



## International Journal of Information Technology, Research and Applications (IJITRA)

**S. Luvis Savla, R. Gethsi Sharmila (2026). Numerical Solution for Fuzzy Fractional Predator- Prey Model Using Shehu Adomian Decomposition Method, 5(3), 01-14.**

**ISSN: 2583-5343**

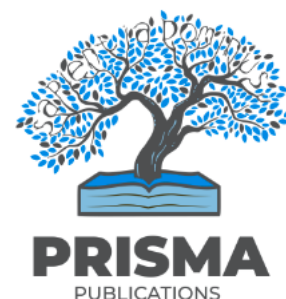
**DOI:10.59461/ijitra.v5i3.231**

The online version of this article can be found at:  
<https://www.ijitra.com/index.php/ijitra/issue/archive>

Published by:  
PRISMA Publications

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# Numerical Solution for Fuzzy Fractional Predator-Prey Model Using Shehu Adomian Decomposition Method

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## Article Info

### Article history:

Received Feb 11, 2026

Revised June 25, 2026

Accepted July 15, 2026

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### Keywords:

Fuzzy fractional prey-predator model,  
Triangular fuzzy number,  
Shehu transform,  
Shehu Adomian decomposition method.

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## ABSTRACT

Most of the ecological models need to have an approximate solution for finding an analytic solution. This paper aims to find the approximate solution of the Fuzzy Fractional Predator-Prey Model (FFPPM) with the triangular fuzzy number. In this paper, the study is about the Shehu Adomian Decomposition Method (SHADM) to give a numerical technique for solving FFPPM. This method is easy to implement and applicable for solving linear and nonlinear Fuzzy Fractional Differential Equations (FFDEs). The main advantage of this method is the higher efficiency for non-linear systems. The numerical example verifies the effectiveness of this proposed method. The obtained result using SHADM is balanced with the Homotopy Perturbation Method (HPM) which shows the efficiency of the proposed method.

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## 1 Introduction

The history of continuous fractional calculus is as old as that of conventional integer-order calculus. In the recent past, fractional calculus has been researched from both theoretical and practical perspectives [2], [7]. Until relatively recently, there had been little significant advancement in discrete fractional calculus in relation to the continuous case. However, due to an increase in interest in developing this theory during the past ten years, discrete fractional calculus has received significant attention [11], [19].

Alternately, one is not able to produce a complete and accurate version for the analysis of such systems due to the uncertainty and imperfections in the belief of a dynamical system. As a result, the fuzzy form can be offered as a suitable mathematical technique for presenting the subjective aspects that may influence the phenomena depicted by a device. Fuzzy differential equations and fuzzy difference equations have received a lot of attention in recent years as useful models to forecast the behavior of discrete and continuous procedures that are susceptible to imprecision based solely on subjective judgments [6], [8].

Lotka [15] proposed a model for the study of an herbivorous animal species and a plant species, and then developed the application to the study of the dynamics of a predator-prey system. Volterra [20] stated a simple system of ordinary differential equations. He considered  $x(t)$  and  $y(t)$  the densities of prey and predators, and assuming linear behaviors and taking positive constants  $a, b, c$  and  $d$ , he stated the following model

$$\begin{aligned}\frac{dx}{dt} &= ax - bxy, \\ \frac{dy}{dt} &= -cy + dxy\end{aligned}\quad (1)$$

Fractional calculus is merged into complicated, dynamical systems which extremely renovates the theory of the design and control performance for complex systems. Recently, quite a few researchers introduced fractional calculus into the predator-prey model and constructed fractional predator-prey models and also developed this model in uncertain situations. The fuzzy fractional predator-prey equation is defined as follows,

$$\begin{aligned}{}^C D_t^\alpha \tilde{x}(t; r) &= a(t)\tilde{x}(t; r) - b(t)\tilde{x}(t; r)\tilde{y}(t; r), \\ {}^C D_t^\beta \tilde{y}(t; r) &= c(t)\tilde{x}(t; r)\tilde{y}(t; r) - d(t)\tilde{y}(t; r)\end{aligned}\quad (2)$$

with fuzzy triangular initial conditions  $\tilde{x}(0; r) = [\underline{x}(0; r), \bar{x}(0; r)]$ ,  $\tilde{y}(0; r) = [\underline{y}(0; r), \bar{y}(0; r)]$ . Here  ${}^C D_t^\alpha$  is the Caputo fractional derivative.

In the field of fuzzy fractional differential equations, there have been numerous implementations in order to find exact and approximate solutions [5], [17]. R. Gethsi Sharmila et al. [9] proposed the Shehu transform method to solve linear fuzzy fractional differential equations. The Shehu transform method is combined with the Adomian decomposition method to establish a new methodology named the Shehu Adomian Decomposition Method (SHADM). R. Gethsi Sharmila and S. Luvis Savla [10] developed a fuzzy fractional fourth-order Runge–Kutta method based on the root mean square and contraharmonic mean for obtaining numerical solutions of fuzzy fractional differential equations. Luvis Savla et al. [21] & [22] proposed the Shehu Adomian Decomposition Method to solve the fuzzy fractional biological population model and fuzzy fractional Volterra Fredholm integro differential equations. Tapaswini et al. [18] proposed a homotopy perturbation method to solve fuzzy arbitrary-order predator-prey equations. In this paper, SHADM is developed to solve the system of nonlinear fuzzy fractional differential equations.

This paper is structured as follows: Section 2 gives some basic tools that involves the Caputo fractional derivative, Shehu transform, and triangular fuzzy number. Section 3 describes the algorithm of SHADM for the fuzzy fractional predator-prey equation. Section 4 contains the numerical example and figures that demonstrate the effectiveness of using SHADM to solve the fuzzy fractional predator-prey equation. Finally, Section 5 offers the conclusion.

## 2 Basic Concepts

In this section, the fundamental definitions of fractional calculus and the Shehu transform of fractional derivatives are given in [3] which are used in this paper.

