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Modified Mid-Pointmethod Method For Solving Linear Fredholm Integral Equations Of The Second Kind

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Abstract

In this paper we use the Modified mid-pointmethod for solving the linear Fredholm integral equations of the second kind. In numerical examples we showed the effectiveness of this method, in comparison with other numerical methods such as, midpoint, trapezoidal, Simpson's and Modified trapezoidal methods.

1. Introduction

The theory and application of integral equations is an important subject within applied mathematics. Integral equations are used as mathematical models for many and varied physical situations, and also occur as reformulations of other mathematical problems. Many physical problems are modeled by integral equations the numerical solutions of such equations have been highly studied by many authors, [1-4]. In recent years, numerous works have been focusing on the development of more advanced and efficient methods for integral equations such as Taylor-series method [5], Neumann series method [6], Decompostion method [7], Homotopy perturbation method [7, 8] and Homotopy analysis method [9, 10].

In recent years a number of authors have considered Modified quadrature rules, and applications it in numerical integration. For example, the Modified trapezoidal, Modified mid-point and Modified Simpson quadrature rules are considered in [11-15, 19, 21]. Sometimes they have considered generalizations of these rules in [16, 17, 20]. Some authors used Modified quadrature rules in numerical solutions of integral equations, such as Nadjafi in [22] used Modified trapezoidal method for solving integral equations, Majeed in [23] used this method for solving system of integral equations.

In this paper we use the composted Modified mid-pointrule

$$\int_a^b f(x)dx = \left(h\sum_{j=1}^{n} f(x_j) + \frac{h^2}{24}\left[f'(b) - f'(a)\right] \right) + \frac{7}{5760}(b-a)h^4 f^{(4)}(\xi).$$
..(1.1)

where n is the number of subinterval of [a, b] , $h = \frac{b-a}{n}$, $x_j = a + (j - 1/2)h, j = 1, 2, ..., n$, to solve linear Fredholm integral equations of the second kind given by

$$u(x) = f(x) + \lambda\int_a^b k(x,y)u(y)dy, \ a \le x \le b$$
…………… (1.2)

where λ is a scalar parameter, f(x) and k(x,y) are given continuous functions, whereas u(x) is to be determined.

2- The Modified mid-pointmethod:

We consider the linear Fredholm integral equation of the second kind :

$$u(x) = f(x) + \int_a^b k(x,y)u(y)dy, \ a \le x \le b$$
……...…..(2.1)

where, k(x,y) and f(x) is a differentiable functions with respect to their variables, i.e. the functions $\frac{\partial k(x,y)}{\partial x}$, $\frac{\partial k(x,y)}{\partial y}$ and $f'(x)$ exist.

To solve this equation, we approximate the integral part that appeared in the right hand side by the composed Modified mid-pointrule to get,

$$u(x) = f(x) + h\sum_{j=1}^{n} k(x,x_j)u(x_j) + \frac{h^2}{24}\big(J(x,x_{n+1/2})u(x_{n+1/2}) + k(x,x_{n+1/2})u'(x_{n+1/2}) -$$
$$J(x,x_{1/2})u(x_{1/2}) - k(x,x_{1/2})u'(x_{1/2})\big),$$
.....……… (2.2)

where, $x_{1/2} = a$, $x_{n+1/2} = b$ and $J(x,y) = \frac{\partial k(x,y)}{\partial y}$.

Hence for $x = x_{1/2}, x_1, \ldots, x_n, x_{n+1/2}$ we get the following system of equations:

$$u_i = f_i + h\sum_{j=1}^{n} k_{i,j}u_j + \frac{h^2}{24}\left(J_{i,n+1/2}u_{n+1/2} + k_{i,n+1/2}u'_{n+1/2} - J_{i,1/2}u_{1/2} - k_{i,1/2}u'_{1/2}\right)\Big],$$
……..…….. (2.3)

where $u_i = u(x_i)$, $u'_i = u'(x_i)$, $f_i = f(x_i)$, $k_{i,j} = k(x_i, x_j)$ and $J_{i,j} = J(x_i, x_j)$.

