objects in question, but through their relation to the user: a machine forces the person working with it into a big system, a tool permits him to stay small. A tool serves its user; machines have to be served.

Therefore an appropriate formulation might be: Automation should not be taken abstractly, since it is done by people. People can use automation as a tool in their small systems, and may obtain many of its desired effects this way. Indeed they may obtain its desirable effects only in small systems. I will present an example in the next section.
5. **Lecturing once more**

As an example of automatization within a small system, I consider the following problem, which also relates to the question in section 2.

**Problem:** Use the computer to regulate and monitor the student activities in an introductory programming course.

**Conventional solution:** Before the term starts, design and implement a service program through which the computer does the following: it tests the students' programs for errors, grades them, and prints out its results plus comments and advises; it keeps records of the grades, of the terminal time, the error frequency, and the programming style of each student; it watches out for students copying other students' assignments; at the end of the term it computes the grade distribution, determines the final grades and prints out the results. Using this procedure one might save many positions for teaching associates and graders. On the other hand, it will take considerable effort and money to design and service the program. In effect the course will turn into a big system in every respect: it is rigid and elaborate; it is secure, determined, and presumptuous on the side of the teacher; and it makes, or leaves, the students ignorant, feebie, and unconcerned.

**Solution in a small system:** The students themselves write service programs as term projects. There will be no central lecture. The students work mainly on their own, in small groups of up to four participants - called "teams" - using
books, manuals, and the computer. Every team is assigned a tutor, who is either a lecturer, or a teaching assistant, or a graduate student; as far as possible the assignment is done on mutual agreement, and can be changed. The tutor offers office hours where the teams come regularly with their pieces of programs to be discussed and tested. During the term the team is expected to make the pieces grow into a service program (or a part of it) similar to that of the conventional solution; only that the team decides what it wants the program to do. So each team creates its particular program, and applies it to their own programs only, as far as it goes. The tutors take pains that the students get to know the essentials of algorithmic reasoning with its merits and its drawbacks. To keep this process going they meet regularly, discuss the results and the further course, and on that basis offer lectures on selected subjects to their teams. If grades are asked for, they are provided through the evaluations of the tutors and/or from written/oral practical examinations. This solution does not decrease the number of students, rather on the contrary. But it requires no more positions than the conventional solution, and no large computer system either. Also in other respects the system can be small, if only the participants want it: the students work mainly within their team, at certain times the tutor comes in, occasionally his other teams. The tutors work mainly with their teams, and with the other tutors, and also with books and the computer.
Since these proposals again sound perhaps idealistic, I discuss shortly four main objections:

**Objection 1:** Many students learn under direction and pressure only. As a lecturer you have to furnish at least a foundation of ready-made knowledge; otherwise it will not work. - To this I agree. On the other hand a big central lecture is terribly dangerous, because it procures knowledge, and no abilities. This is dangerous for the student: it undermines his self-reliance and his self-esteem, and impairs his will. It threatens his individuality. Later in his life he is likely to apply his knowledge as he received it: feeble against his employers, unconcerned with the people involved, ignorant about the consequences of his work. Thus teaching and learning done in a big system is dangerous for the society, too.

**Objection 2:** The teams are small systems alright; but together they yield a big system, or else chaos. - To this objection I answer: The teams need not deteriorate into a big system, if every team works on its own. And the forming of the teams will be less chaotic when there is enough time and opportunity to meet, and when the tutors form a small system themselves before the term begins. That is to say, if they know each other and the task, if they like their job and the way it is done, if they are dedicated to care for their students. Namely then they can nurture small systems out of their teams. Working in small systems thus brings into the open what one should aim at anyway.
Objection 3: You cannot turn a lecture into a small system, if the surrounding university is a big one. Grades, regulations, other lectures, the very buildings will thwart any effort you might make. This objection is crucial. Big surroundings can make living in a small system difficult. But they make it impossible only if one conceives small systems as a purely organizational problem. If you reduce a system to its means and rules, it becomes a technicality, thus becomes big. This has been the underlying problem with any kind of university reform. It is fine to want to change the system; but to want to have it changed is a big-systems-attitude which brings forth big systems. Small systems are a human problem, not an organizational one. Thus they are a task we have to start under any circumstance. We are everywhere surrounded by big systems; thus small systems can only grow from inside out. "Small" lectures and "small" research (see next section) rather than "big" plans may yield a "small" university.