### 2.1 Definition

In the Caputo sense, the fractional derivative of  $f(t)$  is defined as follows:

$${}^C D_t^\delta f(t) = \frac{1}{\Gamma(n-\delta)} \int_0^t (t-\tau)^{n-\delta-1} f^{(n)}(\tau) d\tau, n-1 < \delta \leq n, n \in \mathbb{N}.$$

### 2.2 Definition

Over the set of functions, the Shehu transform of the function  $f(t)$  is defined as

$$B = \left\{ f(t) : \exists M, \Psi_1, \Psi_2 > 0, |f(t)| < M \exp\left(\frac{|t|}{\Psi_j}\right), t \in (-1)^j \times [0, \infty) \right\}.$$

by the following integral

$$\mathbb{S}[f(t)] = F(s, u) = \int_0^\infty e^{-st/u} f(t) dt.$$

Next, the inverse of the Shehu transform is denoted by  $\mathbb{S}^{-1}[F(s, u)] = f(t), t \geq 0$ . For  $\delta$  is a fractional number,

$$\mathbb{S}[t^\delta] = \left(\frac{u}{s}\right)^{\delta+1} \Gamma(\delta+1).$$

## 2.3 Definition

The Shehu transform of the Caputo fractional derivative is defined as

$$\mathbb{S}[{}^C D_t^\delta f(t)] = \frac{s^\delta}{u^\delta} F(s, u) - \sum_{q=0}^{n-1} \left(\frac{s}{u}\right)^{\delta-(q+1)} f^{(q)}(0), n-1 < \delta \leq n$$

## 2.4 Definition (Triangular fuzzy number)

It's a three-pointed fuzzy number represented by  $N = (\theta_1, \theta_2, \theta_3)$ .  $N$ 's membership function is as follows:

$$\mu_N(\chi) = \begin{cases} 0, \chi < \theta_1 \\ \frac{\chi - \theta_1}{\theta_2 - \theta_1}, \theta_1 \leq \chi \leq \theta_2 \\ \frac{\theta_3 - \chi}{\theta_3 - \theta_2}, \theta_2 \leq \chi \leq \theta_3 \\ 0, \chi > \theta_3 \end{cases}$$

## 3 Fuzzy Fractional Predator-Prey Equations Using Shehu Adomian Decomposition Method

Let us consider the fuzzy fractional predator-prey equations

$$\begin{aligned} {}^C D_t^\alpha \tilde{x}(t; r) &= a(t)\tilde{x}(t; r) - b(t)\tilde{x}(t; r)\tilde{y}(t; r), \\ {}^C D_t^\alpha \tilde{y}(t; r) &= c(t)\tilde{x}(t; r)\tilde{y}(t; r) - d(t)\tilde{y}(t; r). \end{aligned} \quad (3)$$

with fuzzy triangular initial condition  $\tilde{x}(0; r) = [\underline{x}(0; r), \bar{x}(0; r)]$ ,  $\tilde{y}(0; r) = [\underline{y}(0; r), \bar{y}(0; r)]$ .

Applying Shehu transform on both sides of equation (1)

$$\begin{aligned} \mathbb{S}[{}^C D_t^\alpha \tilde{x}(t; r)] &= \mathbb{S}[a(t)\tilde{x}(t; r) - b(t)\tilde{x}(t; r)\tilde{y}(t; r)], \\ \mathbb{S}[{}^C D_t^\alpha \tilde{y}(t; r)] &= \mathbb{S}[c(t)\tilde{x}(t; r)\tilde{y}(t; r) - d(t)\tilde{y}(t; r)] \end{aligned} \quad (4)$$

$$\begin{aligned} \mathbb{S}[\tilde{x}(t; r)] &= \frac{u}{s} \tilde{x}(0; r) + \frac{u^\alpha}{s^\alpha} \mathbb{S}[a(t)\tilde{x}(t; r)] - \frac{u^\alpha}{s^\alpha} \mathbb{S}[a(t)\tilde{x}(t; r)\tilde{y}(t; r)], \\ \mathbb{S}[\tilde{y}(t; r)] &= \frac{u}{s} \tilde{y}(0; r) + \frac{u^\alpha}{s^\alpha} \mathbb{S}[c(t)\tilde{x}(t; r)\tilde{y}(t; r)] - \frac{u^\alpha}{s^\alpha} \mathbb{S}[d(t)\tilde{y}(t; r)] \end{aligned} \quad (5)$$

Applying the inverse Shehu transform on both sides,

$$\begin{aligned} \tilde{x}(t; r) &= \mathbb{S}^{-1} \left[ \frac{u}{s} \tilde{x}(0; r) \right] + \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S}[a(t)\tilde{x}(t; r)] \right] - \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S}[a(t)\tilde{x}(t; r)\tilde{y}(t; r)] \right], \\ \tilde{y}(t; r) &= \mathbb{S}^{-1} \left[ \frac{u}{s} \tilde{y}(0; r) \right] + \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S}[c(t)\tilde{x}(t; r)\tilde{y}(t; r)] \right] - \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S}[d(t)\tilde{y}(t; r)] \right] \end{aligned} \quad (6)$$

The Adomian decomposition approach is based on the assumption that the functions  $\tilde{x}(t, r)$  and  $\tilde{y}(t, r)$  can be broken into an infinite series [1]

$$\tilde{x}(t; r) = \sum_{n=0}^{\infty} \tilde{x}_n(t; r) = \tilde{x}_0 + \tilde{x}_1 + \tilde{x}_2 + \dots, \quad (7)$$

$$\tilde{y}(t; r) = \sum_{n=0}^{\infty} \tilde{y}_n(t; r) = \tilde{y}_0 + \tilde{y}_1 + \tilde{y}_2 + \dots, \quad (8)$$

where  $\tilde{x}_n(t; r), \tilde{y}_n(t; r)$  are recursively provided. The nonlinear operators can be broken into an infinite polynomial series using this method.

$$\tilde{x}(t; r)\tilde{y}(t; r) = \tilde{z} = \sum_{n=0}^{\infty} A_n(\tilde{z}_0, \tilde{z}_1, \tilde{z}_2, \dots, \tilde{z}_k) \quad (9)$$

where  $A_n$  is defined Adomian polynomial,

$$A_n(\tilde{z}_0, \tilde{z}_1, \dots, \tilde{z}_k) = \frac{1}{n!} \frac{d^n}{d\lambda^n} \left[ N \left( \sum_{k=0}^n \lambda^k \tilde{z}_k \right) \right]_{\lambda=0}, n = 0, 1, 2, \dots \quad (10)$$

where  $\lambda$  is a parameter. is the Adomian polynomial that can be described as follows:

$$\begin{aligned} A_0 &= \frac{1}{0!} \frac{d^0}{d\lambda^0} \left[ N \left( \sum_{k=0}^0 \lambda^k z_k \right) \right]_{\lambda=0} = \tilde{x}_0 \tilde{y}_0 \\ A_1 &= \frac{1}{1!} \frac{d^1}{d\lambda^1} \left[ N \left( \sum_{k=0}^1 \lambda^k z_k \right) \right]_{\lambda=0} = \tilde{x}_0 \tilde{y}_1 + \tilde{x}_1 \tilde{y}_0, \\ A_2 &= \frac{1}{2!} \frac{d^2}{d\lambda^2} \left[ N \left( \sum_{k=0}^2 \lambda^k z_k \right) \right]_{\lambda=0} = \tilde{x}_0 \tilde{y}_2 + \tilde{x}_1 \tilde{y}_1 + \tilde{x}_2 \tilde{y}_0, \\ &\vdots \end{aligned}$$