If we differentiate both sides of equation (2.1) with respect to x and setting $H(x,y) = \frac{\partial k(x,y)}{\partial x}$ one can obtain:

$$u'(x) = f'(x) + \int_a^b H(x,y)u(y)dy,\ a \le x \le b,$$
...…………..... (2.4)

We note that if u is a solution of eq.(2.1) then it is a solution of eq.(2.4) too.

Now, for solving eq.(2.4), we must consider two cases.

Case 1: The partial derivatives $L(x,y) = \frac{\partial^2 k(x,y)}{\partial x \partial y}$ exist. In this case, we approximate the integral part that appeared in the right hand side of eq.(2.4) by the composed modified mid-pointrule to get,

$$u'(x) = f'(x) + h\sum_{j=1}^{n} H(x,x_j)u(x_j) + \frac{h^2}{24}\Big(L(x,x_{n+1/2})u(x_{n+1/2}) + H(x,x_{n+1/2})u'(x_{n+1/2}) - L(x,x_{1/2})u(x_{1/2}) - H(x,x_{1/2})u'(x_{1/2})\Big)\Big],$$
...…………. (2.5)

By setting $x = x_{1/2}, x_{n+1/2}$, in eq.(2.5), one can get

$$u'_i = f'_i + h\sum_{j=1}^{n} H_{i,j}u_j + \frac{h^2}{24}\Big(L_{i,n+1/2}u_{n+1/2} + H_{i,n+1/2}u'_{n+1/2} - L_{i,1/2}u_{1/2} - H_{i,1/2}u'_{1/2}\Big)\Big],$$
$i = 1/2, n+1/2.$ ………..…. (2.6)

where $f'_i = f'(x_i)$, $H_{i,j} = H(x_i,x_j)$ and $L_{i,j} = L(x_i,x_j)$.

From eq.(2.6) and eq.(2.3) we get the following linear system

$$AU = F$$
………..…. (2.7)

of (n+4) equations in (n+4) unknowns $\{u_i\},\{u'_{1/2}\}$ and $\{u'_{n+1/2}\}$, $i = 1/2, 1, 2, \ldots, n, n+1/2$, where A, U, F are matrices defined by

$$A=\left[\begin{array}{cccccc|cc}
1+\frac{h^2}{24}J_{\frac{1}{2},\frac{1}{2}} & -hk_{\frac{1}{2},1} & -hk_{\frac{1}{2},2} & \cdots & -hk_{\frac{1}{2},n} & -\frac{h^2}{24}J_{\frac{1}{2},n+\frac{1}{2}} & \frac{h^2}{24}k_{\frac{1}{2},\frac{1}{2}} & -\frac{h^2}{24}k_{\frac{1}{2},n+\frac{1}{2}} \\
\frac{h^2}{24}J_{1,\frac{1}{2}} & 1-hk_{1,1} & -hk_{1,2} & \cdots & -hk_{1,n} & -\frac{h^2}{24}J_{1,n+\frac{1}{2}} & \frac{h^2}{24}k_{1,\frac{1}{2}} & -\frac{h^2}{24}k_{1,n+\frac{1}{2}} \\
\frac{h^2}{24}J_{2,\frac{1}{2}} & -hk_{2,1} & 1-hk_{2,2} & \cdots & -hk_{2,n} & -\frac{h^2}{24}J_{2,n+\frac{1}{2}} & \frac{h^2}{24}k_{2,\frac{1}{2}} & -\frac{h^2}{24}k_{2,n+\frac{1}{2}} \\
\vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots \\
\frac{h^2}{24}J_{n,\frac{1}{2}} & -hk_{n,1} & -hk_{n,2} & \cdots & 1-hk_{n,n} & -\frac{h^2}{24}J_{n,n+\frac{1}{2}} & \frac{h^2}{24}k_{n,\frac{1}{2}} & -\frac{h^2}{24}k_{n,n+\frac{1}{2}} \\
\frac{h^2}{24}J_{n+\frac{1}{2},\frac{1}{2}} & -hk_{n+\frac{1}{2},1} & -hk_{n+\frac{1}{2},2} & \cdots & -hk_{n+\frac{1}{2},n} & 1-\frac{h^2}{24}J_{n+\frac{1}{2},n+\frac{1}{2}} & \frac{h^2}{24}k_{n+\frac{1}{2},\frac{1}{2}} & -\frac{h^2}{24}k_{n+\frac{1}{2},n+\frac{1}{2}} \\
\hline
\frac{h^2}{24}L_{\frac{1}{2},\frac{1}{2}} & -hH_{\frac{1}{2},1} & -hH_{\frac{1}{2},2} & \cdots & -hH_{\frac{1}{2},n} & -\frac{h^2}{24}L_{\frac{1}{2},n+\frac{1}{2}} & 1+\frac{h^2}{24}H_{\frac{1}{2},\frac{1}{2}} & -\frac{h^2}{24}H_{\frac{1}{2},n+\frac{1}{2}} \\
\frac{h^2}{24}L_{n+\frac{1}{2},\frac{1}{2}} & -hH_{n+\frac{1}{2},1} & -hH_{n+\frac{1}{2},2} & \cdots & -hH_{n+\frac{1}{2},n} & -\frac{h^2}{24}L_{n+\frac{1}{2},n+\frac{1}{2}} & \frac{h^2}{24}H_{n+\frac{1}{2},\frac{1}{2}} & 1-\frac{h^2}{24}H_{n+\frac{1}{2},n+\frac{1}{2}}
\end{array}\right]$$