Objection 4: I have tried your "solution", and it doesn't work. To this I answer with the question: Have you really brought into bearing all five aspects? Recall that this is not an organizational problem. All people involved have to be involved as people, the students as well. Therefore "my solution" is not a receipt. It might not work this way with you, or with other people involved. And the final question is: Does the "big solution" work? In a way which enables all of us to do good work?
6. Science

What I have said in sect. 4 about automatization applies to any kind of work: working we go through stages of analysis and synthesis, walking through a meandering half-circle; if we leave out any of the stages, we go too straight, missing our goal; any work changes the reality for everybody around; therefore if I want to work in a small system I have to take care that everybody affected by the work is involved as a person, not as an abstract entity. Only in such a small system we do "good work" (Schumacher; References part 4); in big systems the worker in neglected, or "alienated" to use Marx's terminology.

I translate Marx's analysis of work into the terminology of 'small' and big'. Private work which I do for my own small system, or joint work which we do for each other in turns like the harvest in former times - either may well keep the system small. But already commercial barter, of goods or abilities, makes the system big: while bartering we have to abstract from the meaning and value of the objects in question, and consider only their barter value. Thereby our knowledge of the objects changes: we know their value exactly, but we have to give up the intimacy of every-day use. We cannot commercially exchange food while we eat it. Thus during the exchange we do not compare the objects, but their value. Actually - and here Marx seems less explicit to me - the other bearings change as well: in commercial
barter we follow stricter rules than in private work; we are more determined after our goal; we are concerned with our own well-being, not with that of our partner. The system becomes really big if we work for money, buying or selling goods or abilities. There finally the auxiliary means become excessive: by relying on money we become part of a world-wide system. This in turn pushes the other bearings into extremes: money as the common denominator makes it so easy to compare values that we tend to look at the price-tags more carefully than at the things we buy. This is an every-day experience from the supermarket, but is true as well when we go to a concert or hire a teacher: it is only the credentials which count, since we do not know the person.

If we work only to possess, we are attracted only by this goal - possession -, and we abstract from everything else. Since possession in itself is not real, we live as aliens in an abstract world. This abstraction becomes manifest in money as a goal: money is worthless in itself, but can be changed at any time into any form of possession. In the same way any of the other bearings when driven to the extremes, becomes a pure potentiality, which can be transformed at any time into any concrete form. Money has the same function for the laborer, as Theory has for the scientist, Religion for the faithful, Law for the politician and Power for the ruler. Who takes these abstractions as the goal of his work, alienates himself from his
surroundings.

Preoccupied with the rise of capitalism, Marx accepts possession as the only determinant: the capital determines every situation, everything else is reducible to it. In his succession one tries to counteract alienation by changing ownership, thus one tries to rule a situation through the first bearing alone. This is a reduction even more drastic than the reduction to means and rules in the technical realm which I considered in sect. 4. Therefore such changes make the system bigger instead of smaller; the relations become more abstract, alienating the workers more than ever.

Since Marx does not account for the other four bearings, they enter his system unchecked. In his book "Geistige und körperliche Arbeit" (References part 4) Alfred Sohn-Rethel extends Marx's analysis by including science, and thus the category 'knowledge'. It would be worthwhile to do the same for the remaining three bearings. Wolfgang Coy quoted Marx as saying "The true wealth of a person lies in his relations". Which relations does Marx mean?

After the general investigation on working in small systems I turn to a special kind of work, namely in science, with a particular emphasis on Computer Science. I have written about teaching and learning in sections 2 and 5; what about research? Can I do it in small systems?

The answer is similar to the one concerning teaching:
Obviously I will have less problems working on my own desk than when employed and controlled by, say, some government agency. But in any situation I have to keep asking myself the five crucial questions: First, do I work with simple means? Do I understand the machine, the programming language, the theory, well enough to be able to use them as tools? Second, what kind of rules do I obey? Am I a slave of the scientific bustle? Do I gripe about seeing only my own nose? Or do I follow simple rules which I feel responsible for? Fourth, do I carry my research with delight, with resignation or with grim determination? Fifth, why am I a scientist? Do I care for my work and for everybody involved, am I a workaholic or am I oblivious to the results, the motivations, and the consequences? Do I do research as art pour l'art, or is there more to it?