Substitute equations (5) and (6) in (4)

$$\begin{aligned} \sum_{n=0}^{\infty} \tilde{x}_n(t; r) &= \mathbb{S}^{-1} \left[ \frac{u}{s} \tilde{x}(0; r) \right] + \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ a(t) \sum_{n=0}^{\infty} \tilde{x}_n(t; r) \right] \right] - \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ a(t) \sum_{n=0}^{\infty} A_n \right] \right], \\ \sum_{n=0}^{\infty} \tilde{y}_n(t; r) &= \mathbb{S}^{-1} \left[ \frac{u}{s} \tilde{y}(0; r) \right] + \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ c(t) \sum_{n=0}^{\infty} A_n \right] \right] - \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ d(t) \sum_{n=0}^{\infty} \tilde{y}_n(t; r) \right] \right] \end{aligned} \quad (11)$$

If both sides of equation (9) are described, as follows:

$$\begin{aligned} \tilde{x}_0 &= \tilde{x}(0; r), \\ \tilde{x}_1 &= \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ a(t) \tilde{x}_0 \right] \right] - \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ a(t) A_0 \right] \right], \\ \tilde{x}_2 &= \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ a(t) \tilde{x}_1 \right] \right] - \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ a(t) A_1 \right] \right], \\ \tilde{x}_3 &= \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ a(t) \tilde{x}_2 \right] \right] - \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ a(t) A_2 \right] \right], \\ &\vdots \\ \tilde{y}_0 &= \tilde{y}(0; r), \\ \tilde{y}_1 &= \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ c(t) A_0 \right] \right] - \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ d(t) \tilde{y}_0 \right] \right], \\ \tilde{y}_2 &= \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ c(t) A_1 \right] \right] - \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ d(t) \tilde{y}_1 \right] \right], \\ \tilde{y}_3 &= \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ c(t) A_2 \right] \right] - \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ d(t) \tilde{y}_2 \right] \right], \\ &\vdots \end{aligned}$$

The SHADM was used to derive the recursive relation [12] of equation (1),

$$\begin{aligned} \tilde{x}_0 &= \tilde{x}(0; r), \\ \tilde{x}_{n+1} &= \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ a(t) \tilde{x}_n \right] \right] - \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ a(t) A_n \right] \right], \quad n = 0, 1, 2, \dots \end{aligned} \quad (12)$$

$$\begin{aligned} \tilde{y}_0 &= \tilde{y}(0; r), \\ \tilde{y}_{n+1} &= \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ c(t) A_n \right] \right] - \mathbb{S}^{-1} \left[ \frac{u^\alpha}{s^\alpha} \mathbb{S} \left[ d(t) \tilde{y}_n \right] \right], \quad n = 0, 1, 2, \dots \end{aligned} \quad (13)$$

## 4 Numerical Examples

Example 4.1 Consider the fuzzy fractional predator-prey equations [5],

$$\begin{aligned} {}^c D_t^\alpha \tilde{x}(t; r) &= a(t)\tilde{x}(t; r) - b(t)\tilde{x}(t; r)\tilde{y}(t; r), \\ {}^c D_t^\beta \tilde{y}(t; r) &= c(t)\tilde{x}(t; r)\tilde{y}(t; r) - d(t)\tilde{y}(t; r) \end{aligned} \quad (14)$$

with fuzzy triangular initial condition

$$\tilde{x}(0; r) = [0.2r + 1.1, 1.5 - 0.2r] = [\Phi_1, \Phi_2]$$

and

$$\tilde{y}(0; r) = [0.2r + 0.4, 0.8 - 0.2r] = [\chi_1, \chi_2]$$

Let us consider  $a(t) = t, b(t) = 1, c(t) = 1, d(t) = t$ . Then equation (12) becomes,

$$\begin{aligned} {}^c D_t^\alpha \tilde{x}(t; r) &= t\tilde{x}(t; r) - \tilde{x}(t; r)\tilde{y}(t; r), \\ {}^c D_t^\beta \tilde{y}(t; r) &= \tilde{x}(t; r)\tilde{y}(t; r) - t\tilde{y}(t; r) \end{aligned} \quad (15)$$

