Zen and the Art of Motorcycle Maintenance

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It's about ten o'clock in the morning and I'm sitting alongside the machine on a cool, shady curbstone back of a hotel we have found in Miles City, Montana. Sylvia is with Chris at a Laundromat doing the laundry for all of us. John is off looking for a duckbill to put on his helmet. He thought he saw one at a cycle shop when we came into town yesterday. And I'm about to sharpen up the engine a little.

Feeling good now. We got in here in the afternoon and made up for a lot of sleep. It was a good thing we stopped. We were so stupid with exhaustion we didn't know how tired we were. When John tried to register rooms he couldn't even remember my name. The desk girl asked us if we owned those "groovy, dreamy motorcycles" outside the window and we both laughed so hard she wondered what she had said wrong. It was just numb skull laughter from too much fatigue. We've been more than glad to leave them parked and walk for a change.

And baths. In a beautiful old enameled cast-iron bathtub that crouched on lion's paws in the middle of a marble floor, just waiting for us. The water was so soft it felt as if I would never get the soap off. Afterward we walked up and down the main streets and felt like a family... .

On this machine I've done the tuning so many times it's become a ritual. I don't have to think much about how to do it anymore. Just mainly look for anything unusual. The engine has picked up a noise that sounds like a loose tappet but could be something worse, so I'm going to tune it now and see if it goes away. Tappet adjustment has to be done with the engine cold, which means wherever you park it for the night is where you work on it the next morning, which is why I'm on a shady curbstone back of a hotel in Miles City, Montana. Right now the air is cool in the shade and will be for an hour or so until the sun gets around the tree branches, which is good for working on cycles. It's important not to tune these machines in the direct sun or late in the day when your brain gets muddy because even if you've been through it a hundred times you should be alert and looking for things.

Not everyone understands what a completely rational process this is, this maintenance of a motorcycle. They think it's some kind of "knack" or some kind of "affinity for machines" in operation. They are right, but the knack is almost purely a process of reason, and most of the troubles are caused by what old-time radio men called a "short between the earphones," failures to use the head properly. A motorcycle functions entirely in accordance with the laws of reason, and a study of the art of motorcycle maintenance is really a miniature study of the art of rationality itself. I said yesterday that the ghost of rationality was what Phaedrus, pursued and what led to his insanity, but to get into that it's vital to stay with down-to-earth examples of rationality, so as not to get lost in generalities no one else can understand. Talk about rationality can get very confusing unless the things with which rationality deals are also included.

We are at the classic-romantic barrier now, where on one side we see a cycle as it appears immediately—and this is an important way of seeing it—and where on the other side we can begin to see it as a mechanic does in terms of underlying form—and this is an important way of seeing things too. These tools for example—this wrench—has a certain romantic beauty to it, but its purpose is always purely classical. It's designed to change the underlying form of the machine.

The porcelain inside this first plug is very dark. That is classically as well as romantically ugly because it means the cylinder is getting too much gas and not enough air. The
carbon molecules in the gasoline aren’t finding enough oxygen to combine with and they’re just sitting there loading up the plug. Coming into town yesterday the idle was loping a little, which is a symptom of the same thing.

Just to see if it’s just the one cylinder that’s rich I check the other one. They’re both the same. I get out a pocketknife, grab a stick lying in the gutter and whittle down the end to clean out the plugs, wondering what could be the cause of the richness. That wouldn’t have anything to do with rods or valves. And carbs rarely go out of adjustment. The main jets are oversized, which causes richness at high speeds but the plugs were a lot cleaner than this before with the same jets. Mystery. You’re always surrounded by them. But if you tried to solve them all, you’d never get the machine fixed. There’s no immediate answer so I just leave it as a hanging question.

The first tappet is right on, no adjustment required, so I move on to the next. Still plenty of time before the sun gets past those trees ... I always feel like I’m in church when I do this ... The gage is some kind of religious icon and I’m performing a holy rite with it. It is a member of a set called “precision measuring instruments” which in a classic sense has a profound meaning.

