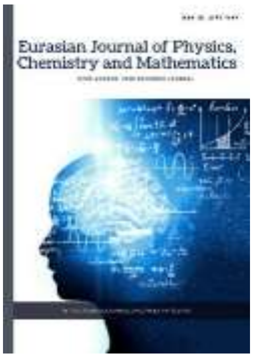

Application of Derivative of Function to Solving Equations

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ABSTRACT
This article shows the application of derivative of function to solving equations

Keywords: derivative of function

Let us be given a non-standard equation in the form of some kind of $f(x)=0$ in Section $[a,b]$. Let it be required to find the solution of this equation in Section $[a,b]$ (if it exists) ε in accuracy.
First of all, we check whether the function $f(x)$ satisfies the conditions of Baltsano-Cauchy theorem 1 in the section $[a,b]$ or not.
Theorem one of Balsano-Koshi. If the function $f(x)$ is defined on the section $[a,b]$ and is continuous and has different sign value at the extreme points of the interval, then there exists a point $c\in(a,b)$ such that $f(c)=0$.
So, if the function $f(x)$ fulfills the conditions of the theorem, then the section $[a,b]$ contains the solution of the equation $f(x)=0$.
Suppose that the section $[a,b]$ contains the root of the equation $f(x)=0$. That is, let $x\in[a,b]$ exist such that $f(x)=0$ is equal. Also let $x=a+\Delta x$ be. Then the equality $f(a+\Delta x)=0$ holds. If we consider the equation $f(x_0+\Delta x)\approx f(x_0)+f'(x_0)\cdot\Delta x$,

$$f(a+\Delta x)\approx f(a)+f'(a)\cdot\Delta x\approx 0$$

equality, that is, $\Delta x\approx-\dfrac{f(a)}{f'(a)}$ is formed. From this, if we consider the equality $\Delta x=a-x$,

$$x-a\approx-\frac{f(a)}{f'(a)},\qquad x\approx a-\frac{f(a)}{f'(a)}$$

equalities are formed [1-9].
If the equality $\left|-\dfrac{f(a)}{f'(a)}\right|<\varepsilon$ is fulfilled, the solution of the equation will be found approximately with accuracy ε.
Suppose that this inequality does not hold, then we denote $a-\dfrac{f(a)}{f'(a)}$ by x_1 and consider the equation in the interval $[x_1,b]$. Denote the root of the equation as $x=x_1+\Delta x$ and calculate

$x \approx x_1 - \frac{f(x_1)}{f'(x_1)}$. If we denote it as x_2 and $|x_2 - x_1| < \varepsilon$ then $x_1 + \Delta x$ is the root. Continuing in this way, after a finite step, the inequality $|x_n - x_{n-1}| < \varepsilon$ is satisfied and x_n is taken to be an approximate solution of the given equation around ε [10-23].

Example 1. Prove that the equation $f(x) = x^3 - 3x - 6$ has a unique solution in the interval $[2;3]$ and find it with precision 0.001.

Solving. $f(x) = x^3 - 3x - 6$ is a function defined on the interval $[2;3]$, continuous and $f(2) = -4 < 0$, $f(3) = 12 > 0$. On the other hand $\forall x = (2;3)$ for $f'(x) = 3(x^2 - 1) > 0$, that is, the function is increasing. Therefore, the equation $x^3 - 3x - 6 = 0$ has a unique solution in the interval $[2;3]$. Now let's say $x = 2 + \Delta x$ and find Δx such that $f(x) = f(2 + \Delta x) = 0$. For sufficiently small Δx

$f(2 + \Delta x) = f(2) + \Delta f(2) \approx f(2) + f'(2) \cdot \Delta x$.

Then we come to the equation $f(2) + f'(2) \cdot \Delta x \approx 0$. By finding $\Delta x \approx -\frac{f(2)}{f'(2)}$ from this, we find the equation $x = 2 + \Delta x \approx 2 - \frac{f(2)}{f'(2)}$ for the solution.

Finally, taking into account that $f(2) = -4$, $f'(2) = (3x^2 - 3)\big|_{x=2} = 9$, we find $x \approx x_1 = 2 - \frac{-4}{9} = 2.4$. Using the same reasoning, we find the solution [24-36]:

$$x_2 = 2.4 - \frac{f(2.4)}{f'(2.4)} = 2.4 - \frac{0.62}{14,28} \approx 2.360,$$

$|x_2 - x_1| = 0.40 > 0.001;$

$$x_3 = 2.360 - \frac{f(2.360)}{f'(2.360)} \approx 2.356,$$

$|x_3 - x_2| = 0.004 > 0.001;$

$$x_4 = 2.356 - \frac{f(2.356)}{f'(2.356)} \approx 2.356,$$

$|x_4 - x_3| = 0.000 < 0.001.$

Therefore, the number 2.356 is the solution of the equation with an accuracy of 0.001.