Solving equation (13) using Shehu Adomian decomposition method,

$$\begin{aligned} \underline{x}_0(t; r) &= \Phi_1, \bar{x}_0(t, r) = \Phi_2, \\ \underline{y}_0(t; r) &= \chi_1, \bar{y}_0(t, r) = \chi_2 \\ \underline{x}_1(t; r) &= \frac{t^{\alpha+1}}{\Gamma(\alpha+2)}\Phi_1 - \frac{t^\alpha}{\Gamma(\alpha+1)}\Phi_2\chi_2, \\ \bar{x}_1(t; r) &= \frac{t^{\alpha+1}}{\Gamma(\alpha+2)}\Phi_2 - \frac{t^\alpha}{\Gamma(\alpha+1)}\Phi_1\chi_1 \\ \underline{y}_1(t; r) &= \frac{t^\beta}{\Gamma(\beta+1)}\Phi_1\chi_1 - \frac{t^{\beta+1}}{\Gamma(\beta+2)}\chi_2, \\ \bar{y}_1(t; r) &= \frac{t^\beta}{\Gamma(\beta+1)}\Phi_2\chi_2 - \frac{t^{\beta+1}}{\Gamma(\beta+2)}\chi_1 \\ \underline{x}_2(t; r) &= \frac{t^{2\alpha}}{\Gamma(2\alpha+1)}\Phi_1\chi_1\chi_2 - \frac{(\alpha+2)t^{2\alpha+1}}{\Gamma(2\alpha+2)}\Phi_2\chi_2 + \frac{(\alpha+2)t^{2\alpha+2}}{\Gamma(2\alpha+3)}\Phi_1 - \frac{t^{\alpha+\beta}}{\Gamma(\alpha+\beta+1)}\Phi_2^2\chi_2 + \frac{t^{\alpha+\beta+1}}{\Gamma(\alpha+\beta+2)}\chi_1\Phi_2 \\ \bar{x}_2(t; r) &= \frac{t^{2\alpha}}{\Gamma(2\alpha+1)}\Phi_2\chi_2\chi_1 - \frac{(\alpha+2)t^{2\alpha+1}}{\Gamma(2\alpha+2)}\Phi_1\chi_1 + \frac{(\alpha+2)t^{2\alpha+2}}{\Gamma(2\alpha+3)}\Phi_2 - \frac{t^{\alpha+\beta}}{\Gamma(\alpha+\beta+1)}\Phi_1^2\chi_1 + \frac{t^{\alpha+\beta+1}}{\Gamma(\alpha+\beta+2)}\chi_2\Phi_1 \\ \underline{y}_2(t; r) &= \frac{t^{2\alpha}}{\Gamma(2\beta+1)}\Phi_1^2\chi_1\chi_2 - \frac{t^{2\beta+1}}{\Gamma(2\beta+2)}\chi_2\{\Phi_1 + (\beta+1)\Phi_2\} + \frac{(\beta+2)t^{2\beta+2}}{\Gamma(2\beta+3)}\chi_1 - \frac{t^{\alpha+\beta}}{\Gamma(\alpha+\beta+1)}\Phi_2\chi_2\chi_1 + \frac{t^{\alpha+\beta+1}}{\Gamma(\alpha+\beta+2)}\Phi_1\chi_1 \\ \bar{y}_2(t; r) &= \frac{t^{2\alpha}}{\Gamma(2\beta+1)}\Phi_2^2\chi_2\chi_1 - \frac{t^{2\beta+1}}{\Gamma(2\beta+2)}\chi_1\{\Phi_2 + (\beta+1)\Phi_1\} + \frac{(\beta+2)t^{2\beta+2}}{\Gamma(2\beta+3)}\chi_2 - \frac{t^{\alpha+\beta}}{\Gamma(\alpha+\beta+1)}\Phi_1\chi_1\chi_2 + \frac{t^{\alpha+\beta+1}}{\Gamma(\alpha+\beta+2)}\Phi_2\chi_2 \\ \underline{x}_3(t; r) &= -\frac{t^{3\alpha}}{\Gamma(3\alpha+1)}\chi_2^2\Phi_2\chi_1 + \frac{(\beta+1)t^{3\alpha+1}}{\Gamma(3\alpha+2)}\chi_1\Phi_1\chi_2 - \frac{(\alpha+2)(2\alpha+3)t^{3\alpha+2}}{\Gamma(3\alpha+3)}\Phi_2\chi_2 \\ &\quad + \frac{(\alpha+2)(2\alpha+3)t^{3\alpha+3}}{\Gamma(3\alpha+4)}\Phi_1 - \frac{t^{\alpha+2\beta}}{\Gamma(\alpha+2\beta+1)}\Phi_2^3\chi_2 + \frac{t^{\alpha+2\beta+1}}{\Gamma(\alpha+2\beta+2)}\Phi_2\chi_1\{\Phi_2 + (\beta+1)\Phi_1\} \\ &\quad - \frac{(\beta+2)t^{\alpha+2\beta+2}}{\Gamma(\alpha+2\beta+3)}\Phi_2\chi_2 + \frac{t^{2\alpha+\beta}}{\Gamma(2\alpha+\beta+1)}\chi_2\chi_1\Phi_1 - \frac{t^{2\alpha+\beta+1}}{\Gamma(2\alpha+\beta+2)}\chi_1 \\ &\quad + \frac{t^{2\alpha+\beta+2}}{\Gamma(2\alpha+\beta+3)}\chi_1\Phi_2\chi_1 \end{aligned}$$

where  $\Upsilon_1 = (\alpha + \beta + 2)\Phi_2^2\chi_2 + \chi_2^2\Phi_1 + \frac{\Gamma(\alpha+\beta+2)}{\Gamma(\alpha+2)\Gamma(\beta+1)}(\Phi_2^2\chi_2 + \Phi_1\chi_1^2)$  and  $\xi_1 = (\alpha + \beta + 2) + \frac{\Gamma(\alpha+\beta+3)}{\Gamma(\alpha+2)\Gamma(\beta+2)}$

$$\begin{aligned}\bar{x}_3(t; r) = & -\frac{t^{3\alpha}}{\Gamma(3\alpha+1)}\chi_1^2\Phi_1\chi_2 + \frac{(\beta+1)t^{3\alpha+1}}{\Gamma(3\alpha+2)}\chi_2\Phi_2\chi_1 - \frac{(\alpha+2)(2\alpha+3)t^{3\alpha+2}}{\Gamma(3\alpha+3)}\Phi_1\chi_1 \\ & + \frac{(\alpha+2)(2\alpha+3)t^{3\alpha+3}}{\Gamma(3\alpha+4)}\Phi_2 - \frac{t^{\alpha+2\beta}}{\Gamma(\alpha+2\beta+1)}\Phi_1^3\chi_1 + \frac{t^{\alpha+2\beta+1}}{\Gamma(\alpha+2\beta+2)}\Phi_1\chi_2\{\Phi_1 + (\beta+1)\Phi_2\} \\ & - \frac{(\beta+2)t^{\alpha+2\beta+2}}{\Gamma(\alpha+2\beta+3)}\Phi_1\chi_1 + \frac{t^{2\alpha+\beta}}{\Gamma(2\alpha+\beta+1)}\chi_1\chi_2\Phi_2 - \frac{t^{2\alpha+\beta+1}}{\Gamma(2\alpha+\beta+2)}\Upsilon_2 \\ & + \frac{t^{2\alpha+\beta+2}}{\Gamma(2\alpha+\beta+3)}\chi_2\Phi_1\xi_2\end{aligned}$$

where  $\Upsilon_2 = (\alpha + \beta + 2)\Phi_1^2\chi_1 + \chi_1^2\Phi_2 + \frac{\Gamma(\alpha+\beta+2)}{\Gamma(\alpha+2)\Gamma(\beta+1)}(\Phi_1^2\chi_1 + \Phi_2\chi_2^2)$  and  $\xi_2 = (\alpha + \beta + 2) + \frac{\Gamma(\alpha+\beta+3)}{\Gamma(\alpha+2)\Gamma(\beta+2)}$

