D. F. Knuth

while preparing a book on combinatorial algorithms, I fait a strong need for a new technical term, a word which is constituting a one-sided version of polymental complete. A great many problems of precious in polymonial wave the property that they are at least as difficult to motive in polymonial wave the property that they are at least as difficult to make a large of problems of the polymonial case of many of the fact that the polymonial case of many of the fact that the polymonial case of many of the fact that the fact that a strong or possible.

The covering problem is x.

It is x to decide whether a given graph has a Hamiltonian circuit.

It is unknown whether or not primality testing is an x problem.

If I and L' are problems, we say L polynomial-bounded transduction f such that alphabet {(,),^,v,-v, '} defined reduces to L' if there is xeL if and only if f(x)eL

We also probably need the associated noun "x-most" or "x-bood" as appropriate. Here X is not necessarily to suby that a probability that the territory of the probability testing is in the polymenial complete." I suply that there is uncertainty at their short primality in the or both primality that the polymenial complete. I suply that there is uncertainty atther about primality in the or both primality in the origination of "tough" because it is informal amough that it is protty clear bone frainfaint under it is informal amough that it is protty clear bone frainfaint in complicational problem; they unfortunately cult then "combinatorial", which of course is a completally unclease stage.

I think many people are interested in how terminology dets farted, and it seem that it often happen by occident, with the originator having no idea that he is 'thing a mase To, and thus. That certainly was the case with ne when I defined his term into 1), and an orability interest, etc. It is proposed in the terminology of the proposed of the propo

The distributions are reuniform and 'arduous' ve all three words fared raffrom a majority of the whardly conclusive. : remarkably different, 'Herculean' being rather
'very peaked. But one thing was perfectly clear:
'rether badly. Only 'archans' was able to get > :
ne voters, and this majority (16 votes to 15) was

In this case I wanted to try to do conclude better, to get a large number of qualified people schiping to decide on a name before the first publication. So I did two things: (1) I get out my copy of Seget and my unabridged distributionly, and found a set of candidates for the continuous part formula set of candidates for the people asking them to write on these choices. By sincere apologies to all readers who I forgot to include in the balloting.)

The three choices I listed were "Herculean", "formidable", and a "archous". I saided all voters to assign a real masher between 0 and 1 to each term, indicating the degree to which they approved of it. (Thus,

Then I applied a secret weighting factor to all the ballots, based on approximately how many papers related to this subject I fait each particular voter void be writing in the next few years, and how much influence on computer science students he has, etc. [Naturally I assigned the weights

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Al Meyer tried also <u>superset</u>, meening greater than or equal to satisfiability. Another excellent one comes from Bi Reingold and his classicist friend Howard Jacobson;

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In other words, very low. [1712 bet that the tem 'polymental complete' would have faced even overs the early days but I'm just trying to head my conded feelings when I say this.]

Portmenticly, there was a try of bep resisting, amony the pace of worder-in votes. I rectived very many imperious negotitions inches, the write-in purved conclusively that creative research workers are as fall of ideas for me tenisology as they are empty of embusians for adopting it. The write-in votes were no interesting. I'd like to discuss them extended the continuation of the particular of the particular contribution interminable difficults.

NP-hard means as hard as the most difficult problem in NP. NP-complete means representative of the complete class NP with respect to difficulty.

Also, hem Strightte suggested "mand-boiled", in honor of Cook who originated this subject. Al Report trief "hund-sas" (laset as sentimically). [Tou can see what I seem about treative researchers.]

Bab Flow suggested Signhess intends of Hermilans, times the problem difficult by problems seem to be core the excession of the company of the sector term. On the other hand, Stryphus server finished had task, on we could use this sore appropriately for unavalvable problems.

A similar remark applies to "Hiberian. I prefer Unyessen to these, because the task, on we could use this sore appropriately for unavalvable problems.

A similar remark applies to "Hiberian. I prefer Unyessen to these, because the state of the second to the sore in "trying to cleam the theory of computing of 18 suggest estamlong". So, we find classificate senger us.

The next group of suggestions was based on acronyms. Some Lin thought of calling time FET problems, as he likes to work on the (e.g. the twenting schemes problem) in spite of their difficulty. He points out the string problem, as he likes to work on the (e.g. the resulting to "provedly componental time", and if the it that goes proved, where way, it studie for "previously exponential time", provided goes the state of the provided proposed to the state of th

In recent weeks, kmp and I have tried that terminology, and it seems to study up well in practice. As Jeff Ullman remarked in his letter, The matural thing to do its mobetitude hard to see other wend for complete so that thinks hard means to hat thinks that means to hat thinks the means to have the strength of support for his ornigate or worse."

In strength or support for his writers were makes it reasonable to propose it for immediate adoption by all vertices in the field. I will conclude this note by examining means a proposal critically and concluding that it survives all the attacks I can master.

on ment complete disagrement, I ment complete agreement, and 1/2 or more ment "quald use if it became standard".) I also loft space for write-in votes.

