

NOTES ON USING COPILOT FOR SOLVING PROBLEMS IN MATHEMATICS IN CZECH

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Abstract

The rapid development and growing accessibility of generative artificial intelligence tools based on large language models have opened new possibilities for their integration into mathematics education. This paper explores the potential of using Bing Chat with Copilot to solve mathematical tasks formulated in the Czech language. The study focuses on a specific topic: the application of derivative of a real function of two real variables. It includes a sequence of user requests—generating an exercise, providing a solution, illustrating an economic application, and visualizing the problem. Additionally, the ability to generate LaTeX-formatted output, a standard in mathematical typesetting, is evaluated. Bing Chat with Copilot was chosen for this study due to its high availability and ease of access. The aim is to assess its usefulness in supporting Czech-speaking students in mathematics courses. The results show that the responses are generally sufficient and appear helpful to people seeking online support in mathematics. The language quality of the responses to Czech-language prompts is also commendable.

Key words: education, mathematics, generative AI

JEL Code: C80, C88

Introduction

The rapid development and growing accessibility of generative artificial intelligence tools based on large language models have opened new possibilities for their integration into mathematics education. This paper explores the potential of using Bing Chat with Copilot to solve mathematical tasks formulated in the Czech language. The study focuses on a specific topic: the directional derivative of a real function of two real variables. It includes a sequence of user requests—generating an exercise, providing a solution, illustrating an economic application, and visualizing the problem. Additionally, the ability to generate LaTeX-formatted output, a standard in mathematical typesetting, is evaluated. Bing Chat with Copilot

was chosen for this study due to its high availability and ease of access. The aim is to assess its usefulness in supporting Czech-speaking students in mathematics courses.

The recent applications of generative artificial intelligence tools based on large language models in education are reflected in (Ellis and Slade, 2023) and in (Jauhainen and Garagorry, 2024). Some authors also mention concerns about the risks of using such tools, see (Lambert and Stevens, 2023), (Chan, 2023), (McIntire et al, 2024), (Chen et al., 2024), (Ülkü, 2023), (Pudasaini et al., 2024) or (Xing, 2024). The literature considering the application of generative AI tools for support in mathematics education in Czech language includes the paper (Vítá, 2023).

1 Generating exercises and solved problems

The first request to generate a solved problem in mathematics in this study is a request to generate an example of calculation of a directional derivative of a real function of two real variables (in Czech the prompt used was “příklad na výpočet derivace funkce dvou reálných proměnných ve směru zadaného vektoru”). Directional derivatives topic is a common part of elementary mathematics courses at the university level. The first part of the response generated by Copilot is shown in Figure 1.

Fig. 1: First part of response to request to generate calculation of directional derivative

Zde je příklad výpočtu derivace funkce dvou reálných proměnných ve směru zadaného vektoru:

Zadání:

Mějme funkci:

$$f(x, y) = x^2y + \sin(xy)$$

a vektor:

$$\vec{v} = \begin{pmatrix} 3 \\ 4 \end{pmatrix}$$

Chceme spočítat směrovou derivaci funkce f v bodě $A = (1, 0)$ ve směru vektoru \vec{v} .

Source: Bing.com chat with Copilot

The response of Copilot contains the function of two variables, which will be used later in the calculation, setting a vector of two real numbers and a point in RxR. Then the response proceeds as shown in Figure 2.

Fig. 2: Response showing calculation of directional derivative

Postup:

1. Normalizace směrového vektoru:

$$\|\vec{v}\| = \sqrt{3^2 + 4^2} = 5 \quad \Rightarrow \quad \vec{u} = \frac{1}{5} \begin{pmatrix} 3 \\ 4 \end{pmatrix}$$

2. Gradient funkce:

$$\nabla f(x, y) = \left(\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y} \right)$$

Vypočítáme parciální derivace:

- $\frac{\partial f}{\partial x} = 2xy + y \cos(xy)$
- $\frac{\partial f}{\partial y} = x^2 + x \cos(xy)$

3. Dosazení bodu $A = (1, 0)$:

- $\frac{\partial f}{\partial x}(1, 0) = 0$
- $\frac{\partial f}{\partial y}(1, 0) = 1^2 + 1 \cdot \cos(0) = 1 + 1 = 2$

Gradient v bodě A je tedy:

$$\nabla f(1, 0) = \begin{pmatrix} 0 \\ 2 \end{pmatrix}$$

4. Směrová derivace:

$$D_{\vec{u}} f(1, 0) = \nabla f(1, 0) \cdot \vec{u} = \begin{pmatrix} 0 \\ 2 \end{pmatrix} \cdot \frac{1}{5} \begin{pmatrix} 3 \\ 4 \end{pmatrix} = \frac{1}{5} (0 \cdot 3 + 2 \cdot 4) = \frac{8}{5}$$

Source: Bing.com chat with Copilot

The response shows in the first step of the solution how to calculate the length of the vector and how to normalize the original vector using its length. Then the gradient of the function, i. e. the two component vector of the partial derivatives is computed and this gradient vector is then evaluated at the point specified in the assignment, obtaining a two component vector of real numbers in step number 3. Finally the directional derivative calculation is finished in step 4, providing the product of gradient and vector which specified

the direction of the derivative, normalized by the length of this vector. The response is generated in Czech language and it may be considered clear and correct.

