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Kampus Sungai Petani

Faculty of Administrative
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NEW FUNDAMENTAL THEORY IN SOLVING THE ROYALTY PAYMENT PROBLEM

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ABSTRACT
This study deal with the non-classical Optimal Control problem (OCP) where we want to maximize the functional objective function. However, this project has to clarify a few constraints. Firstly, the final state value is unknown. Furthermore, the objective function involved the royalty function which is in terms of the piecewise function of the unknown final state value. In addition, the non-classical OCP of the unknown final state value resulting in the nonzero shadow value at the final time. Moreover, the royalty function is non-differentiable at a certain process. Therefore, this study applied a new modified shooting method which is Sufahani-Ahmad-Newton-Golden-Royalty Algorithm. The program is constructed in the C++ program language. As a validation process, the result was compared with the discretization method which is constructed in AMPL program language with MINOS solver. The discretization method involved Euler, Runge-Kutta, Trapezoidal, and Hermite-Simpson methods. It is expected that the new modified shooting method will give a more accurate optimal solution when compared with the discretization method. The difficulty in using the royalty function that is in the piecewise function is overcome by utilizing the continuous approximation of the hyperbolic tangent (tanh) approach. This is to make sure that the objective function can be differentiated at all processes. This project can be a stepping-stone for the researcher to explore a new approach in solving a real-world problem. The most important is, this project addressed the importance of fundamental theory in solving the untangled issue.

Keywords: optimal Control, royalty payment, shooting method

INTRODUCTION

A current Optimal Control (OC) problem in the financial aspects has numerical properties that do not fall into the classical OC formulation. This study deal with the non-classical OC problem where we want to maximize the functional performance index. However, solving the problem, this project has to clarify a few constraints. Firstly, the final state value is unknown. Furthermore, the integrand in the functional performance index involved royalty function which is in term of piecewise function of the unknown final state value. In addition, the non-classical setting of the unknown final state value resulting in the nonzero value of costate at the terminal time. Moreover, the royalty function is non-differentiable at certain process.

METHODOLOGY

Therefore, this study applied indirect method to solve the problem. This is by using new modified

shooting method which is constructed in C++ program language. The new modified shooting method involved Sufahani-Ahmad-Newton-Golden-Royalty Algorithm. As a validation process, the result will be compared with the direct method (discretization method) which is constructed in AMPL programming language with MINOS solver.

RESULT AND DISCUSSION

Finally, it is expected that new modified shooting method yield highly accurate optimal solution when compared to the direct method.

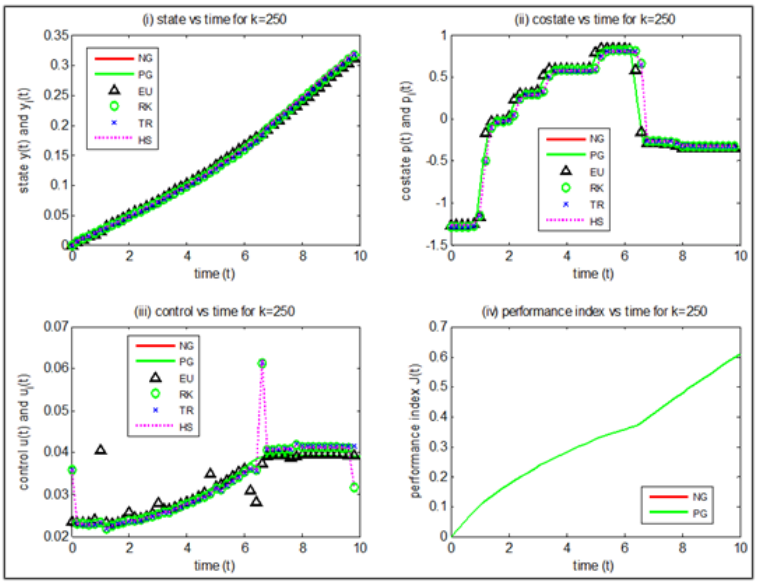


Figure 1. Optimal result of numerical testing with seven-stage royalty function. (EU=Euler; RK=Runge-Kutta; TM=Trapezoidal; HS=Hermite-Simpson)

RESULT AND DISCUSSION

Table 1. Result for the shooting and discretization methods with royalty function

Methods	Results				
	$y(T)$	$J(T)$	$p(0)$	$p(T)$	η_T
Shooting					
Newton & Golden Section Search	0.317978	0.606969	-1.254410	-0.356795	-0.356795
Discretization					
Euler	0.319074	0.611833	-1.26011	-	-
Runge-Kutta	0.323087	0.612860	-1.28002	-	-
Trapezoidal	0.322194	0.614032	-1.28354	-	-
Hermite-Simpson	0.328815	0.61295	-1.25833	-	-

To conclude, modified shooting method yield a more accurate and smooth optimal solution

and the differentiation process can be done in any time frame.

CONCLUSION

The difficulty in using the royalty function that is in piecewise function is overcome by utilizing the continuous approximation of hyperbolic tangent (tanh) approach. This is to make sure that the functional objective function can be differentiated at all process. This project can be a stepping-stone to researcher and academician to explore new approach in solving real-world problem. The most important is, this project addressed the importance of fundamental theory in solving the untangled issue

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