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Program Accelerators and Automated Conjectures

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In the seventies, Lenat initiated a controversy about what is a conjecture-making program, by announcing that his program AM had rediscovered Goldbach's Hypothesis, but at the same time admitting that this program was "unlikely to make many startling new discoveries". Lenat found quite a few followers in attributing the re-discovery of known facts to computers. One of them was Herb Simon, a Nobel and Turing Award Prize winner, who led the effort of claiming the rediscovery of New-ton's, Kepler's, and other famous laws by computers, but also admitting that these systems were not able to make authentic discoveries. Less than ten years later, Graffiti became the first program whose conjectures inspired mathematicians to write papers about them. Since responses to conjectures, although highly subjective, are one of the simplest predictors of their potential, it should be noted that conjectures of Graffiti inspired results by many researchers including Alon, Bollobas, Chung, Erdos, Kleitman, and Lovasz. Science may be written in the language of mathematics, but the problems even in its closest relative, theoretical physics-usually are of a different nature, so it had not come as a great surprise to me, when Professor Simon had insisted that Graffiti could not make discoveries in physical sciences. At the time, the famous Galileo quote was all that I could think of to argue with Simon's claim, but later I formed a belief in the program accelerators axiom, according to which one could write a program A, making conjectures about basically any other program P, including itself, and then on the basis of these conjectures, A could rewrite P in a simpler, and hence less error- prone, form that would (conjecturally) get the same results as P, but possibly much faster. These concepts are similar to Universal Turing Machines and the Church-Turing thesis, and they may be even suitable for discussion of the Turing's original question whether machines can think [1]. As soon as these ideas had occurred to me, I realized that one version of Graffiti already was a program accelerator. The Dalmatian version of the program may systematically search through formulas built from polynomially computable invariants for bounds for theoretically difficult concepts, as for example the independence number [2]. A conjectured lower (or upper) bound is accepted by the Dalmatian version as interesting, if the program is familiar with at least one "challenger" object for which this bound predicts a higher (or lower, respectively) independence value than all of the previously conjectured bounds. If eventually the last challenger is "fended off," the program stops, and in particular, it conjectures that P=NP-a *big bang* in the language of [2]. After realizing that Graffiti was a program accelerator, I also realized that the idea could be instantly tested. The first program P that came to my mind was

k:= 0; s:=0; while k ≤ 100 do begin k:= k+1; s=s+k; A(P) end;

Where A was a call to Graffiti to make conjectures about P. After a few rounds, A ran out of challenger objects, printed

$$s = \frac{k}{2}(k+1)$$

and stopped. While not a big bang, it was notable nonetheless, because the next day, I realized that A had replicated the well-known story about young Gauss.

Apart from conjectures, the Dalmatian version presents its users with invariant interpolation problems, [2]. The user can assist the program by adding a new invariant to handle a challenger object. These problems are somewhat similar to problems on which Euler and his predecessors worked in the 17th and 18th century. After writing [2], I was encouraging my PhD students to run the Dalmatian version "one step at a time," by identifying the simplest challengers and solving the corresponding interpolation problems. Only one of these problems was solved in [3], conj. 814.

Before I had a chance to finish [4], to refute the claim of Professor Simon on theoretical grounds, the "carbon" version of Graffiti conjectured, that the first eight observed fullerenes tend to minimize their maximum independent sets, [3], conj. 899. After announcement of this conjecture during a DIMACS meeting, Patrick Fowler-a fullerene researcher-initially expressed considerable skepticism about it, but then, the very same day he announced that Buckminsterfullerene, the most stable fullerene isomer is the unique 60-atom spherical carbon molecule minimizing its independence number among 1812 mathematically possible fullerene models, and that the icosahedral C70 the unique stable fullerene molecule with 70 atoms was again unique among about 8000 mathematically possible fullerenes minimizing its independence number.

Graffiti's conjecture was result of one of its sorting patterns procedures [2,3], and Fowler's confirmation, the same day that I announced it, showed that the original interpretation of this conjecture was correct, in a much stronger form than anybody could anticipate it at the time. In fact, the independence number of molecules had not even been studied in chemistry before conjectures of Graffiti, although since then, this concept has inspired a number of publications in chemistry.

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