1 3F-1 Bookkeeping

- 0 pts Correct

Ans:

$$\frac{\vdash \mathsf{e}_1 \text{ matches } s \text{ leaving } s'' \quad \vdash \mathsf{e}_2 \text{ matches } s'' \text{ leaving } s'}{\vdash \mathsf{e}_1\mathsf{e}_2 \text{ matches } s \text{ leaving } s'}$$

$$\frac{\vdash \mathsf{e}_1 \text{ matches } s \text{ leaving } s'}{\vdash \mathsf{e}_1 \mid \mathsf{e}_2 \text{ matches } s \text{ leaving } s'} \qquad \frac{\vdash \mathsf{e}_2 \text{ matches } s \text{ leaving } s'}{\vdash \mathsf{e}_1 \mid \mathsf{e}_2 \text{ matches } s \text{ leaving } s'}$$

$$\frac{}{\vdash \mathsf{e}{*} \text{ matches } s \text{ leaving } s} \qquad \frac{\vdash \mathsf{e} \text{ matches } s \text{ leaving } s'' \vdash \mathsf{e}{*} \text{ matches } s'' \text{ leaving } s'}{\vdash \mathsf{e}{*} \text{ matches } s \text{ leaving } s'}$$

2 3F-2 Regular Expressions, Large Step

- 0 pts Correct

Exercise 3F-2. Regular Expression and Sets [5 points]. We want to update our operational semantics for regular expressions to capture multiple suffices. We want our new operational semantics to be deterministic — it return the set of all possible answers from the single-answer operational semantics above. We introduce a new judgment:

$$\vdash e \ \mathsf{matches}\ s\ \mathsf{leaving}\ S$$

And use rules of inference like the following:

$$\frac{}{\vdash \text{"x"}\ \mathsf{matches}\ s\ \mathsf{leaving}\ \{s' \mid s = \text{"x"} :: s'\}} \qquad \frac{}{\vdash \mathsf{empty}\ \mathsf{matches}\ s\ \mathsf{leaving}\ \{s\}}$$

$$\frac{\vdash e_1\ \mathsf{matches}\ s\ \mathsf{leaving}\ S \qquad \vdash e_2\ \mathsf{matches}\ s\ \mathsf{leaving}\ S'}{\vdash e_1 \mid e_2\ \mathsf{matches}\ s\ \mathsf{leaving}\ S \cup S'}$$

You must do one of the following:

- *either* give operational semantics rules of inference for $e*$ and e_1e_2. You may *not* place a derivation inside a set constructor, as in: $\{x \mid \exists y.\ \vdash e\ \mathsf{matches}\ x\ \mathsf{leaving}\ y\}$. Each inference rules must have a finite and fixed set of hypotheses.

- *or* argue in one or two sentences that it cannot be done correctly in the given framework. Back up your argument by presenting two attempted but "wrong" rules of inference and show that each one is either unsound or incomplete with respect to our intuitive notion of regular expression matching.

Part of doing research is getting stuck. When you get stuck, you must be able to recognize whether "you are just missing something" or "the problem is actually impossible".

Ans: I don't think it cannot be done correctly as it's not possible to chain together two operational sementic for the given semantic for e_1e_2; e_1 $\mathsf{matches}\ s\ \mathsf{leaving}\ S$ and e_2 $\mathsf{matches}\ S\ \mathsf{leaves}\ S'$is not defined for matching a set. Furthermore, it's the same case for $e*$ as it would require chaining between e $\mathsf{matches}\ s\ \mathsf{leaving}\ S''$ and $e*$ $\mathsf{matches}\ S\ \mathsf{leaving}\ S'$.

3 3F-3 Regular Expressions and Sets

- 0 pts Correct

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Exercise 3F-3. Equivalence [7 points]. In the class notes (usually marked as "optional material" for the lecture component of the class but relevant for this question) we defined an equivalence relation $c_1 \sim c_2$ for IMP commands. Computing equivalence turned out to be undecideable: $c \sim c$ iff c halts. We can define a similar equivalence relation for regular expressions: $e_1 \sim e_2$ iff $\forall s \in S.\ \vdash e_1\ \mathsf{matches}\ s\ \mathsf{leaving}\ S_1\ \wedge\ \vdash e_2\ \mathsf{matches}\ s\ \mathsf{leaving}\ S_2 \implies S_1 = S_2$ (note that we are using an "updated" operational semantics that returns the set of all possible matched suffices, as in the previous problem).

You must *either* claim that $e_1 \sim e_2$ is undecideable by reducing it to the halting problem *or* explain in two or three sentences how to compute it. You may assume that I the reader is familiar with the relevant literature.

Ans: If $e_1 \sim e_2$ is decideable, than it would mean that it is also capable of telling whether $\vdash e_2\ \mathsf{matches}\ s\ \mathsf{leaving}\ S$ halts or not. However, as it is impossible to solve the halting problem, the assumption $e_1 \sim e_2$ creates an contradiction. Therefore, $e_1 \sim e_2$ is undecideable.

4 3F-4 Equivalence

- 0 pts Correct

Exercise 3F-4. SAT Solving [6 points]. Why do the last two included tests take such a comparatively long time? Impress me with your knowledge of DPLL(T) — feel free to use information from the assigned reading or related papers, not just from the lecture slides. I am looking for a reasonably detailed answer. Include a discussion of which single module you would rewrite first to improve performance, as well as how you would change that module.

Potential bonus point: The provided code contains at least one fairly egregious defect. Comment.

Ans: The given code is essentially doing a brute force search on all possible combinations of x, y, z within the lower and higher bounds. Therefore it's a $O(256^n)$ algorithm, where n is the number of variables and 256 is the width of the range for the vairables. A more clever way of approaching this would be to utilize the simplex algorithm, where you compute the "corners" of the possible feasible reason and see if any of them satisfies the contraints.

Bonus: The variables are limited to range between -127 and 128, therefore any equation that's goes beyond the range would return unsatisfiable, for example $x > 128$.

5 3F-5 SAT Solving

- 0 pts Correct