$$\begin{aligned}y_3(t; r) = & -\frac{t^{3\beta}}{\Gamma(3\beta+1)}\Phi_2^2\chi_1 - \frac{t^{3\beta+1}}{\Gamma(3\beta+2)}\{(2\beta+1)\Phi_2^2\chi_2 + \Phi_1^2\chi_2 + (\beta+1)\Phi_2\chi_2\Phi_1\} \\ & + \frac{t^{3\beta+2}}{\Gamma(3\beta+3)}\chi_1\{(\beta+2)\Phi_1 + 2(\beta+1)\Phi_2 + 2(\beta+1)^2\Phi_1\} \\ & + \frac{(\beta+2)(2\beta+3)t^{3\beta+3}}{\Gamma(3\beta+4)}\chi_2 + \frac{t^{2\alpha+\beta}}{\Gamma(2\alpha+\beta+1)}\Phi_1\chi_1^2\chi_2 - \frac{(\alpha+2)t^{2\alpha+\beta+1}}{\Gamma(2\alpha+\beta+2)}\Phi_2\chi_1\chi_2 \\ & + \frac{(\alpha+2)t^{2\alpha+\beta+2}}{\Gamma(2\alpha+\beta+3)}\Phi_1\chi_1 + \frac{t^{\alpha+2\beta+1}}{\Gamma(2\alpha+\beta+2)}\Xi_1 - \frac{t^{\alpha+2\beta+2}}{\Gamma(\alpha+2\beta+3)}\chi_2\omega_1 \\ & - \frac{t^{\alpha+2\beta}}{\Gamma(\alpha+2\beta+1)}\chi_1\Phi_2\chi_2\{\Phi_1 + \frac{\Gamma(\alpha+\beta+1)}{\Gamma(\alpha+1)\Gamma(\beta+1)}\Phi_1 + \Phi_2\} + \frac{t^{\alpha+2\beta+1}}{\alpha+2\beta+2}\Xi_1 \\ & - \frac{t^{\alpha+2\beta+2}}{\alpha+2\beta+3}\chi_2\omega_1\end{aligned}$$

where  $\Xi_1 = \Phi_1^2\chi_1\left(1 + \frac{\Gamma(\alpha+\beta+2)}{\Gamma(\alpha+2)\Gamma(\beta+1)}\right) + \frac{\Gamma(\alpha+\beta+2)}{\Gamma(\alpha+1)\Gamma(\beta+2)}\Phi_2\chi_2^2 + \chi_1^2\Phi_2 + (\alpha+\beta+1)\Phi_1\chi_2\chi_1$  and  $\omega_1 = (\alpha+\beta+2)\Phi_2 + \frac{\Gamma(\alpha+\beta+3)}{\Gamma(\alpha+2)\Gamma(\beta+2)}\Phi_1\chi_2$

$$\begin{aligned}\bar{y}_3(t; r) = & -\frac{t^{3\beta}}{\Gamma(3\beta+1)}\Phi_1^2\chi_2 - \frac{t^{3\beta+1}}{\Gamma(3\beta+2)}\{(2\beta+1)\Phi_1^2\chi_1 + \Phi_2^2\chi_1 + (\beta+1)\Phi_1\chi_1\Phi_2\} \\ & + \frac{t^{3\beta+2}}{\Gamma(3\beta+3)}\chi_2\{(\beta+2)\Phi_2 + 2(\beta+1)\Phi_1 + 2(\beta+1)^2\Phi_2\} \\ & + \frac{(\beta+2)(2\beta+3)t^{3\beta+3}}{\Gamma(3\beta+4)}\chi_1 + \frac{t^{2\alpha+\beta}}{\Gamma(2\alpha+\beta+1)}\Phi_2\chi_2^2\chi_1 - \frac{(\alpha+2)t^{2\alpha+\beta+1}}{\Gamma(2\alpha+\beta+2)}\Phi_1\chi_2\chi_1 \\ & + \frac{(\alpha+2)t^{2\alpha+\beta+2}}{\Gamma(2\alpha+\beta+3)}\Phi_2\chi_2 + \frac{t^{\alpha+2\beta+1}}{\Gamma(2\alpha+\beta+2)}\Xi_2 - \frac{t^{\alpha+2\beta+2}}{\Gamma(\alpha+2\beta+3)}\chi_1\omega_2 \\ & - \frac{t^{\alpha+2\beta}}{\Gamma(\alpha+2\beta+1)}\chi_2\Phi_1\chi_1\{\Phi_2 + \frac{\Gamma(\alpha+\beta+1)}{\Gamma(\alpha+1)\Gamma(\beta+1)}\Phi_2 + \Phi_1\} + \frac{t^{\alpha+2\beta+1}}{\alpha+2\beta+2}\Xi_2 \\ & - \frac{t^{\alpha+2\beta+2}}{\alpha+2\beta+3}\chi_1\omega_2\end{aligned}$$

where  $\Xi_2 = \Phi_2^2\chi_2\left(1 + \frac{\Gamma(\alpha+\beta+2)}{\Gamma(\alpha+2)\Gamma(\beta+1)}\right) + \frac{\Gamma(\alpha+\beta+2)}{\Gamma(\alpha+1)\Gamma(\beta+2)}\Phi_1\chi_1^2 + \chi_2^2\Phi_1 + (\alpha+\beta+1)\Phi_2\chi_1\chi_2$  and  $\omega_2 = (\alpha+\beta+2)\Phi_1 + \frac{\Gamma(\alpha+\beta+3)}{\Gamma(\alpha+2)\Gamma(\beta+2)}\Phi_2\chi_1$

In a similar way, the rest of the components can be obtained.

