VU Programm- und Systemverifikation

Assignment 2: Equivalence Partitioning and Boundary Value Testing

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Due: April 29, 4pm

Task 1: Equivalence Partitioning (5 points). A univariate polynomial equation of degree n is an equation of the form

$$\sum_{i=0}^{n} a_i \cdot x^i = 0 \qquad \text{or} \qquad a_n \cdot x^n + a_{n-1} \cdot x^{n-1} + \ldots + a_2 \cdot x^2 + a_1 \cdot x + a_0 = 0\,,$$

where $a_i \in \mathbb{R}$ (for $0 \leq i \leq n$) are numerical constants called *coefficients* and x is a *variable*. A polynomial equation is *zero* if all coefficients are zero, and *non-zero* otherwise. The solutions of this equation are the *roots* of the polynomial. A number a is a root if and only if the polynomial $(x - a)$ (where $a \in \mathbb{R}$) divides $\sum_{i=0}^{n} a_i \cdot x^i$. If $(x - a)^2$ divides $\sum_{i=0}^{n} a_i \cdot x^i$ then a is called a *multiple* root, otherwise a is a *simple* root. For non-zero polynomials, there is a highest power m such that $(x - a)^m$ divides $\sum_{i=0}^{n} a_i \cdot x^i$, which is called the *multiplicity* of the root a. If the polynomial is non-zero, the number of roots cannot exceed its degree (even counting the respective multiplicities). Note that there are polynomial equations which have no roots (e.g. $x^2 + 1 = 0$).

Let `unsigned roots (float` a_0`, ...)` be a function (which takes at least one parameter) that returns the number of roots of the non-zero polynomial determined by the coefficients given as a parameter. Multiplicities are counted accordingly, i.e., for the polynomial equation $x^3 + 2 \cdot x^2 - 7 \cdot x + 4 = 0$ which can be written as $(x + 4) \cdot (x - 1)^2$ and has the roots -4 and 1 with multiplicity 1 and 2, respectively, the output should be 3.

Provide *at least 5* equivalence classes derived using equivalence partitioning.

Condition	Valid	ID	Invalid	ID
$n=0$	$a_0 \notin \{-\infty, \infty, NaN, 0\}$	1	$a_0 = -\infty$ $a_0 = \infty$ $a_0 = NaN$ $a_0 = 0$	2 3 4 5
max. 1 solution $n=1$	$a_0 \notin \{-\infty, \infty, NaN\} \wedge$ $a_1 \notin \{-\infty, \infty, NaN\} \wedge$ $(a_0 \neq 0 \vee a_1 \neq 0)$	6	$a_0 = \infty$ $a_0 = -\infty$ $a_0 = NaN$ $a_1 = \infty$ $a_1 = -\infty$ $a_1 = NaN$	7 8 9 10 11 12
max. 2 solutions $n=2$	$a_1^2 > 4a_0 \wedge$ no ∞ $a_1^2 = 4a_0 \wedge$ no ∞	13 14	~~$a_1^2 < 4a_0$~~ ∞ somewhere etc	~~15~~
max. 3 solutions $n=3$	no ∞ etc	16	∞ somewhere etc	
max. 4 solutions $n=4$	no ∞ etc	17		
(etc.)				

Choose n s.t. $a_n \neq 0$, if possible, and $\forall i\ (i > n \Rightarrow a_i = 0)$.

Task 2: Boundary Value Testing (10 points). Use *Boundary Value Testing* to derive a test-suite for the method `roots`. For each test case, provide a brief explanation (why is this a boundary case?) and indicate which equivalence class(es) it covers. You can receive up to 1 point per test case. [1]

just outside problem area, both sides

maybe impl. by shifting

redundant

$0 > 4a_0$ degenerate case

Input	Output	Classes Covered
0	exception	5
∞	exception	3
$-\infty$	exception	2
NaN	exception	4
[illegible]	[illegible]	~~1~~
$-\varepsilon$	0	1
ε	0	1
0, 1	1	6
ε, 1	1	6
$-\varepsilon$, 1	1	6
0, 0, 1; one multiple root [2]	2	14
1, 2, 1; one multiple root	2	14
1, 3, 1; two simple roots	2	13
$-\varepsilon$, 0, 1; two simple roots	2	13
ε, 0, 1; complex roots don't count	0	15
4, −7, 2, 1; one multiple root, one simple r.	3	16
36, 0, −13, 0, 1; no multiple roots; gaps	4	17

(etc.)

Please hand in your assignment via TUWEL (as a single PDF file) by April 29, 2015, 4pm.

[2] for leading $a_i = 0$ (i.e. $a_0 = 0$, $a_1 = 0$ etc.) there's at least one root ($x=0$) and then the case can be reduced to the case without leading $a_i = 0$ by division by x.

[1] in general, if $a_n \neq 0$ (which should be in valid cases), then one can divide the equation by a_n and so get an equivalent one where $a_n = 1$.