In a motorcycle this precision isn’t maintained for any romantic or perfectionist reasons. It’s simply that the enormous forces of heat and explosive pressure inside this engine can only be controlled through the kind of precision these instruments give. When each explosion takes place it drives a connecting rod onto the crankshaft with a surface pressure of many tons per square inch. If the fit of the rod to the crankshaft is precise the explosion force will be transferred smoothly and the metal will be able to stand it. But if the fit is loose by a distance of only a few thousandths of an inch the force will be delivered suddenly, like a hammer blow, and the rod, bearing and crankshaft surface will soon be pounded flat, creating a noise which at first sounds a lot like loose tappets. That’s the reason I’m checking it now. If it is a loose rod and I try to make it to the mountains without an overhaul, it will soon get louder and louder until the rod tears itself free, slams into the spinning crankshaft and de-

stroys the engine. Sometimes broken rods will pile right down through the crankcase and dump all the oil onto the road. All you can do then is start walking.

But all this can be prevented by a few thousandths-of-an-inch fit which precision measuring instruments give, and this is their classical beauty—not what you see, but what they mean—what they are capable of in terms of control of underlying form.

The second tappet’s fine. I swing over to the street side of the machine and start on the other cylinder.

Precision instruments are designed to achieve an idea, dimensional precision, whose perfection is impossible. There is no perfectly shaped part of the motorcycle and never will be, but when you come as close as these instruments take you, remarkable things happen, and you go flying across the countryside under a power that would be called magic if it were not so completely rational in every way. It’s the understanding of this rational intellectual idea that’s fundamental. John looks at the motorcycle and he sees steel in various shapes and has negative feelings about these steel shapes and turns off the whole thing. I look at the shapes of the steel now and I see ideas. He thinks I’m working on parts. I’m working on concepts.

I was talking about these concepts yesterday when I said that a motorcycle can be divided according to its components and according to its functions. When I said that suddenly I created a set of boxes with the following arrangement:

![Diagram](image-url)
And when I said the components may be subdivided into a power assembly and a running assembly, suddenly appear some more little boxes:

- Motorcycle
  - Components
  - Functions
    - Power Assembly
    - Running Assembly

And you see that every time I made a further division, up came more boxes based on these divisions until I had a huge pyramid of boxes. Finally you see that while I was splitting the cycle up into finer and finer pieces, I was also building a structure.

This structure of concepts is formally called a hierarchy and since ancient times has been a basic structure for all Western knowledge. Kingdoms, empires, churches, armies have all been structured into hierarchies. Modern businesses are so structured. Tables of contents of reference material are so structured, mechanical assemblies, computer software, all scientific and technical knowledge is so structured—so much so that in some fields such as biology, the hierarchy of phylum-order-class-genus-species is almost an icon.

The box "motorcycle" contains the boxes "components" and "functions." The box "components" contains the boxes "power assembly" and "running assembly," and so on. There are many other kinds of structures produced by other operators such as "causes" which produce long chain structures of the form, "A causes B which causes C which causes D," and so on. A functional description of the motorcycle uses this structure. The operators "exists," "equals," and "implies" produce still other structures. These structures are normally interrelated in patterns and paths so complex and so enormous no one person can understand more than a small part of them in his lifetime. The overall name of these interrelated structures, the genus of which the hierarchy of containment and structure of causation are just species, is system. The motorcycle is a system. A real system.

To speak of certain government and establishment institutions as "the system" is to speak correctly, since these organizations are founded upon the same structural conceptual relationships as a motorcycle. They are sustained by structural relationships even when they have lost all other meaning and purpose. People arrive at a factory and perform a totally meaningless task from eight to five without question because the structure demands that it be that way. There's no villain, no "mean guy" who wants them to live meaningless lives, it's just that the structure, the system demands it and no one is willing to take on the formidable task of changing the structure just because it is meaningless.

But to tear down a factory or to revolt against a government or to avoid repair of a motorcycle because it is a system is to attack effects rather than causes; and as long as the attack is upon effects only, no change is possible. The true system, the real system, is our present construction of systematic thought itself, rationality itself, and if a factory is torn down but the rationality which produced it is left standing, then that rationality will simply produce another factory. If a revolution destroys a systematic government, but the systematic patterns of thought that produced that government are left intact, then those patterns will repeat themselves in the succeeding government. There's so much talk about the system. And so little understanding.