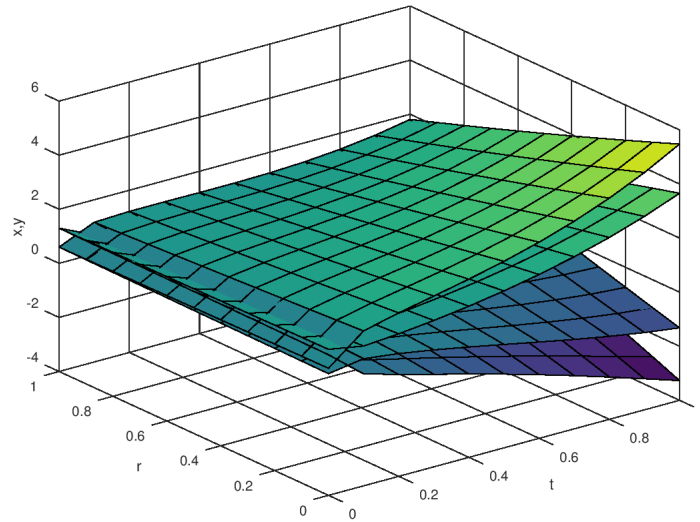


Figure 1: 3D Approximate Solution for Example 4.1 at  $\alpha = 0.25$  and  $\beta = 0.25$

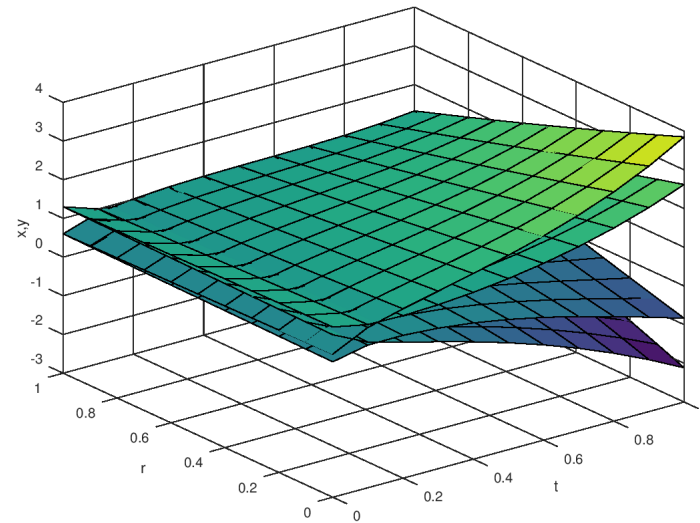


Figure 2: 3D Approximate Solution for Example 4.1 at  $\alpha = 0.5$  and  $\beta = 0.5$

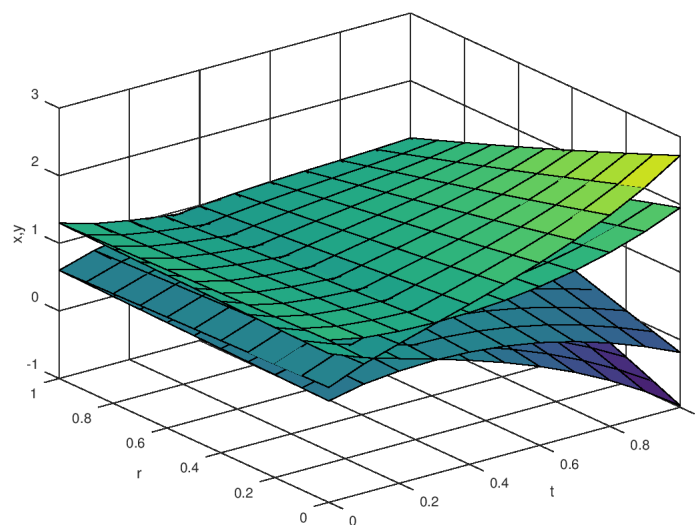


Figure 3: 3D Approximate Solution for Example 4.1 at  $\alpha=0.75$  and  $\beta=0.75$

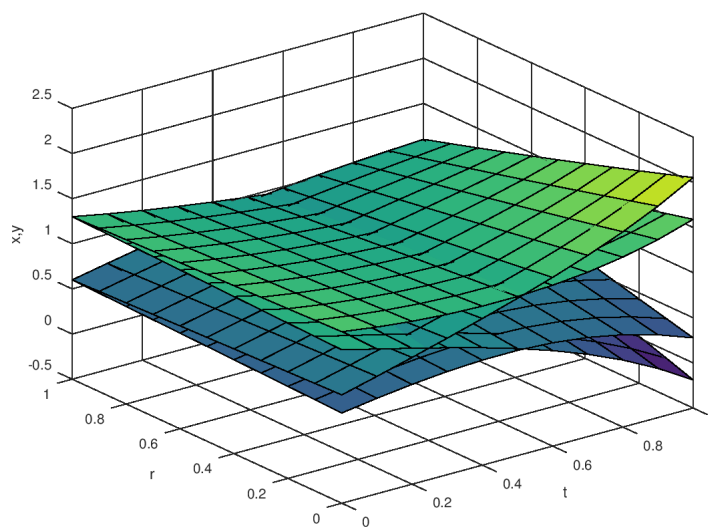


Figure 4: 3D Approximate Solution for Example 4.1 at  $\alpha=1$  and  $\beta=1$

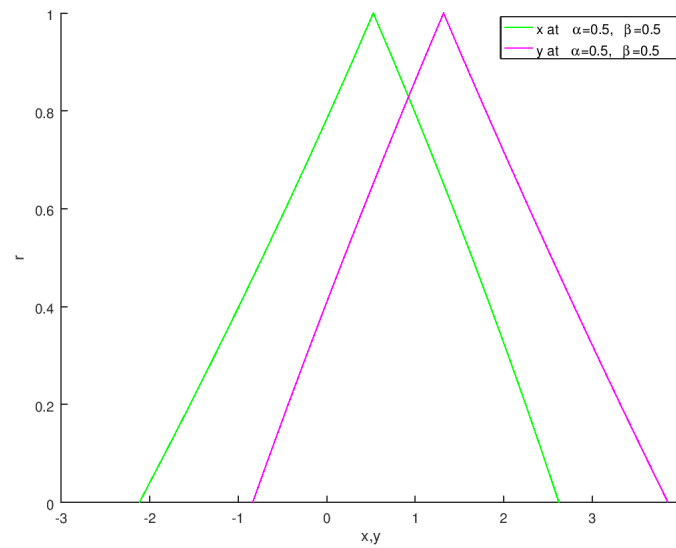


Figure 5: 2D Approximate Solution for Example 4.1 at  $\alpha, \beta = 0.5$  and  $t=1$