$$U=\begin{bmatrix} u_{\frac{1}{2}} \\ u_1 \\ u_2 \\ \vdots \\ u_n \\ u_{n+\frac{1}{2}} \\ \hline u'_{\frac{1}{2}} \\ u'_{n+\frac{1}{2}} \end{bmatrix}, \quad F=\begin{bmatrix} f_{\frac{1}{2}} \\ f_1 \\ f_2 \\ \vdots \\ f_n \\ f_{n+\frac{1}{2}} \\ \hline f'_{\frac{1}{2}} \\ f'_{n+\frac{1}{2}} \end{bmatrix}$$

By solving the above system by any suitable method the numerical solutions of eq.(2.1) is obtained.

Case 2: The partial derivatives $L(x,y)=\frac{\partial^2 k(x,y)}{\partial x\partial y}$ does not exist. In this case, we approximate the integral part that appeared in the right hand side of eq. (2.4) by the composed mid-pointrule to get, $u'(x)=f'(x)+h\sum_{j=1}^{n}H(x,x_j)u(x_j)$ ……..…. (2.8)

By setting $x=x_{1/2},\ x_{n+1/2}$ in eq.(2.8), one can get:

$u_i'=f_i'+h\sum_{j=1}^{n}H_{i,j}u_j$, $\qquad i=1/2, n+1/2.$ …………..…. (2.9)

From eq.(2.9) and eq.(2.3) we get the following linear system

$BU=F$ …………..…. (2.10)

of (n+4) equations in (n+4) unknowns $\{u_i\}$, $\{u_{1/2}'\}$ and $\{u_{n+1/2}'\}$, $i=1/2,1,2,\ldots,n,n+1/2$, where the matrices U and F are defined perversely,