Example 2. Compute the solution of the equation $f(x) = x^3 + x^2 - 5$ in the **interval** $[a;b]$ using the derivative ε with precision $(a = 1,\ b = 2,\ \varepsilon = 0.01)$.

Solving. The function $f(x) = x^3 + x^2 - 5$ is defined on the interval $[1;2]$, continuous and $f(1) = -3 < 0$, $f(2) = 7 > 0$. On the other hand $\forall x \in (1;2)$ for $f'(x) = 3x^2 + 2x > 0$, that is, the function is increasing. Therefore, the equation $x^3 + x^2 - 5 = 0$ has a unique solution in the interval $[1;2]$.

Now, taking $x = 1 + \Delta x$, we find Δx such that $f(x) = f(1 + \Delta x) = 0$. For sufficiently small Δx

$f(1 + \Delta x) = f(1) + \Delta f(1) \approx f(1) + f'(1) \cdot \Delta x$.

Then we come to the equation $f(1) + f'(1) \cdot \Delta x \approx 0$. By finding $\Delta x \approx -\frac{f(1)}{f'(1)}$ from this, we find the equation

$x = 1 + \Delta x \approx 1 - \frac{f(1)}{f'(1)}$ for the solution.

$$x \approx x_1 = 1 - \frac{f(1)}{f'(1)} = 1 - \frac{-3}{5} = 1.6,$$

$$x_2 = 1.6 - \frac{f(1.6)}{f'(1.6)} = 1.6 - \frac{1.656}{10.88} = 1.45,$$

$|x_2 - x_1| = 0.15 > 0.01;$

$$x_3 = 1.45 - \frac{f(1.45)}{f'(1.45)} = 1.45 - \frac{0.151}{9.208} = 1.43,$$

$$|x_3 - x_2| = 0.016 > 0.01;$$

$$x_4 = 1.43 - \frac{f(1.43)}{f'(1.43)} = 1.43 - \frac{-0.03}{8.99} = 1.43,$$

$$|x_4 - x_3| = 0.00 < 0.01.$$

Therefore, the number 1.43 is a solution of the equation with an accuracy of 0.01 [37-53].

Example 3. Compute the solution of the equation $f(x) = x - \sqrt{2-x} + 1$ in the interval $[a;b]$ using the derivative ε with precision $(a = 0,\ b = 1,\ \varepsilon = 0.01)$.

Solving. The function $f(x) = x - \sqrt{2-x} + 1$ is defined on the interval $[0;1]$, continuous and $f(0) = -0.4 < 0$, $f(1) = 0 \geq 0$. On the other hand $\forall x \in (0;1)$ for $f'(x) = 1 + \frac{1}{2\sqrt{2-x}} > 0 \quad (2 - x > 0, x < 2)$ ie the function is increasing. Therefore, the equation $x - \sqrt{2-x} + 1 = 0$ has a unique solution in the interval $[0;1]$.

Now, taking $x = 0 + \Delta x$, we find Δx such that $f(x) = f(0 + \Delta x) = 0$. For sufficiently small Δx

$$f(0 + \Delta x) = f(0) + \Delta f(0) \approx f(0) + f'(0) \cdot \Delta x.$$

Then we come to the equation $f(0) + f'(0) \cdot \Delta x \approx 0$. By finding $\Delta x \approx -\frac{f(0)}{f'(0)}$ from this, we find the equation $x = 0 + \Delta x \approx -\frac{f(0)}{f'(0)}$ for the solution:

$$x \approx x_1 = -\frac{f(0)}{f'(0)} = -\frac{-0.4}{1.36} = 0.29,$$

$$x_2 = 0.29 - \frac{f(0.29)}{f'(0.29)} = 0.29 - \frac{-0.02}{1.38} = 0.30,$$

$$|x_2 - x_1| = 0.014 > 0.01;$$

$$x_3 = 0.30 - \frac{f(0.30)}{f'(0.30)} = 0.30 - \frac{-0}{1.38} = 0.30,$$

$$|x_3 - x_2| = 0.00 < 0.01.$$

Therefore, the number 0.30 is a solution of the equation with an accuracy of 0.01.

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