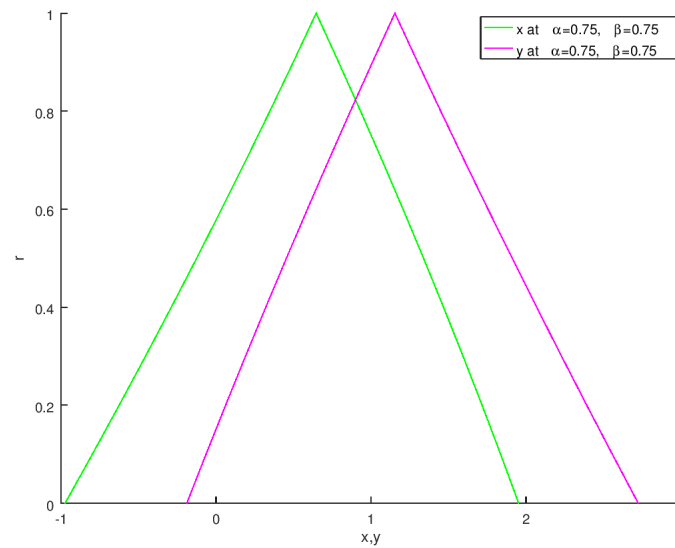


Figure 6: 2D Approximate Solution for Example 4.1 at  $\alpha, \beta = 0.75$  and  $t=1$

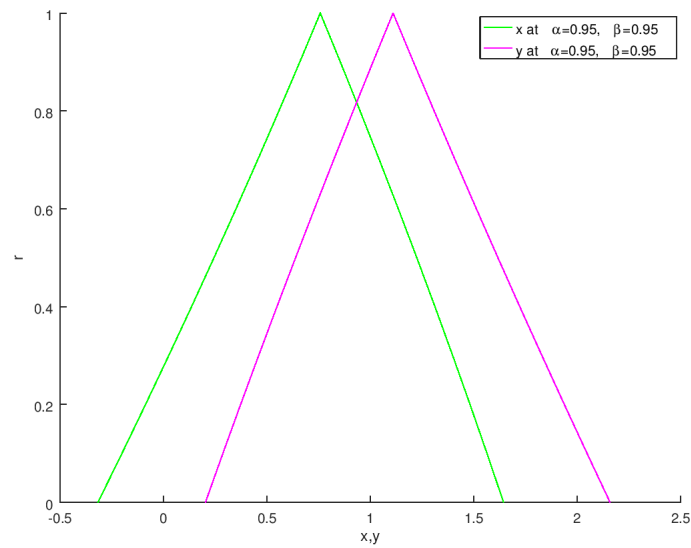


Figure 7: 2D Approximate Solution for Example 4.1 at  $\alpha, \beta = 0.95$  and  $t=1$

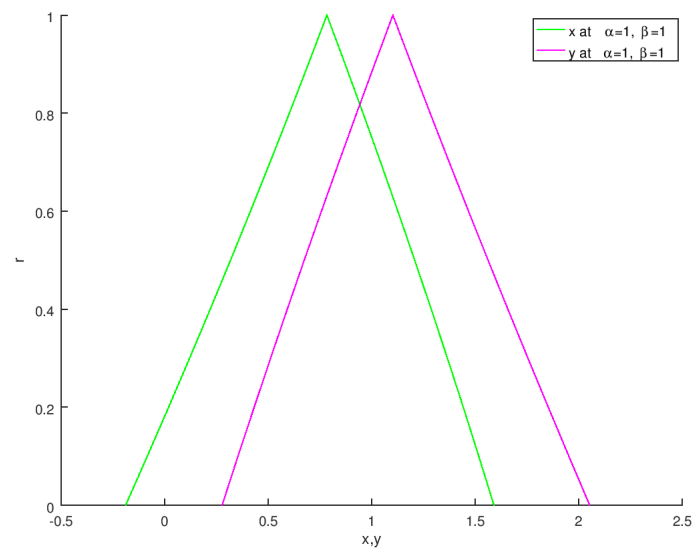


Figure 8: 2D Approximate Solution for Example 4.1 at  $\alpha, \beta = 1$  and  $t=1$

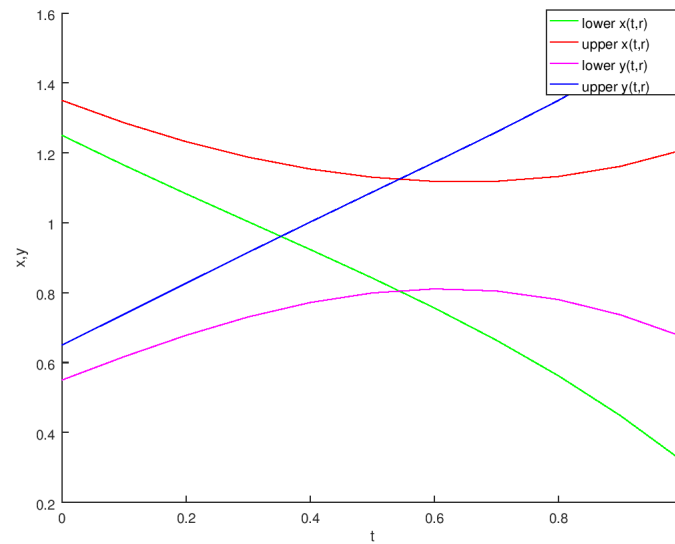


Figure 9: 2D Approximate Solution for Example 4.1 at  $\alpha, \beta = 1$  and  $r = 0.5$

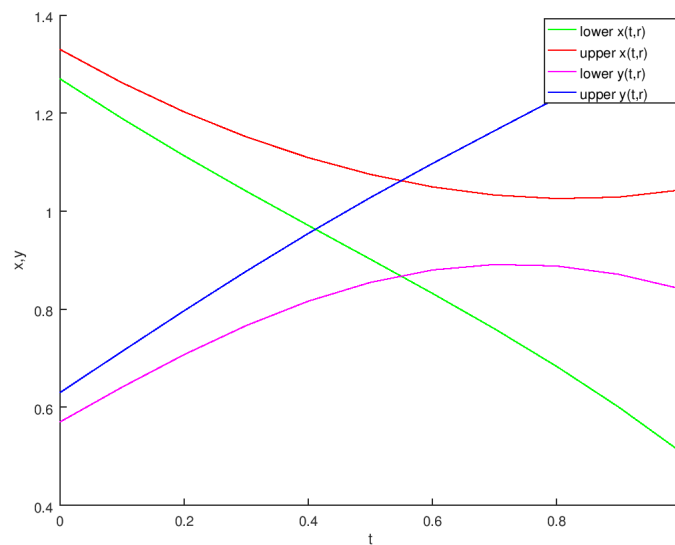


Figure 10: 2D Approximate Solution for Example 4.1 at  $\alpha, \beta = 1$  and  $r = 0.7$