$$B=\left[\begin{array}{cccccc|cc}
1+\frac{h^2}{24}J_{\frac12,\frac12} & -hk_{\frac12,1} & -hk_{\frac12,2} & \cdots & -hk_{\frac12,n} & -\frac{h^2}{24}J_{\frac12,n+\frac12} & \frac{h^2}{24}k_{\frac12,\frac12} & -\frac{h^2}{24}k_{\frac12,n+\frac12}\\
\frac{h^2}{24}J_{1,\frac12} & 1-hk_{1,1} & -hk_{1,2} & \cdots & -hk_{1,n} & -\frac{h^2}{24}J_{1,n+\frac12} & \frac{h^2}{24}k_{1,\frac12} & -\frac{h^2}{24}k_{1,n+\frac12}\\
\frac{h^2}{24}J_{2,\frac12} & -hk_{2,1} & 1-hk_{2,2} & \cdots & -hk_{2,n} & -\frac{h^2}{24}J_{2,n+\frac12} & \frac{h^2}{24}k_{2,\frac12} & -\frac{h^2}{24}k_{2,n+\frac12}\\
\vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots\\
\frac{h^2}{24}J_{n,\frac12} & -hk_{n,1} & -hk_{n,2} & \cdots & 1-hk_{n,n} & -\frac{h^2}{24}J_{n,n+\frac12} & \frac{h^2}{24}k_{n,\frac12} & -\frac{h^2}{24}k_{n,n+\frac12}\\
\frac{h^2}{24}J_{n+\frac12,\frac12} & -hk_{n+\frac12,1} & -hk_{n+\frac12,2} & \cdots & -hk_{n+\frac12,n} & 1-\frac{h^2}{24}J_{n+\frac12,n+\frac12} & \frac{h^2}{24}k_{n+\frac12,\frac12} & -\frac{h^2}{24}k_{n+\frac12,n+\frac12}\\
\hline
0 & -hH_{\frac12,1} & -hH_{\frac12,2} & \cdots & -hH_{\frac12,n} & 0 & 1 & 0\\
0 & -hH_{n+\frac12,1} & -hH_{n+\frac12,2} & \cdots & -hH_{n+\frac12,n} & 0 & 0 & 1
\end{array}\right]$$

By solving the system given by eq. (2.10) by any suitable method, the numerical solutions of eq.(2.1), is obtained.

3-Numerical examples:

In this section we represent four examples and their numerical results to show the high accuracy of the solution of the linear Fredholm integral equations of the second kind obtained by modified mid-pointmethod and then we compare all results with numerical results obtained by trapezoidal, Simpson, modified trapezoidal and mid-pointmethods, the computations were carried out using MALAB® 7.6.

Example 1 Consider the following linear Fredholm integral equation

$$u(x) = 1 + \int_0^{\pi} \sin(x+y)u(y)dy,\ 0 \le x \le \pi$$

………..… (3.1)

where the exact solution $u(x) = 1 + \dfrac{2\cos x + \pi \sin x}{1 - \frac{1}{4}\pi^2}$.

It is clear that, $\dfrac{\partial^2 k(x,y)}{\partial x \partial y} = -\sin(x+y)$ exists for $x, y \in [0, \pi]$. Therefore the numerical solution of eq.(3.1) can be obtained by system (2.7), the results errors of which being presented in table 1 for h=$p/10$ and in table 2 for h=$p/20$.

Table 1: Comparison between the results errors via trapezoidal, Simpson's 1/3, Modified trapezoidal, mid-pointand modified mid-pointmethods for example 1 with h= p/10 .

x_i	trapezoidal method	Simpson's method	modified trapezoidal method	x_i	mid-point method	Modified mid-point method
0	**1.1228E-002**	**7.4634E-005**	**1.8483E-005**	**0**		**1.6177E-005**
p/10	**1.6129E-002**	**1.0721E-004**	**2.6550E-005**	p/20	**6.9331E-003**	**1.9952E-005**
2p/10	**1.9451E-002**	**1.2929E-004**	**3.2018E-005**	3p/20	**9.0170E-003**	**2.5949E-005**
3p/10	**2.0869E-002**	**1.3871E-004**	**3.4352E-005**	5p/20	**1.0218E-002**	**2.9406E-005**
4p/10	**2.0244E-002**	**1.3456E-004**	**3.3323E-005**	7p/20	**1.0419E-002**	**2.9985E-005**
5p/10	**1.7637E-002**	**1.1723E-004**	**2.9033E-005**	9p/20	**9.6002E-003**	**2.7628E-005**
6p/10	**1.3304E-002**	**8.8433E-005**	**2.1900E-005**	11p/20	**7.8416E-003**	**2.2567E-005**
7p/10	**7.6691E-**	**5.0976E-005**	**1.2624E-005**	13p/20	**5.3153E-**	**1.5297E-**