The third question, the one concerning knowledge, is the most difficult: Is science without fixed knowledge conceivable? I have to question both, knowledge as the result of research, and knowledge concerning the mechanisms of research; both questions are related. If I do not reflect on the mechanisms of science, I conceive knowledge as secure. If I think I am in control of the mechanisms, I become rigid, and my knowledge does not progress. If I try to fully understand my ideas, my methods and means, my goals and motivations, then science can become a tool which I can trust.
There is no such thing as objective knowledge. Knowledge is secure inside science, but applicable only outside. Sure enough $1+1 = 2$ is true for anything measurable; but in a friendship we can have $1+1 = 1$, or $1+1 = 0$ in a marriage, or $1+1 = 0$ in a battle. This example may sound silly; it serves to say: where are the borders of the measurable world? Scientific knowledge is certain only under secure conditions, thus in the big system. If I use science as the path to secure knowledge, everybody involved becomes alienated. The theorems of the mathematician are like money: vouchers worthless as such, to be cashed any time in any practical situation.

Again I emphasize that this is not a declaration of war, this time against science. I am a scientist. And as such I point to an indeterminateness principle in science, which only the physicists seem to know: The more precise I try to make my scientific knowledge, the less am I myself included; the more general I try to make my theories, the less can I apply them. On the other hand, there is no such thing as subjective knowledge either. I cannot possess knowledge; rather knowledge can relate people if it is common ground, or if missing it separates them. I can keep scientific knowledge alive only through teaching, applying, and developing it at the same time; this I can do only in small systems.

These statements may sound familiar, as though they
were reviving the old antinomy between theory and praxis. But in discussing this antinomy one normally does not include the most important part: praxis consists not only in the material things (means and rules), but in the last two bearings as well; namely how our work is guided by our will and our values. Western science would be less aggressive, and more open for other kinds of knowledge and wisdom, if one would keep this in mind.

In this way, I can do Computer Science with gumption: I set myself to the task to do it in small systems. This seems more appropriate than leaving the field, or trying to vindicate it, or closing one's eyes. Computer Science may suffer as a field; but computer scientists will gain.
7. Literature of ecology

What I have said up to now is hardly fit to change anyone’s conscience. Even for a scientist, science is rather remote from every-day life. As I have mentioned in the introduction, my analysis of big and small system takes root in reading nature books in a course on the Literature of Ecology. But what has nature to do with these ideas?

The distinction between small and big systems in sect. 3 expressly covers only systems with human participants. Natural systems as such are neither big nor small. Nature is often exuberant in numbers, for example in reproduction; it seems the more exuberant, the simpler the mechanisms are. Ants and termites build their colonies in accordance with rigid rules; each single insect seems to act randomly. Thus one is tempted to say that nature keeps its systems small by balancing between abundance and scantiness. But this attempt does not bring us humans into the picture.

The situation is the same as with science or technology: Nature by itself is neither beautiful nor horrid, it is just by itself. But here’s the point: We can leave or take technology and science, but we are a part of nature without being asked. (Although it may seem the other way around today.) And although we are insolubly entangled with nature, just how this relation works, depends on us.

If I am greedy or overdetermined towards nature, I
exploit and devastate it; if I glorify it, it becomes idyllic, eludes me, ridicules me; if I attack it with heavy means or seize it with strict rules, it deserts me and becomes deserted. If I am caught by nature acting with improper means or rules, with weak knowledge or will, it kills me; and if I undervalue it, I ravage it. Only if I live up to the standards of nature, nature stays alive and I live to see it as a small system. If man's natural bearings go out of kilter, man will vanish from the earth and likely nature with him.