That's all the motorcycle is, a system of concepts worked out in steel. There's no part in it, no shape in it, that is not out of someone's mind ... number three tappet is right on too. One more to go. This had better be it. ... I've noticed that people who have never worked with steel have trouble seeing this—that the motorcycle is primarily a mental phenomenon. They associate metal with given shapes—pipes, rods, girders, tools, parts—all of them fixed and inviolable, and think of it as primarily physical. But a person who does
maching or foundry work or forge work or welding seems
"steel" as having no shape at all. Steel can be any shape you
want if you are skilled enough, and any shape but the one
you want if you are not. Shapes, like this tappet, are what
you arrive at, what you give to the steel. Steel has no more
shape than this old pile of dirt on the engine here. These
shapes are all out of someone's mind. That's important to
see. The steel? Hell, even the steel is out of someone's mind.
There's no steel in nature. Anyone from the Bronze Age
could have told you that. All nature has is a potential for
steel. There's nothing else there. But what's "potential"?
That's also in someone's mind! "Ghosts.

That's really what Phaedrus was talking about when he
said it's all in the mind. It sounds insane when you just
jump up and say it without reference to anything specific
like an engine. But when you tie it down to something speci-
cific and concrete, the insane sound tends to disappear and
you see he could have been saying something of impor-
tance.

The fourth tappet is too loose, which is what I had hoped.
I adjust it. I check the timing and see that it is still right on
and the points are not pitted, so I leave them alone, screw on
the valve covers, replace the plugs and start it up.

The tappet noise is gone, but that doesn't mean much yet
while the oil is still cold. I let it idle while I pack the tools
away, then climb on and head for a cycle shop a cyclist on
the street told us about last night where they may have a
chain-adjuster link, and a new foot-peg rubber. Chris must
have nervous feet. His foot pegs keep wearing out.

I go a couple blocks and still no tappet noise. It's begin-
ning to sound good, I think it's gone. I won't come to any
conclusions until we've gone about thirty miles though. But
until then, and right now, the sun is bright, the air is cool,
my head is clear, there's a whole day ahead of us, we're
almost to the mountains, it's a good day to be alive. It's this
thinner air that does it. You always feel like this when you
start getting into higher altitudes.

The altitude! That's why the engine's running rich. Sure,
that's got to be the reason. We're at twenty-five hundred feet
now. I'd better switch to standard jets. They take only a few
minutes to put in. And lean out the idle adjustment a little.
We'll be getting up a lot higher than this.

Under some shady trees I find Bill's Cycle Shop but no
Bill. A passerby says he has "maybe gone fishing some-
where," leaving his shop wide open. We really are in the
West. No one would leave a shop like this open in Chicago or
New York.

Inside I see that Bill is a mechanic of the "photographi-

c mind" school. Everything lying around everywhere. Wrench-

ch, screwdrivers, old parts, old motorcycles, new parts,
new motorcycles, sales literature, inner tubes, all scattered
so thickly and clutteredly you can't even see the work
benches under them. I couldn't work in conditions like this
but that's just because I'm not a photographic-mind me-
chanic. Bill can probably turn around and put his hand on
any tool in this mess without having to think about where it
is. I've seen mechanics like that. Drive you crazy to watch
them, but they get the job done as well and sometimes
faster. Move one tool three inches to the left though, and
he'll have to spend days looking for it.

Bill arrives with a grin about something. Sure, he's got
some jets for my machine and knows right where they are.
I'll have to wait a second though. He's got to close a deal out
in back on some Harley parts. I go with him out in a shed in
back and see he is selling a whole Harley machine in used
parts, except for the frame, which the customer already has.
He is selling them all for $125. Not a bad price at all.

Coming back I comment, "He'll know something about
motorcycles before he gets those together."

Bill laughs. "And that's the best way to learn, too."

He has the jets and foot-peg rubber but no chain-adjuster
link. I get the rubber and jets installed, take the lump out of
the idle and ride back to the hotel.