	003				**003**	**005**
8p/10	**1.2831E-003**	**8.5287E-006**	**2.1121E-006**	15p/20	**2.2688E-003**	**6.5291E-006**
9p/10	**5.2285E-003**	**3.4753E-005**	**8.6066E-006**	17p/20	**9.9988E-004**	**2.8775E-006**
				19p/20	**4.1706E-003**	**1.2002E-005**
p	**1.1228E-002**	**7.4634E-005**	**1.8483E-005**	p		**1.6177E-005**
Absolute error	**0.1443**	**9.5896E-004**	**2.3749E-004**		**0.0668**	**2.2455E-004**
Lest square error	**0.0023**	**1.0214 E-007**	**6.2642E-009**		**5.4779E-004**	**5.0602E-009**

Table 2: Comparison between the results errors via trapezoidal, Simpson's 1/3, Modified trapezoidal, mid-pointand modified mid-pointmethods for example 1 with h= p/20 .

x_i	trapezoidal method	Simpson method	modified trapezoidal method	x_i	mid-point method	Modified mid-point method
0	**2.8036E-003**	**4.6234E-006**	**1.1531E-006**	**0**		**1.0091E-006**
p/10	**4.0273E-003**	**6.6414E-006**	**1.6564E-006**	p/40	**1.5707E-003**	**1.1303E-006**
2p/10	**4.8567E-003**	**8.0092E-006**	**1.9976E-006**	5p/40	**2.1384E-003**	**1.5388E-006**
3p/10	**5.2108E-003**	**8.5931E-006**	**2.1432E-006**	9p/40	**2.4968E-003**	**1.7967E-006**
4p/10	**5.0547E-003**	**8.3358E-006**	**2.0790E-006**	13p/40	**2.6107E-003**	**1.8787E-006**
5p/10	**4.4039E-003**	**7.2625E-006**	**1.8114E-006**	17p/40	**2.4691E-003**	**1.7768E-006**
6p/10	**3.3220E-003**	**5.4783E-006**	**1.3664E-006**	21p/40	**2.0858E-003**	**1.5010E-006**
7p/10	**1.9149E-**	**3.1579E-**	**7.8762E-007**	25p/40	**1.4984E-**	**1.0782E-**

	003	006			003	006
8p/10	**3.2038E-004**	**5.2834E-007**	**1.3177E-007**	29p/40	**7.6421E-004**	**5.4993E-007**
9p/10	**1.3055E-003**	**2.1529E-006**	**5.3697E-007**	33p/40	**4.4733E-005**	**3.2190E-008**
				37p/40	**8.4930E-004**	**6.1116E-007**
p	**2.8036E-003**	**4.6234E-006**	**1.1531E-006**	p		**1.0091E-006**
Absolute error	**0.0693**	**1.1434E-004**	**2.8517E-005**		**0.0332**	**2.5921E-005**
Lest square error	**2.8041E-004**	**7.6257E-010**	**4.7437E-011**		**6.8179E-005**	**3.7342E-011**

Example 2 Consider the following linear Fredholm integral equations

$$u(x) = e^{2x} - \frac{1}{2+2x} e^{(x^2+2)} + \frac{1}{2+2x} + \int_0^1 e^{x^2 y} u(y)dy, \ \ 0 \le x \le 1$$

………… (4.2) where the exact solution $u(x) = e^{2x}$. It is clear that, $\frac{\partial^2 k(x,y)}{\partial x \partial y} = \left(2x + 2x^3 y\right) e^{x^2 y}$ exist for $x, y \in [0,1]$. Therefore the numerical solution of eq.(3.2) can be obtained by system (2.7), the results errors of which being presented in table 3 with h=0.1.

