### **Joint Research With Birzeit University**

- Third Year of Collaboration
  - Professor Hani M. Kabajah, Birzeit University
  - Dr. Peter J. Kempthorne, MIT
- 2024-2025 Research
  - Topics
    - Regression and Time Series Modeling
    - Brownian Motion Modeling and Forecasting
  - MIT Researchers
    - Mohamed Wacyl Meddour (MIT '27)
  - Kai Samaroo (MIT/Imperial College '26)
  - Birzeit U. Researchers ()
    - Khaled Hasan
    - Leen Foqahaa

### **2024-25 Research Summaries**

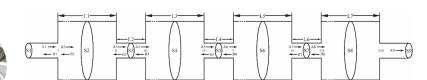
- Regression and Time Series Modeling and Forecasting (1\_Khaled\_Hasan.pdf)
- Brownian Motion Modeling and Forecasting (2\_Khaled\_Hasan.pdf)
- Brownian Motion Modeling and Forecasting (3\_Leen\_Fogahaa.pdf)
- Time Series Analysis of Model Stability (4\_Mohamed\_Wacyl\_Meddour.pdf)
- A comparative analysis of classical and machine learning techniques for time series forecasting (5\_Kai\_Samaroo.pdf)



Fransmission loss analysis for a silencer with an infinite number of expansion chambers using the transfer matrix method

Dr. Mamon Horoub





- Key Findings: 1. Effect of increasing the number of expansion chambers on noise reduction.
- Effect of expansion chamber length configurations on their performance and hence on noise reduction. 3. Generalized mathematical model to find the amount of noise attenuated for any number of expansion

### Regression and Time Series Modeling and Forecasting



- Students: Mohamed Wacyl Meddour, Feyi Adebekun and Carol Chen from MIT and Khaled Hasan from Birzeit University.
- Professors: Hani Kabajah (Birzeit University), Peter Kempthorne (MIT).

The aim of this project was to get introduced to time series analysis and its possible applications in physics. Exploring fundamental concepts in time series analysis and some associated forecasting methods, including simple regression, ARIMA and its variations.





# The Palestine UROP Program



Large Hadron Collider (LHC) and ATLAS

New Systen

14 TeV (second run, 2015 - 2018)

13 TeV (expected in 2015)

7 and 8 Tev (first run, 2009 - 20012)

Fall 2024 UROP Project: Brownian Motion Modeling & Forecasting

Machine learning Applications of Brownian Motion

Made by Leen Fogahaa, Birzeit University Supervised by Professor Hani Kabajah, Birzeit University & Professor Peter Kempthorne, MIT

### **Project Overview**

The main objective of this project is to explore the applications of the statistical methodology of brownian motion in particular and stochastic time series analysis in general, like parameter estimation and time series decomposition in the context of machine learning applications of image analysis.



ESTIMATING THE OUTPUT CURRENT BASED ON A MEASURED DATA FROM PHOTOVOLTAIC POWER GENERATION IN BIRZEIT UNIVERSITY

Birzeit University based on measurements data from the photovoltaic power generation in Naseeb Shaheen building. We combine the estimated solution by the power formula to get the first nonlinear relation between the current and voltage. The second well-known nonlinear equation is the characteristic equation obtained from Kirschoff laws. We solve this nonlinear system to estimate the output current generpanels, including cloud shadow, dust accumulation, panel's temperatu and fluctuations in sunlight intensity, we study the impact of the shadowing factors on the output current in terms of efficiency and reliability of solar power generation.

Single diode model, Parameter estimation, Measured data.

Modeling the power production of photovoltaic (PV) power generation is important for optimizing the efficiency of solar energy systems. Several research models allow for the prediction of energy output based on various factors such as solar irradiance, weather conditions, panel orientation and system losses. This predictive process is essential for grid integration as it helps the balance of supply and demand. Hence, ensuring grid stability and reducing the reliance on fossil fuels. On the other hand, such models enable stakeholders to maximize energy yield while minimizing costs. It also supports maintenance planning by identifying potential performance issues before they become critical. Additionally, these models are important for financial planning and investment decisions, as it provides realistic estimates of energy production and return on investment. In the context of climate change and the global transition to renewable energy, PV power production models used to achieve sustainable energy solutions and obtain long-term environmental goals.

Villalva et al. [15] provided a comprehensive framework for modeling PV arrays, integrating the characteristics of individual cells to predict the over all array performance. Surya and Sai [1] developed mathematical model for a PV cell by using advanced software tools like MATLAB-Simulink. Abdul et al. [2] investigated the implementation of Maximum Power Point Track ing (MPPT) algorithms in PV systems using LabVIEW, showing how these techniques can enhance energy harvesting by optimizing PV systems' performance. Ramos-Hernanz et al. [3] presented comparative simulations of

Ahmed Bassalat

Handle higher

radiation doses and

save its components

from damage.