Figure 3 shows the remaining part of the response, which is the conclusion, presenting the assignment together with the result, which is a real number. In this case even the calculation with numbers, which is often a pitfall of using generative AI tools based on large language models, is correct.

Fig. 3: Conclusion of the calculation of directional derivative

Výsledek:

Směrová derivace funkce $f(x, y) = x^2y + \sin(xy)$ v bodě $(1, 0)$ ve směru vektoru $\vec{v} = (3, 4)$ je:

$$\boxed{\frac{8}{5}}$$

Source: Bing.com chat with Copilot

Users may often prefer to receive responses that include mathematical expressions formatted using specialized typesetting systems, such as LaTeX. LaTeX is a widely used and powerful tool for producing high-quality mathematical and scientific documents, particularly valued for its precision in rendering complex formulas and symbols.

In this study, it was observed that when users explicitly requested output in LaTeX format—using prompts such as „v texu“ in Czech—the system was able to generate the corresponding LaTeX syntax effectively. Figure 4 illustrates the first part of such a response, showcasing how mathematical content can be seamlessly translated into LaTeX code.

Following the generation of the LaTeX-formatted response, Copilot also suggested creating a .tex file containing the source code. This file, produced automatically by the system, was syntactically correct and ready for compilation in any standard LaTeX editor. This functionality is particularly useful for students, educators, and researchers who wish to integrate AI-generated content directly into academic documents or presentations.

Fig. 4: Response showing source for LaTeX

Zde je celý příklad výpočtu směrové derivace funkce dvou proměnných ve formátu LaTeX:

```
\documentclass{article}
\usepackage{amsmath}
\usepackage{amssymb}

\begin{document}

\section*{Příklad: Směrová derivace funkce dvou proměnných}

Mějme funkci:
\[
f(x, y) = x^2y + \sin(xy)
\]

a vektor:
\[
\vec{v} = \begin{pmatrix} 3 & 4 \end{pmatrix}
\]

Chceme spočítat směrovou derivaci funkce  $f$  v bodě  $A = (1, 0)$  ve směru vektoru  $\vec{v}$ .
```

Source: Bing.com chat with Copilot

It can be highly beneficial for students studying mathematics—particularly those applying it in interdisciplinary contexts such as economics or the social sciences—to receive examples that are directly relevant to their field of study. Tailoring mathematical concepts to real-world applications not only enhances comprehension but also increases student engagement and motivation. In this study, one of the final requests examined was the generation of an example illustrating the economic application of the directional derivative. This type of example is especially valuable for economics students, as it bridges abstract mathematical theory with practical analytical tools used in economic modeling and optimization.

Figure 5 presents the initial portion of the response generated for this request (in Czech the prompt was „aplikáční příklad na směrovou derivaci v ekonomice“), demonstrating how the concept of a directional derivative can be contextualized within an economic framework—such as analyzing the rate of change of a production function in a specific direction of input variation.

Fig. 5: Response to request for an economic application of directional derivative

Zde je aplikovaný příklad směrové derivace v ekonomii, konkrétně v oblasti produkční funkce:

Ekonomický kontext:

Firma vyrábí produkt pomocí dvou vstupů: práce L a kapitálu K . Produkční funkce je dána jako:

$$f(L, K) = L^{0.5} K^{0.5}$$

což je Cobb-Douglasova produkční funkce.

Otázka:

Jak se bude měnit produkce, pokud firma současně zvýší práci i kapitál v poměru $\vec{v} = (2, 1)$, a to v bodě $(L, K) = (4, 1)$?

Source: Bing.com chat with Copilot

The assignment generated by Copilot utilizes the well-established Cobb-Douglas production function, which models output as a function of two key input variables: labour and capital. Figure 6 presents the second part of the response—the solution—which demonstrates the calculation and application of the directional derivative. The methodology employed in this solution closely mirrors the approach illustrated in Figure 2. However, a notable distinction lies in the order of operations: in this instance, the normalization of the direction vector is performed at the outset of the solution process, rather than later in the sequence. This adjustment reflects a slight variation in the procedural steps while maintaining the overall analytical framework.