Table 3: Comparison between the results errors via trapezoidal, Simpson's 1/3, Modified trapezoidal, mid-pointand modified mid-pointmethods for example 2 with h=0.1.

x_i	trapezoidal method	Simpson method	modified trapezoidal method	x_i	mid-point method	modified mid-point method
0	7.8964E-002	3.5814E-004	9.0113e-005	0		7.8843E-005
0.1	7.9263E-002	3.5938E-004	9.0424e-005	0.05	3.9837E-002	7.8911E-005
0.2	8.0167E-002	3.6306E-004	9.1350e-005	0.15	4.0140E-002	7.9454E-005
0.3	8.1690E-002	3.6909E-004	9.2869e-005	0.25	4.0751E-002	8.0528E-005
0.4	8.3854E-002	3.7727E-004	9.4926e-005	0.35	4.1679E-002	8.2100E-005
0.5	8.6689E-002	3.8716E-004	9.7412e-005	0.45	4.2937E-002	8.4104E-005
0.6	9.0225E-002	3.9789E-004	1.0011e-004	0.55	4.4540E-002	8.6404E-005
0.7	9.4482E-	4.0788E-	1.0261e-	0.6	4.6500E-	8.8740E

	002	004	004	5	002	-005
0.8	9.9461E-002	4.1416E-004	1.0417e-004	0.75	4.8824E-002	9.0625E-005
0.9	1.0511E-001	4.1134E-004	1.0341e-004	0.85	5.1498E-002	9.1172E-005
				0.95	5.4470E-002	8.8779E-005
1	1.1126E-001	3.8979E-004	9.7885e-005	1		8.5651E-005
Absolute error	0.9912	0.0042	0.0011		0.4512	0.0010
Lest square error	0.0906	1.6350E-006	1.0344E-007		0.0206	8.6139E-008

Example 3 Consider the following linear Fredholm integral equations

$$u(x) = x^3 + 2x + \frac{1}{20}\left(-\frac{26}{15}x - \frac{13}{15}x^2\right) + \int_0^1 .05y(x^2+2x)u(y)dy, \;\; 0 \le x \le 1 \qquad \ldots\ldots\ldots\ldots$$

(3.3) with the exact solution $u(x) = x^3 + 2x$. It is clear that, $\frac{\partial^2 k(x,y)}{\partial x \partial y} = 0.1(x+1)$ exists for $x, y \in [0,1]$. Therefore the numerical solution of eq.(3.3) can be obtained by system (2.7), the results errors of which being presented in table 3 with h=0.1.

Table 4: Comparison between the results errors via trapezoidal, Simpson's 1/3, modified trapezoidal, mid-pointand modified mid-pointmethods for example 2 with h=0.1.

x_i	trapezoidal method	Simpson method	modified trapezoidal method	x_i	mid-point method	modified mid-pointmethod
0	0	0	0	0		0
0.1	7.3348E-005	1.4672E-007	3.6681E-008	0.05	1.7886E-005	1.5666E-008
0.2	1.5368E-004	3.0742E-007	7.6856E-008	0.15	5.6274E-005	4.9290E-008
0.3	2.4100E-004	4.8210E-007	1.2052E-007	0.25	9.8152E-005	8.5972E-008
0.4	3.3531E-004	6.7074E-007	1.6769E-007	0.35	1.4352E-004	1.2571E-007
0.5	4.3660E-004	8.7336E-007	2.1834E-007	0.45	1.9238E-004	1.6850E-007
0.6	5.4487E-004	1.0900E-006	2.7249E-007	0.55	2.4473E-004	2.1436E-007
0.7	6.6013E-004	1.3205E-006	3.3013E-007	0.65	3.0056E-004	2.6326E-007
0.8	7.8238E-004	1.5651E-	3.9127E-007	0.7	3.5989E-	3.1523E-007

		006		5	004	
0.9	9.1161E-004	1.8236E-006	4.5590E-007	0.85	4.2271E-004	3.7025E-007
				0.95	4.8902E-004	4.2833E-007
1	1.0478E-003	2.0961E-006	5.2402E-007	1		4.5852E-007
Absolute error	0.0052	1.0376e-005	2.5939e-006		0.0023	2.4951E-006
Lest square error	3.6639e-006	1.4661e-011	9.1633e-013		7.6830E-007	7.9968E-013