The intimate relationship between humans and nature is not restricted to means like food, shelter, etc.; it penetrates the other bearings as well. I consider the theory of evolution as an example. When Darwin and others developed it in the last country, it changed profoundly our knowledge, of nature in general and of man in particular. The new knowledge in turn changed people's attitude towards nature, made them look closer, or frightened them. The new theory also changed the way how people valued themselves and nature. This was not a simple process, it could make people prouder or humbler, depending on their religious background. Influenced by, and supporting the then prevailing ideology, one took the theory, and does till today, on saying: "Evolution is a continuous battle where the fittest survives". From this, one derives that aggression is a natural, and therefore a good, impulse. Only today some biologists are willing to propose 'cooperation' instead of 'aggression' as
the leading natural principle, proclaiming "survival of the best adapted" instead of "survival of the fittest". (This idea is from Lewis Thomas, "The lives of a cell", References part 1, who describes on p. 31 immune reactions as "necessary for the regulation and modulation of symbiosis". See also the book by Manfred Eigen and Paul Schuster, References part 2, on the cooperation of enzymes to create life cycles.) Finally Gregory Bateson (in his books "Steps to an ecology of mind" and "Mind and nature", References part 2) conceives the individual human mind as an evolutionary system, thus getting insights into its working which are quite different from those where one identifies the mind with the brain as a neural system, or as a God-given mystery. Thus for Bateson, we can keep mind and nature in balance, in small systems. (See also the book by Erich Jantsch, References part 4.)

Still this is farfetched. We experience nature quite directly, as beautiful and as terrifying, and we do not need small systems to create or even explain this experience. In fact, it goes the other way around: by observing nature I became aware of the small systems in which I lived, and began to think about them. And I was enticed into observing nature more closely by reading books on ecology.

Ecology shows one the proper place man has in nature. Ecology as a science at its best tries to find the proper measures (i.e. means and rules) to be taken to ensure man
his place in nature. (At its worst it tries to tailor
nature accordingly. Again the German term - Unweltwissen-
schaften - Science of Surroundings - is a revealing here:
Man is viewed as standing in the center, surrounded by
nature.) In terms of the analysis presented here, ecology as
a science is reduced to the first three bearings - means, rules and knowledge; thus it deals with big systems in a
big-systems way. If I want to experience nature in small
systems, the proper attitude and morale are as important.
As early as 1940 or so, Aldo Leopold has created the term
ecological conscience for this kind of approaching nature
and man in balance.

I cannot grow an ecological conscience like a cabbage,
by adding two more dimensions to the science of ecology.
Rather it has to start from the roots of wonder and terror,
growing into an open-minded exploratory consciousness,
branching into the intricate capacities needed to deal with
nature, thus experienced as something to be nurtured instead
of exploited. I advise the reader who wants to experience
small systems in this undeflected way to read the following
tive books in this order (all in References part 1): Henry
David Thoreau "Walden", John Muir in "The Wilderness World
of John Muir" (Edwin Way Teale, ed.), Aldo Leopold "A Sand
County Almanac", Annie Dillard "Pilgrim at Tinker Creek",
Wendell Berry "The Unsettling of America". These five peo-
ple have lived in nature, or still do, each in his or her
specific small systems. By writing about their experiences
with nature, they do not just describe nature, but they transform it into language, which I digest reading, growing in my mind fruits from seeds they harvested, to sow in turn.

Douglas Hofstadter in his book "Gödel, Escher, Bach: An Eternal Golden Braid" (References part 5) compares the communication in the human brain with the interactions going on in an anthill: we see the neurons and the ants and we experience thoughts and ant activities, but we do not know how these two layers are connected. The book is written in a playful and aesthetically satisfying way and thus worthwhile reading, as opposed to many purely scientific books on the subject. The author, however, never asks for the value of the thus postulated relation between man and anthill; on the contrary he explores human intelligence in order to understand artificial intelligence.

More precious in the understanding of small systems is the book "The lives of a cell" by Lewis Thomas (References part 1). He asks the same question differently: Do humans build their language as ants build their hill? Can we understand better the meaning of human life through this analogy? I find his analogy striking, and reformulate here the language part of it: The system of language as a totality is unmeasurably gigantic in time and space if the individual is taken as the measure; everybody works on his language continuously and compulsorily (acting under a genetic force, according to Thomas; I would call it an edu-
cational force as well); through this everybody is familiar with some part of the language, and thus is connected to the language as a whole; without language the individual could not exist as human, language is his home and stimulates him; without language mankind would not exist.

Following Thomas' analysis, are we entitled to conceive men and their language as a small system? In this generality it is a Big-Systems question which I refuse to answer. Let us look more closely. In the dialects of a region, a town, a class, a group, or a family, people can form small systems, and normally do. The official language of a nation, like German or English, is a rather big system. Since hundreds of years administrators, merchants, clergy men, and artists(!) have enlarged and fortified it. But it is still staying alive through its dialects. Esperanto is a dead language, and so is the "Newpeak" of George Orwell in "1984" (References part 3.) Scientific languages lie in a coma, dying from cancerous growth, and kept alive here and there through the conscious effort of an occasional scientist.