After mainly the hallots, I percently ones to the combinion that "specific mainly one has been a supplementation of the first conformation be next; I first outsign if for a week, and found that it felt conformation is next; I first outsign in outsign in the first in the conformation of the section of t

that "Franch veck, many more ballots arrived, and I found to my chagrin that "Franch he" was locking fits early popularity. I began to wonder how been tree from the form and pred, appecially that he mans for the four continuant hornitos case. And I also began to wonder whether my task of assessing the results of the results of the state of the condent whether my task of assessing the results of the results of the state of the stat

and exparent perarduous t (literally, se + apparent) ous (since 'per' 'completely, t; seeming outside; also
it;
xr' means 'through, in s;
tly, extremely'). space joc. 8 17 time exponential and/or

before looking at the ballots.]
a democracy, but I did it. The

to do such a thing

This pleasant word curiously appears in Webster's 2nd unabridged, but not the 3rd or in the forcht habith or appearably any other dictionary. The children given is webster as we're appropriate: dendringly long, and in the step is we're appropriate; dendringly long, and clinically interest to the contrary. Desired paymental the return to contrary.

It can see many words in the above list that I woulm't mind wind, but none that I can see because thanked. There was, however, one further class of vrite-in words, hased on hyperanted compound words that relates that a force of the property setting the state of well of chardy defined as a considered by quite as or popil, approach; setting independently of each others, I believe that the solution to the problem little best.

The "viming" vrite-in word if the term Ni-hand, which was put forward eachers, and the statemation is shallest if not identical proposal were made by several people at bell 150s, after that I moderated was desired. Alternative shallest into identical proposal verse made by the second of the complete and is at the sear time were coast.

Motivation for these terms is easy to describe to a novice, once understands HP, namely

First, are the terms vell-deffined? Answer: Well, not by the above discussion, but we can make then so. One of the things I bearned from the letters received was that Good's original definition or polymental reducibility is not known to be the same as the one Karp used to relate

The nort tartilizing suggestions I received were based on newly-coined day taken from appropriate classical roots. This, after all, is the biologists, etc., get nearly all of their high-faluting terms. Hike erron contributed two nice ones:

so many combinatorial problems to each other. Si to deal with and supports all the constructions w interest to real-world programmers, I propose to definitions (following Karp): Since ; ns which to make the latter is simpler h I believe are of e the following explicit

A problem I is a subset of the (1.e., a problem is a language). strings on воде finite alphabet

A polynomial-bounded transduction Σ and Σ' are finite alphabets, such output $f(\mathbf{x})$ is computable in at most (say) a one-tape Turing machine. f is a function $\Sigma^* \to \Sigma'^*$, that, for some integer k, t $(|x|+2)^K$ steps for all x, the

The satisfiability problem S is the context-free language A over the by syntax and integer-valued semantics

Thus, there exists a way to define the terminology precisely. Note that the definition rate to cooke thereone to relate IP to 'nondetermination' polymental time to the 1 SMM and Scomplice look like better terms in the same of this definition. We define the definition would say that, for any class C of proban, we define chant to mean "I renders to I for see Al I C ", to ", and complete it chart plant" to mean "I renders to I for see Al I C ", to get an observation and the same that that "reduces to' is transitive and reflactive, as

If I is C-hard and I reduces to M then M is C-har
If I is C-complete then I reduces to M if and only
C-hard. M is C-hard.

Cook's estimation of reducibility was different; he said that preduces to lift I is excepted in polymorable that by a furing sanding extended with the capability of desciting saintend in I. I are step, and estimation correspond of carefully saintend definition with respect to recursive functions and unclaimer problemant is raight call the support to Cook-reducibility. However, I guilt call that I don't see a critical distinction nere. Notes I'm assistant, it is possible to prove the following theorem, by extending Cook's original construction anisphily:

If L reduces to S and L' Cook-reduces to L Turing machine, then L' reduces to S . on a nondeterministic

(The clauses generated for those instants of the when I problems are to be solved are replaced by clauses corresponding to the senting of I to be solved are replaced by clauses corresponding to the senting of I to be solved are replaced by clauses corresponding to the senting of I needed with the concepts are the same at this lared of the increasing which is the term of the three concepts are the same at this lared of the horsetted while I have the mediate I would super that it is best to use the simpler definitions in connection with notions that vill be used by non-submate-bedrists. For senting the content of the increasing that vill be used by non-submate-bedrists. There is an encount literature on continutorial algorithms applied to practical problems, and a large body of practical people who get excited about them but no boat the scendial details of what can happen in write cases on curious abstract mechines. For more technical details of the two interesting to considered the end typace are details of the sentiously but details of the two interesting

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'NP-hard' meets Mike Fischer's objection to my original words which gave an absolute meaning to a relative quantity; he said that calling some problems formidable, is as bad as deciding to say that "big" means "greater than 17". [I don't agree here; after all, the word "positive" has merit, and NP-hard problems are just those above the O-th level of difficulty.] Mike was afraid of running out of terms; he said that problems of double exponential difficulty might be called "hopeless", and triple exponential "disastrous", but then he was at a loss for words.

One final criticism (which applies to all the terms suggested) was stated nicely by Vaughan Pratt: "If the Martians know that P = NP for Turing Machines and they kidnap me, I would lose face calling these problems 'formidable'." Yes; if P = NP, there's no need for any term at all. But I'm willing to risk such an embarrassment, and in fact I'm willing to give a prize of one live turkey to the first person who proves that P = NP.