Fig. 6: Solution of directional derivative calculation

Řešení pomocí směrové derivace:

1. Gradient produkční funkce:

$$\frac{\partial f}{\partial L} = \frac{1}{2} L^{-0.5} K^{0.5}, \quad \frac{\partial f}{\partial K} = \frac{1}{2} L^{0.5} K^{-0.5}$$

2. Dosazení bodu (4, 1):

$$\frac{\partial f}{\partial L}(4, 1) = \frac{1}{2} \cdot \frac{1}{2} \cdot 1 = \frac{1}{4}, \quad \frac{\partial f}{\partial K}(4, 1) = \frac{1}{2} \cdot 2 \cdot 1 = 1$$

$$\nabla f(4, 1) = \begin{pmatrix} \frac{1}{4} \\ 1 \end{pmatrix}$$

3. Normalizace směrového vektoru:

$$\vec{v} = \begin{pmatrix} 2 \\ 1 \end{pmatrix}, \quad \|\vec{v}\| = \sqrt{2^2 + 1^2} = \sqrt{5}, \quad \vec{u} = \frac{1}{\sqrt{5}} \begin{pmatrix} 2 \\ 1 \end{pmatrix}$$

4. Směrová derivace:

$$D_{\vec{u}} f(4, 1) = \nabla f(4, 1) \cdot \vec{u} = \begin{pmatrix} \frac{1}{4} \\ 1 \end{pmatrix} \cdot \frac{1}{\sqrt{5}} \begin{pmatrix} 2 \\ 1 \end{pmatrix} = \frac{1}{\sqrt{5}} \left(\frac{1}{4} \cdot 2 + 1 \cdot 1 \right) = \frac{1}{\sqrt{5}} \left(\frac{1}{2} + 1 \right) = \frac{3}{2\sqrt{5}}$$

Source: Bing.com chat with Copilot

The calculation is followed by the conclusion as shown in Figure 7. The conclusion tells what is the economic interpretation of the directional derivative in this case.

Fig. 7: Conclusion of analysis of production function

Interpretace:

Směrová derivace $\frac{3}{2\sqrt{5}}$ udává **rychlosť změny produkce**, pokud firma současně zvýší práci a kapitál v poměru 2:1. Tato hodnota říká, jak efektivní je tento konkrétní způsob zvyšování vstupů.

Source: Bing.com chat with Copilot

The user may then request a graphical representation of the problem and its solution. The response given by Copilot is shown in Figure 8. The response includes an explanation of the important features presented in the plot. The point in red is the starting point, the blue arrow is the production function gradient evaluated at the starting point and the green arrow is

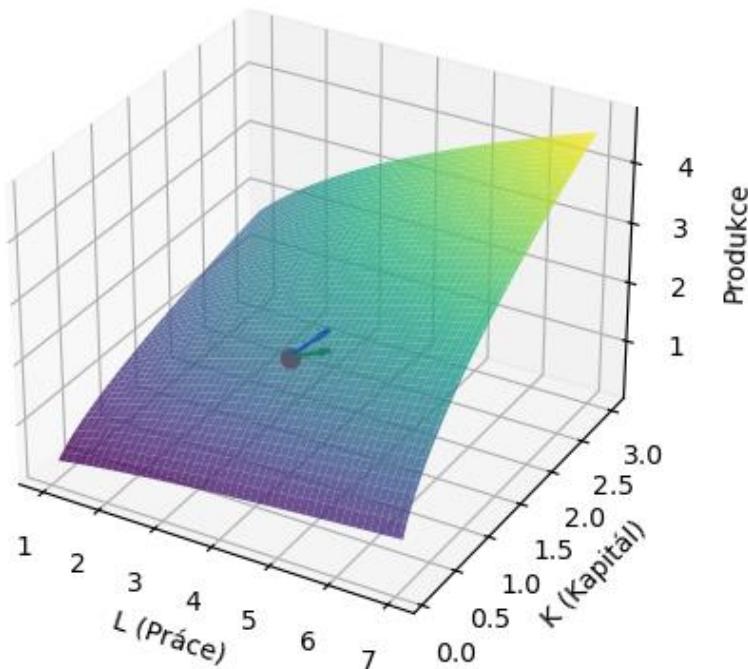
the direction of the change in inputs. The plot is rather clear considering the possibilities of visualization of the problem in two dimensions.

Fig. 8: Response showing graphical representation

Zde je 3D graf Cobb-Douglasovy produkční funkce $f(L, K) = \sqrt{L \cdot K}$ s vyznačeným:

- červeným bodem: výchozí bod $(4, 1)$,
- modrou šipkou: gradientem produkční funkce v tomto bodě,
- zelenou šipkou: směrem změny vstupů $\vec{v} = (2, 1)$.

Cobb-Douglasova produkční funkce s gradientem a směrem



Source: Bing.com chat with Copilot

Conclusion

The responses generated for requests related to directional derivatives and their economic applications, as discussed in this paper, are generally sufficient and appear helpful to students seeking online support in mathematics. The language quality of the responses to Czech-language prompts is also commendable.

Based on the results of the case studies presented, and assuming continued development and refinement of generative AI tools, the findings are promising. These tools

have the potential to provide meaningful support for students studying statistics and data science.

Therefore, it is recommended that tools based on large language models be integrated into statistics and data science curricula. This integration should include classroom discussions of AI-generated results and the sharing of best practices to enhance learning outcomes.

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