So this is the wisdom of the literature of ecology: To stay human I have to know what Man is. I depend on language to express myself in this task. I depend on nature to teach me that everything I create is provided by it. And I have to create and nurture man, and nature, and language in my small systems.
This finally allows another definition of 'system'. Instead of defining a system through its members as in sect. 3, I can look at the interactions. Thus I define: a system is a unity which is distinguished from its surroundings by its language, which means: by the way interactions take place. 'Big' and 'small' systems are then defined as before.

The new definition has its advantages. The old definition comes from, and leads to, a technical, analytical way of looking: I decompose reality into individuals, which I then link together through interactions to form a system. But systems, and especially small ones, are more than the sum of its parts. In Nuclear Physics one considers systems which interact so strongly that one cannot separate them into members and interactions, but one has to describe them through the events which take place in and around the system. (See the beautiful book "The Tao of Physics" by Fritjof Capra, References part 4.) We should make better use of these experiences in social systems, especially in our own small ones.

The new definition also sheds fresh light on the antithesis 'excessive - appropriate - defective', or 'big-small-big'. On the one hand, it shows more clearly that a system which is big by being defective must interact perceptibly in at least one of the bearings; otherwise it would not be recognizable as a system. On the other hand, the
more excessive a systems is, the stricter and more formal its language must be, to be understandable for all members. This is obvious for systems which are big in size, but is easily seen to be true for excessive systems in general. The more formal a language is, the leaner it is; the less have the members in common; the poorer is the communication. For example I can speak very clearly in a scientific language, but I cannot say much. Thus the essential antithesis is not theory against praxis, but theory in a big system (which is too rigid to be applied) as opposed to theory in small systems (which is less attractive, but more helpful).

As the foundations of mathematics one can choose set theory (which builds on elements) or category theory (which builds on relations). Both approaches have their drawbacks, especially if used in extremes and against each other. I take this as an admonition that in a small system neither the members nor the interactions are important on their own.

I quote from my Hort Park Journal 1980: "I want to look closer at the hemlock's bark, to learn its signature. Its many branches keep me away. Sinful to think of thinning them out. The stern boughs build the tree, create a form. Back in the woods I ponder: the trees together from something, too: the woods. Both, branches and roots build One out of Many. What is the difference? On the south edge of the woods I find a tree with a singularly furrowed stem."
Age and sun and rain have eroded its surface into deep cut canyons, leaving chains of light bark packed into a dozen layers. The sun warm on my back I follow the irregular repeating patterns. They keep your eyes afloat and afix, give you a hold on the tree, forming a structure into which they disolve. — Mathematically a structure is a set of objects with relations given between them. The woods in our lot are poorly structured: too many trees, set for money, related only by the greed for light. The branches of the hemlock, shaped like the tree, shape the tree, as the twigs shape the branches, and the twiggies shape the twigs. In the hemlock nothing is set, but all is related. Nothing stands for itself; all stands for the tree, and stands in the sun for you the observer, connecting you intimately to the tree. Also when a wood grows wild, every part small or large is a wild wood, trees overtake shrubs and, overtaken by vines, fall into the weeds. How can nature bear this contradiction: Structure things by letting them be? How many threads can you weave into one picture? — One, many too many. A single creature is rare in nature, if it exists at all. The lone animal, be it leader or outcast or solitary, stands out only against the background of the others; it is singled out from the group, thus structuring it. A structure contains many related animals, or plants. They protect, reproduce, teach, enjoy each other. But if there are too many, by interfering of man or some other affliction, then the group breaks up, or down. Let the wind or
some disease jump into the Hortport lot, and you will see all the too many trees topple."
REFERENCES

I relate a personal selection of books and papers for reference and further reading. I grouped the titles into five fields to entice selection; actually most of the books cover several fields, and resist any grouping. For further provocation, I annotated most titles. If not, I have not read enough of the book, or thought any comments were unnecessary.

1. Nature, Biology, Agriculture

These are "Essays Cultural and Agricultural" on the hidden supports of our life, on our choices. Many themes are drawn together in the next book.