Example 4 Consider the following linear Fredholm integral equations

$$u(x)=x-\frac{1}{2}-\frac{2}{5}(x+1)^{5/2}x+\frac{2}{7}(x+1)^{7/2}+\frac{4}{35}x^{7/2}+\int_0^1\left(1-(x+y)^{3/2}\right)u(y)dy,\ \ 0\le x\le 1 \quad \ldots\ldots\ldots (3.4)$$

with the exact solution $u(x)=x$. It is clear that, $\frac{\partial^2 k(x,y)}{\partial x\partial y}=\frac{-3}{4}(x+y)^{-1/2}$ does not exist for $x,y\in[0,1]$. Therefore the numerical solution of eq.(3.4) can be obtained by system (2.10), the results errors of which being presented in table 4 with h=0.1.

Table 5: Comparison between the results errors via trapezoidal, Simpson's 1/3, Modified trapezoidal, mid-pointand modified mid-pointmethods for example 4 with h=0.1.

x_i	trapezoidal method	Simpson method	modified trapezoidal method	x_i	mid-point method	Modified mid-point method
0	4.0927E-003	6.9958E-006	5.6489E-006	0		1.6558E-006
0.1	3.9711E-003	3.9427E-006	3.7976E-006	0.05	2.0183E-003	5.6586E-007
0.2	3.7965E-003	2.9024E-006	3.3414E-006	0.15	1.9424E-003	1.3385E-007
0.3	3.5807E-003	2.2828E-006	2.9849E-006	0.25	1.8439E-003	1.2565E-008
0.4	3.3292E-003	1.8168E-006	2.6396E-006	0.35	1.7265E-003	8.5904E-008
0.5	3.0459E-003	1.4200E-006	2.2843E-006	0.45	1.5923E-003	1.2727E-007
0.6	2.7333E-003	1.0574E-006	1.9119E-006	0.55	1.4430E-003	1.5085E-007
0.7	2.3938E-003	7.1156E-	1.5198E-006	0.6	1.2798E-	1.6305E-007

		007		5	003	
0.8	2.0290E-003	3.7325E-007	1.1072E-006	0.75	1.1035E-003	1.6724E-007
0.9	1.6402E-003	3.6956E-008	6.7405E-007	0.85	9.1492E-004	1.6543E-007
				0.95	7.1476E-004	1.5887E-007
1	1.2289E-003	3.0071E-007	2.2068E-007	1		1.5409E-007
Absolute error	0.0318	2.1840E-005	2.6130E-005		0.0146	3.5407E-006
Lest square error	1.0163E-004	8.5293E-011	8.6286E-011		2.3049E-005	3.2571E-012

5- Conclusions and Recommendations:

In this paper we proposed a numerical method for solving linear Fredholm integral equations and we introduced the modified mid-pointmethod. The system (2.7) solves eq.(1.1) more accurately than system (2.10). Because in system (2.7) we use composed modified mid-pointmethod for solving eq.(2.4) instead composed mid-pointmethod. From numerical examples it can be seen that the proposed numerical method is more accurate than methods such as the trapezoidal, the Simpson, the modified trapezoidal and the mid-pointmethods to estimate the solution of linear Fredholm integral equations when the functions $\frac{\partial k(x,y)}{\partial x}$, $\frac{\partial k(x,y)}{\partial y}$ and $f'(x)$ exist for $x, y \in [a,b]$, also we show that, when the values of h decreases, the errors decrease to small values. We will use this method to study other types of integral equations and their systems in our future work.

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مقارنة بين طريقة النقطة الوسطية المعدلة وبعض الطرق العددية لحل معادلات فريدهولم التكاملية الخطية من النوع الثاني

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الخلاصه

في هذه البحث إستعملنا طريقة النقطة الوسطية المعدّلة لحلّ معادلات فريدهولم الخطيّة التكاملية من النوع الثاني. في الأمثلة العددية بينا فعالية هذه الطريقة، مقارنة بالطرق العددية الأخرى مثل، طريقة النقطة الوسطية، طريقة شبه المنحرف، طريقة سيمبسون وطريقة شبة المنحرف المعدّلة.