Sylvia and John and Chris are just coming down the
stairs with their stuff as I arrive. Their faces indicate they're
in the same good mood I'm in. We head down the main
street, find a restaurant and order steaks for lunch.

"This is a great town," John says, "really great. Surprised
there are any like this left. I was looking all over this morn-


ample, if, from reading the hierarchy of facts about the machine, the mechanic knows the horn of the cycle is powered exclusively by electricity from the battery, then he can logically infer that if the battery is dead the horn will not work. That is deduction.

Solution of problems too complicated for common sense to solve is achieved by long strings of mixed inductive and deductive inferences that weave back and forth between the observed machine and the mental hierarchy of the machine found in the manuals. The correct program for this interweaving is formalized as scientific method.

Actually I’ve never seen a cycle-maintenance problem complex enough really to require full-scale formal scientific method. Repair problems are not that hard. When I think of formal scientific method an image sometimes comes to mind of an enormous juggernaut, a huge bulldozer—slow, tedious, lumbering, laborious, but invincible. It takes twice as long, five times as long, maybe a dozen times as long as informal mechanic’s techniques, but you know in the end you’re going to get it. There’s no fault isolation problem in motorcycle maintenance that can stand up to it. When you’ve hit a really tough one, tried everything, racked your brain and nothing works, and you know that this time Nature has really decided to be difficult, you say, “Okay, Nature, that’s the end of the nice guy,” and you crank up the formal scientific method.

For this you keep a lab notebook. Everything gets written down, formally, so that you know at all times where you are, where you’ve been, where you’re going and where you want to get. In scientific work and electronics technology this is necessary because otherwise the problems get so complex you get lost in them and confused and forget what you know and what you don’t know and have to give up. In cycle maintenance things are not that involved, but when confusion starts it’s a good idea to hold it down by making everything formal and exact. Sometimes just the act of writing down the problems straightens out your head as to what they really are.

The logical statements entered into the notebook are broken down into six categories: (1) statement of the prob-
lem, (2) hypotheses as to the cause of the problem, (3) experiments designed to test each hypothesis, (4) predicted results of the experiments, (5) observed results of the experiments and (6) conclusions from the results of the experiments. This is not different from the formal arrangement of many college and high-school lab notebooks but the purpose here is no longer just busywork. The purpose now is precise guidance of thoughts that will fail if they are not accurate.

The real purpose of scientific method is to make sure Nature hasn’t misled you into thinking you know something you don’t actually know. There’s not a mechanic or scientist or technician alive who hasn’t suffered from that one so much that he’s not instinctively on guard. That’s the main reason why so much scientific and mechanical information sounds so dull and so cautious. If you get careless or go romanticizing scientific information, giving it a flourish here and there, Nature will soon make a complete fool out of you. It does it often enough anyway even when you don’t give it opportunities. One must be extremely careful and rigidly logical when dealing with Nature: one logical slip and an entire scientific edifice comes tumbling down. One false deduction about the machine and you can get hung up indefinitely.

In Part One of formal scientific method, which is the statement of the problem, the main skill is in stating absolutely no more than you are positive you know. It is much better to enter a statement “Solve Problem: Why doesn’t cycle work?” which sounds dumb but is correct, than it is to enter a statement “Solve Problem: What is wrong with the electrical system?” when you don’t absolutely know the trouble is in the electrical system. What you should state is “Solve Problem: What is wrong with cycle?” and then state as the first entry of Part Two: “Hypothesis Number One: The trouble is in the electrical system.” You think of as many hypotheses as you can, then you design experiments to test them to see which are true and which are false.

This careful approach to the beginning questions keeps you from taking a major wrong turn which might cause you weeks of extra work or can even hang you up completely. Scientific questions often have a surface appearance of

dumbness for this reason. They are asked in order to prevent dumb mistakes later on.