The author contrasts two ways of life: nurturing and exploiting. The nurturer lives only in small systems, the exploiter makes them big. I value this book highly. I like most his understanding of the Greek 'arete', explained through the story of the return of Odysseus.

The classics on how we poison our world. I found it so depressing, I could not read through.

I value Annie Dillard and Aldo Leopold as the true followers of Thoreau. She is both a biologist working in a laboratory and a mystics living in a cabin at a creek, and as such she sees most closely the wonders and terrors of nature, and writes about them in an intriguing and puzzling way. The book I like best.
A passionate and grim reflection on contingency and necessity, on what men do and what God makes them do. Not as intricate as the first book, but very moving.


The author, director of The Land Institute, shows that our agriculture is destructive to the earth in a thorough way: simply by relaying mainly on annual crops we destroy the topsoil. Using more perennial crops we could develop an ecologically stable agriculture.

The best factual book complementing Wendell Berry. Written in a clear, knowledgeable and balanced way - and thereby poetic and affecting.

Reports on a long sabbatical in the lower Sonoran Desert, mixing very fine descriptions and some deep reflections as in "From a Mountaintop" and "The Individual and the Species".

A professor of Biology, advisor to the government, and weekend farmer, the author worked in ecology earlier than anybody. He developed concepts like 'food chain' and 'land pyramid', and argued for "land ethics" and "ecological conscience". His thinking evolves from beautiful observations of nature and of men's role in it.

Wolves are as inscrutable as men.

Stories on life in Alaska, alone and together. Some people realize their dreams of a natural life, others loose them.
The Canadian Government sends the author into the wilderness to prove that wolves kill all the caribou. He finds that the trappers do it, whereas the wolves eat mice — and are lovely and peaceful creatures, which men are not.

Compared to Thoreau John Muir is a wild man. He hikes through North America, sledges down a canyon on an avalanche, and rides the waving top of a pine in a storm. His writing is as powerful today as his fighting for conservation was a 100 years ago.

A short reflection on time, viewed cyclically instead of linearly.

Notes from a diary and reflections, on traveling in the Far East and on keeping watch in the American mountain wilderness. How to get back to archaic values through Western ecstasy and Eastern meditation. I find it a strange and beautiful book.

A biologist draws from his experience in raising fundamental human questions: What is an organism? Is aggression or cooperation the leading principle of evolution? I learnt much from this book.


For two years Thoreau moved into the woods to see whether he could lead a "simple life" there, depending on nature in body and spirit. The classics of the American literature of ecology, written about 1850. I love it better each time I read it.

I like best the essay on "Walking", praising wilderness. He goes as far as to say: "In literature it is only the wild that attracts us."

"Exercises in repose. Students of a course in the Literature of Ecology, mainly scientists, went weekly to a small area in the Horticulture Park at Purdue University to make journal entries of whatever was to be seen."

Jan Wojcik et al. (ed.): The Hemlock's Bark - A composite of expressions of Horticulture Park. Purdue University, Winter-Spring, 1980.
"Exercises in seeing with the ecological eye." Like the first booklet done by the students as a course project. The proceeds went into a local wilderness project.


2. Evolution


great biologist on his life's work.


The exciting thesis about the origin of life through self-preserving and self-governing cycles. The authors discuss the concepts, and develop the chemical and mathematical formalisms in detail.

"In an unusual blend of scientific knowledge and imaginary vision, Loren Eiseley tells the story of man." The anthropologist and naturalist investigates and contemplates the sudden leap in the evolution of the human brain: How did it happen; where will it lead? Very nice to read.


3. Utopias - in reality and in imagination

The three Western States of the USA have separated, and founded an ecological state. Nicely alternating between the diary and the official reports of a newspaper columnist it is a cunning mixture of Thoreau, Skinner and sex.

Covering the 70s and the 80s it gives the history leading to the state of the preceding book, trying to justify its realizability.

On the life in a farm commune. The trees really talk, again and again the cow breaks into the vegetable patch, they never have money, nothing is organized, everybody does everything, and nobody knows where they are going, because it takes a whole life to arrive.


Several authors report on alternative ways of living - "models for survival" - from the past and the present. The editor himself is involved with such projects at the University of Kassel, West Germany.