**Build new modules for ITk** 

400x384

Differential FE

RD53B-ATLAS (ItkPix\_V1) submitted in March 2020

size: 20 mm x 21 mm

N. ZAID AND A. S. MOUSA\*

ABSTRACT. We study the performance of photovoltaic (PV) systems in

Keywords: Photovoltaic power panels, Nonlinear differential equation,

### 1. Introduction

sponding particular solution more rapidly. We solve different differential equations to show the validity of all results. Keywords: The method of undetermined coefficients, Particular solution,

Linear differential equations, Non-homogeneous differential equations.

COMPARISON OF NUMERICAL METHODS TO

ESTIMATE THE ROOTS OF A NONLINEAR EQUATIONS

A. BSHARAT AND A. S. MOUSA\*

ABSTRACT. We propose a new numerical method to estimate the root of the equation f(x) = 0, where f(x) is nonlinear and differentiable function on closed interval [a, b]. The proposed method is a hybrid

of the Newton and Bisection methods. We will compare our method with Newton-Raphson method, Bisection method, Brent's method and

Secant method. We will study the speed of convergence for our method and compare it with other well-known methods by considering different

nonlinear and differentiable functions with simple and multiple roots. Finally, we will generate a numerical algorithm for our proposed method.

Keywords: Numerical estimation, Nonlinear equations, Hybrid meth-

1. Introduction

The problem of estimating the roots of nonlinear and differentiable func-

Historically, the methods that starts to find the root of functions dates

back to ancient times, with early contributions from mathematicians such

as the Babylonians and Greeks. The developments of computation with

efficient algorithms began in the 17th century with the work of Newton

and Raphson, who introduced the Newton-Raphson method [4]. Since then,

numerous techniques have been proposed, each with its own advantages

and limitations depending on the nature of the function and the required

One of the most widely used methods for root estimation is the Newton-

Raphson method, which is an iterative approximation and requires the func-

tion to be differentiable [16]. Newton-Raphson method has quadratic con-

vergence rate when the root is simple, but the method can fail to converge

if the initial guess is not sufficiently close to the root, and we may get oscil-

In addition to the Newton-Raphson method, other iterative techniques,

such as the secant method and fixed-point iteration, have been extensively studied. The secant method is particularly useful when the derivative of the

REVISED APPROACH USING THE METHOD OF

UNDETERMINED COEFFICIENTS TO DETERMINE THE

PARTICULAR SOLUTION

RAMA IRHIMI AND ABDELRAHIM S. MOUSA\*

ABSTRACT. We introduce a revised technique on the method of undeter-

mined coefficients to find explicitly the particular solution of any second

order linear non-homogeneous differential equation with constant coef-

ficients and the non-homogeneous part is either exponential, or polyno-

mial, or sine, or cosine. We state sufficient conditions on the coefficients

for this class of differential equations in order to determined the corre-

lations behaviour or singularities [14].

tions is a fundamental challenge in numerical analysis and applied mathe-

matics. The root of a function f(x) is a solution to the equation f(x) = 0.

ods, Speed of convergence, Simple and multiple roots.

We start to introduce some basics about differential equations. We propose [?] for further details. Differential Equation(DE) is an equation with derivative. The order of a given differential equation is the highest derivative appears in the equation [?]. The general form of a differential equation  $f(t, y, y', ..., y^{(n)}) = 0$ .

The differential equation is linear if f is linear in  $y, y', ..., y^{(n)}$ . Otherwise, the

equations of  $2^{nd}$  order is y'' + p(t)y' + q(t)y = g(t)

### If g(t) = 0, then the DE (1) is called homogenous differential equation. If

 $g(t) \neq 0$ , then the DE (1) is called nonhomogenous differential equation.

### 2. Second order linear homogenous differential equations

To find the solution for any second order linear and nonhomogenous differential equation (1), we first find the homogenous solution corresponding to the homogenous differential equation, and then we find the particular solution based on the form of the nonhomogenous part of the differential equation using for example the Method of Undetermined Coefficients [?, ?]. To use the Method of Undetermined Coefficients, we first consider special

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Key words and phrases. 2<sup>nd</sup> order linear and nonhomogeneous DE; Homogeneous so-

## Developing Carbon-Black-Cement Supercapacitors

Students: Jad Jaffal, Salam Suleiman, and Khaled Hasan (BZU). Supervisors: Prof. Khalid Eid (BZU), Prof. Franz-Josef Ulm (MIT).

### **Motivation:**

- ► Limited access to advanced energy storage technology in Palestine.
- Lack of a stable energy grid in many areas.

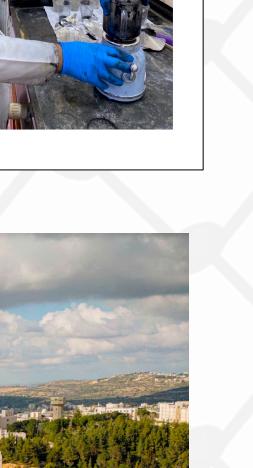
### **Achievements:**

- ► Infrastructure for electrochemical and supercapacitor experimentation at BZU.
- ► Sample supercapacitor with ~0.2 J/cm<sup>3</sup> form widely available materials.



Birzeit University, Ramallah













An-Najah National University, Nablus

Palestine Polytechnic University, Hebron