Part Three, that part of formal scientific method called experimentation, is sometimes thought of by romantics as all of science itself because that’s the only part with much visual surface. They see lots of test tubes and bizarre equipment and people running around making discoveries. They do not see the experiment as part of a larger intellectual process and so they often confuse experiments with demonstrations, which look the same. A man conducting a gee-whiz science show with fifty-thousand-dollars’ worth of Frankenstein equipment is not doing anything scientific if he knows beforehand what the results of his efforts are going to be. A motorcycle mechanic, on the other hand, who honks the horn to see if the battery works is informally conducting a true scientific experiment. He is testing a hypothesis by putting the question to nature. The TV scientist who mutters sadly, “The experiment is a failure; we have failed to achieve what we had hoped for,” is suffering mainly from a bad scriptwriter. An experiment is never a failure solely because it fails to achieve predicted results. An experiment is a failure only when it also fails adequately to test the hypothesis in question, when the data it produces don’t prove anything one way or another.

Skill at this point consists of using experiments that test only the hypothesis in question, nothing less, nothing more. If the horn honks, and the mechanic concludes that the whole electrical system is working, he is in deep trouble. He has reached an illogical conclusion. The honking horn only tells him that the battery and horn are working. To design an experiment properly he has to think very rigidly in terms of what directly causes what. This you know from the hierarchy. The horn doesn’t make the cycle go. Neither does the battery, except in a very indirect way. The point at which the electrical system directly causes the engine to fire is at the spark plugs, and if you don’t test here, at the output of the electrical system, you will never really know whether the failure is electrical or not.

To test properly the mechanic removes the plug and lays
it against the engine so that the base around the plug is electrically grounded, kicks the starter lever and watches the spark-plug gap for a blue spark. If there isn’t any he can conclude one of two things: (a) there is an electrical failure or (b) his experiment is sloppy. If he is experienced he will try it a few more times, checking connections, trying every way he can think of to get that plug to fire. Then, if he can’t get it to fire, he finally concludes that a is correct, there’s an electrical failure, and the experiment is over. He has proved that his hypothesis is correct.

In the final category, conclusions, skill comes in stating no more than the experiment has proved. It hasn’t proved that when he fixes the electrical system the motorcycle will start. There may be other things wrong. But he does know that the motorcycle isn’t going to run until the electrical system is working and he sets up the next formal question: “Solve problem: What is wrong with the electrical system?”

He then sets up hypotheses for these and tests them. By asking the right questions and choosing the right tests and drawing the right conclusions the mechanic works his way down the echelons of the motorcycle hierarchy until he has found the exact specific cause or causes of the engine failure, and then he changes them so that they no longer cause the failure.

An untrained observer will see only physical labor and often get the idea that physical labor is mainly what the mechanic does. Actually the physical labor is the smallest and easiest part of what the mechanic does. By far the greatest part of his work is careful observation and precise thinking. That is why mechanics sometimes seem so taciturn and withdrawn when performing tests. They don’t like it when you talk to them because they are concentrating on mental images, hierarchies, and not really looking at you or the physical motorcycle at all. They are using the experiment as part of a program to expand their hierarchy of knowledge of the faulty motorcycle and compare it to the correct hierarchy in their mind. They are looking at underlying form.

The Role of Technology in Society

EMMANUEL G. MESTHENE

Social Change

THREE UNHELPFUL VIEWS ABOUT TECHNOLOGY While a good deal of research is aimed at discerning the particular effects of technological change on industry, government, or education, systematic inquiry devoted to seeing these effects together and to assessing their implications for contemporary society as a whole is relatively recent and does not enjoy the strong methodology and richness of theory and data that mark more established fields of scholarship. It therefore often has to contend with facile or one-dimensional views about what technology means for society. Three such views, which are prevalent at the present time, may be mildly caricatured somewhat as follows.

The first holds that technology is an unalloyed blessing for man and society. Technology is seen as the motor of all progress, as holding the solution to most of our social problems, as helping to liberate the individual from the clutches of a complex and highly organized society, and as the source of permanent prosperity; in short, as the promise of utopia in our time. This view has its modern origins in the social philosophies of such 19th-century thinkers as Saint-Simon, Karl Marx, and Auguste Comte. It tends to be held by many scientists and engineers, by many military leaders and aerospace industrialists, by people who believe that man is fully in command of his tools and his destiny, and by many of the devotees of modern techniques of “scientific management.”

A second view holds that technology is an unmitigated