The famous farm commune Twin Oaks in Virginia was founded under the principles of "Walden Two" by Skinner (see below). (Its existence seems to be endangered now, maybe by these very principles.) One of the founders reports in detail on the problems and pleasures of the early years.

B.F. Skinner: Walden Two. MacMillan Publ., 1948. The founder of behaviourism tries to come to terms with fascism in 1945, by writing this utopia. He expressly refers to Thoreau, but with all his wonderful ideas about communal life, he is actually antagonistically opposed to Thoreau, and smacks of fascism himself. Everybody should be aware of this book.


4. Social, Political, and Philosophical Topics

Fritjof Capra: The Tao of Physics: Shambala, Berkeley, 1975. The best introduction I know to Western philosophy and Eastern nuclear physics, and to the similarities of their languages. Capra is a nuclear physicist who got to know Zen Buddhism, and since then is hooked to both.

Yona Friedman: Utopies réalisables. German: Machbare Utopien. Fischer alternativ 4018, Frankfurt am Main 1977. Friedman's "critical group" is something like the biggest possible small system of a given type. His analysis is purely structural, thus for me the essential is missing. Still I find his utopias useful, and I like his cartoons.

William Golding: Lord of the Flies. Penguin Books 1960. The great parable on the impossibility of a humanistic democracy, told through the thrilling story of a youth group which is lost on a South Sea island.


Memories of a manager who promotes ecological ideas in big cooperations.

How would it be if everybody would assess literature by his own standards instead of by eternal norms? Lewis' thesis is that it is not the books which are good or bad, but what I do to them, and they do to me.

The author, who is one of Schumacher's coworkers in the Intermediate Technology Development Group, gives "a factual account about who is doing what, where, to put into practice the ideas expressed in E.F. Schumacher's 'Small is Beautiful'.

A man and his son go west on a motorcycle. The man gives Chautauquas: on the journey; why he maintains his own motorcycle; why his friends do not. On the road he pursues the spirit (and the ghosts) of rationality, which have produced the wonderful technology, which oppresses us now. It is not quite too late when he realises that it is his son who has the most important question to ask. Again and again I argue with the book, learning anew.

The author describes three consciousnesses: that of the American settler (which is vanishing), the organizational one (which is prevailing), and the ecological one (which is dawning). Although the book is shallow compared to Berry's, Reich has helped to start the ecological movement in the USA, and has deeply influenced it.

Throughout his life in lectures and projects Schumacher has put into practice the ideas of Thoreau and Leopold as they translate into the realm of economics and technology. His message is that not only the developing countries, but we all have to act "as if people mattered". Very good to read; even better to do.
"A Manual for Survival, concerned not merely with individual physical or even societal endurance (though that, too), but more importantly with the full realization of human potential." Christian humanism, not as a religion, but in the spirit of small systems.

Some later lectures which bring into focus the attitude of Schumacher's whole life. In this edition the book is valuably supplemented by a critical essay "The Making of Good Work" by Schumacher's coworker Peter N. Gillingham.

The author criticizes the analysis of Marx brilliantly by continuing it: Marx has not questioned science, and thus does not understand its influence on society. Hard to read.

If you have problems with the language of small systems, read this book. The chief of a South Sea island is puzzled by everything we do; if you read it, every word turns inside out.

5. Science, especially Computer Science

By the definition of the authors a software system is "large" if several people are needed to understand and design it. Accumulating data from producers and users the authors discuss characteristic problems of such systems.

Computers do not have a living body, and thus perceive any situation as built up, not as whole.


Christian Floyd, Reinhard Keil: Adapting Software Development in view of systems design with the user. IFIP WG9.1 Conference "Systems Design for the Users, with the Users, by the Users", Riva del Sole, Toscana, Italy, 1982, 16 pp. The authors want the users to participate in the software development. Under this attitude they develop the phase model into the "process oriented" model, which repeats all phases cyclically until users and producers agree.


On the reasons for different types of automation.


On the existence of "indescernible elements" in (finite or infinite) "too big" structures - in the mathematical setting.

The author, professor at the Technische Universität Berlin, uses the "strategy" of evolution - namely changing an object probabilistically and continuing with the best result each time - for optimization in engineering problems, with startling results.

In an extreme way people have worked into Ada the two predominant ideals of our time: efficiency and reliability, thus pushing consistently towards big systems.