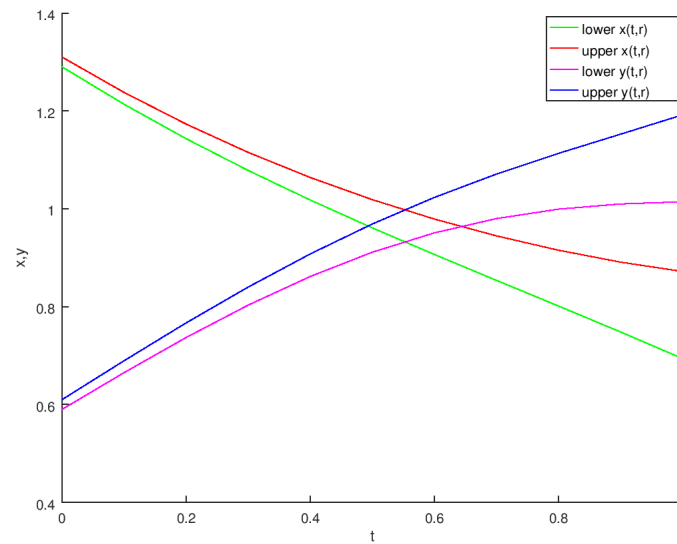


Figure 11: 2D Approximate Solution for Example 4.1 at  $\alpha, \beta = 1$  and  $r=0.9$

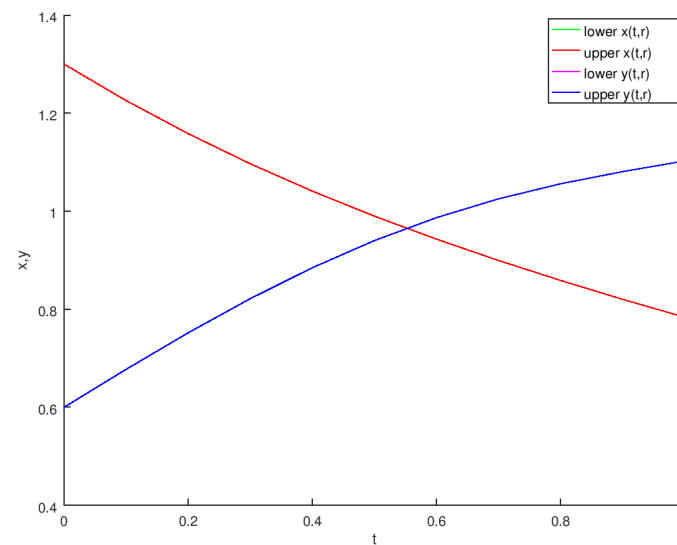
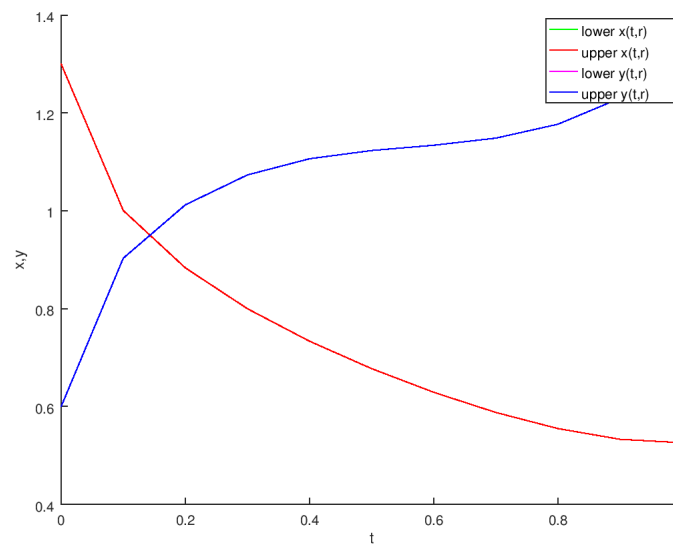
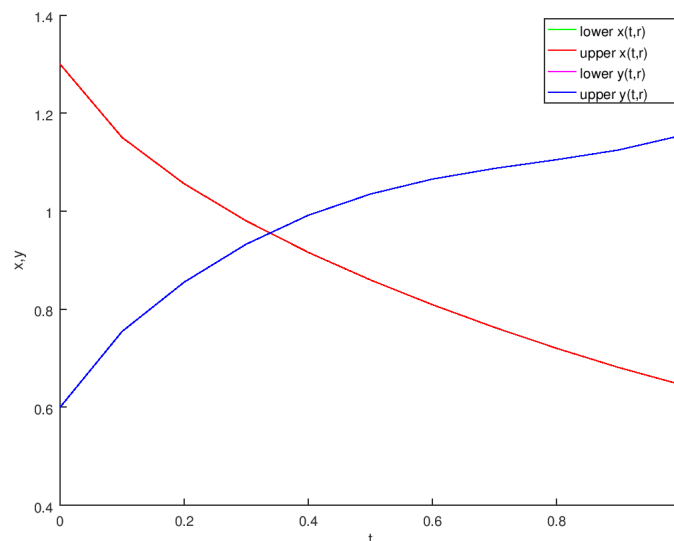


Figure 12: 2D Approximate Solution for Example 4.1 at  $\alpha, \beta = 1$  and  $r=1$

Figure 13: 2D Approximate Solution for Example 4.1 at  $\alpha, \beta = 0.5$  and  $r=1$ Figure 14: 2D Approximate Solution for Example 4.1 at  $\alpha, \beta = 0.75$  and  $r=1$ 

Numerical results are depicted in Figures 1- 12 respectively. In Figures 1- 4, by varying both  $t$  and  $r$  from 0 to 1 for  $\alpha, \beta = 0.25, \alpha, \beta = 0.5, \alpha, \beta = 0.75,$  and  $\alpha, \beta = 1$ . 3D results are depicted. In Figures 5-8, 2D figures are depicted by varying  $r$  from 0 to 1 and  $t$  as constant ( $t = 1$ ) for different values of fractional order. It can be concluded that the crisp solution lies in between the lower and upper bounds of the fuzzy solution. In Figures 9-12, 2D figures are depicted by varying  $t$  from 0 to 1 for different values  $r$ . The above figures noted that the lower and upper bounds of the fuzzy solutions are the same for  $r = 1$ .

## 5 CONCLUSION

The main focus of this work is to find the approximate solution for the system of fuzzy fractional differential equations. Predator-prey model is the most important application in the field of differential equations. The construction of the Shehu Adomian decomposition method is used to solve fuzzy fractional predator-prey equations. The proposed method is easy to

implement and applicable for solving both linear and nonlinear fuzzy fractional differential equations. The given figures show the efficiency of the proposed method.

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