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Identification of insects order by estimating M-polynomial and topological indices (Zagreb Index, Harmonic Index and Inverse Index)

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Abstract
Insect are the important fauna of ecosystem and provide pollination service for the sexually reproducing plants and help in enhancing crop production for the human beings. Present study was totally concerned on the identification of order of insects by estimating Zagreb index, Harmonic index and inverse index. These indices were first time used to identify insect's order by the study of wings belonging to different insect species. Wing graph has been first time plotted and applied globally. Wings of Drosophila, Cicada, Apis, Musca species were amputed and permanent slides were prepared. Venation system of different wings was analyzed by using different vertices (cross-over of venation) and edges (part of vein between two vertices). Wing graphs were plotted with the help of wings photos and studied indices were calculated. The value of Zagreb index, Harmonic index and Inverse index were estimated specific for a particular insect order and insects can be differentiated and order of insects can be identified by using these indices this made this study significant for future study.

Keywords: Vertex degree, topological indices, wing graph, M-Polynomial, Apis spp, Cicada spp, Drosophila spp, Musca spp, 2022 mathematical sciences classification: 05C07, 05C09, 05C31

Introduction

Insects are hexapod invertebrates belonging to the Insecta class of Arthropoda phylum which was derived from word Insectum of Latin language. It was observed that all the members of insecta class have three pairs of legs, compound eyes, one pair of antennae, chitinous exoskeleton and body is divided into head, thorax and abdomen. Insects make over 90% of total life forms globally [5]**.** Insects made biological foundation for all land driven animals by contributing in nutrient cycle, seed dispersion, plant pollination and maintenance of soil structure **[7].** This makes Insects important for the welfare of human being. There are several ways of indentifying insects by using entomological keys and research literature existed in the scientific world but first time in the present study, a new concept has been applied in identifying insect orders by calculating M- Polynomials and different Topological Indices with the help of vertices of wings venation. M- Polynomials express new findings of topological indices which have been used to correlate topological studies to the chemical properties of different chemicals or medical behaviour of drugs **[10].** In the present study, it was used to identify insect orders as wings of different orders of insecta showed different venation pattern and venation vertices in the wings. This idea has been first time employed to identification of Insect orders. Photos of different kind of wings were used to demonstrate the behaviour of these polynomials.

Material and Methods

Insect collection

Four different types of insects (Drosophila melanogaster, Cicada spp, Apis spp, Musca spp) were captured by using hand sweeping net and preserved in the insect killing bottles. These four insects were belonging to four different families and three orders of insecta class i.e. Drosophila: Diptera, Cicada spp: Hemiptera, Apis spp: Hymenoptera, Musca spp: Diptera. Insects were stored in wooden entomological boxes.

Sample preparation

Wings of all captured insects were amputed gently with the help of forceps and placed on glass microscopic slides one on each glass slide then put some drops of Canada balsam and covered with glass cover slips for permanent preparation. Photos of different wings of studied insects snapped with stereo zoom microscope. After taking print out of wings photos, graphs of veins were plotted. Different topological vertices were marked on graphs of wings (Table: 2) and identified as 1^o, 2^o, 3^o and 4^o vertices. A vertex is a cross over point or end point of a vein in the wing and the part of vein connecting two nearby vertices is called edge. Wing graphs were plotted by connecting different vertices and edges (Table: 2).
A vertex which is connected from one, two, three or four other vertices is called 1^o, 2^o, 3^o, 4^o vertices respectively.

Estimation of topological indices

A topological index is a function that characterizes the topology of the graph. Most commonly known invariants of such kinds are degree-based indices. These are actually the numerical values that correlate the structure with various physical properties reactivity, and biological activities [2, 3, 12, 17, 19].

Throughout this article, we considered a simple connected graph G = (V, E). V denotes the set of vertices and E denotes the set of edges (i.e., ordered pair of vertices in G). The degree of vertex v is the number of edges which are incident on vertex v and denoted by d (v).

First Zagreb Index [9]: In 1972, Gutman &Trinajsti´c proposed the "first Zagreb index"$M_1(G)$ and defined by

$$"M_1(G) = \sum_{(u,v)\in E} d(u) + d(v)$$

Second Zagreb Index [9]: In 1972, Gutman &Trinajsti´c proposed the "second Zagreb index" $M_2(G)$ and defined by

$$M_2(G) = \sum_{(u,v)\in E} d(u).d(v)$$

$M_1(G)$ and $M_2(G)$ elaborated [8]

Modified Second Zagreb Index [13]: In 2003, Nikolic *et al*. Introduced "Modified Second Zagreb Index"$MM_2(G)$ and defined by

$$MM_2(G) = \sum_{(u,v)\in E} \frac{1}{d(u).d(v)}$$

Redefined III Zagreb Index [16]: In 2013, Ranjini *et al*. Introduced Redefined III Zagreb Index $ReZ(G)$ and defined by

$$ReZ(G) = \sum_{(u,v)\in E} d(u).d(v)\{d(u) + d(v)\}$$

Harmonic Index [6]: In 1987, S. Fajtlowicz purposed another index called harmonic index H(G) and defined as

$$H(G) = \sum_{(u,v)\in E} \frac{1}{d(u) + d(v)}$$

Inverse sum Indeg Index [18]: The inverse sum indeg index that was selected as a significant predictor of total surface area of octane isomers in 2010, is defined as

$$ISI(G) = \sum_{(u,v)\in E} \frac{d(u).d(v)}{d(u) + d(v)}$$

M-Polynomial [4]: The M-polynomial for the graph G, introduced by E. Deutsch and S. KlavŽar in 2015 is defined as

$$M(G; x, y) = \sum_{\delta \leq i \leq j \leq \Delta} d_{i,j} x^i y^j"$$

$d_{i,j}$ is the no. of edges whose end vertices of degree $i$and j in the graph G.The lowest and highest degree of vertex in the graph $G$are denoted by δ and Δ respectively.

Table 1: Degree Based topological indices from M-Polynomial

S. No.	Topological indices	Notations	Derivation through M-Polynomial $f(x,y)$
1.	First Zagreb Index	$M_1(G)$	$[(D_x + D_y)f(x,y)]_{x=y=1}$

2.	Second Zagreb Index	$M_2(G)$	$[D_x D_y f(x,y)]_{x=y=1}$
3.	Modified Second Zagreb Index	$MM_2(G)$	$[S_x S_y f(x,y)]_{x=y=1}$
4.	Redefined Third Zagreb Index	$ReZ(G)$	$[D_x D_y (D_x + D_y) f(x,y)]_{x=y=1}$
5.	Harmonic Index	$H(G)$	$[2S_x J f(x,y)]_{x=1}$
6.	Inverse Sum Indeg Index	$ISI(G)$	$[S_x J D_x D_y f(x,y)]_{x=1}$

In Table 1,
$D_x f(x,y) = x\frac{\partial f(x,y)}{\partial x}, D_y f(x,y) = y\frac{\partial f(x,y)}{\partial y}, S_x f(x,y) = \int_0^x \frac{f(t,y)}{t} dt\ , S_y f(x,y) = \int_0^y \frac{f(x,t)}{t} dt$ and $Jf(x,y) = f(x,x)$.

Results

It was observed that venation system in the wings of different insects showed variations and differentiation in the patterns of vertices. Topological indices of wings venation for different insect species were estimated and it was found that insects from different orders of insecta have different values for different topological indices (Table 3). The insects from same order but belonging to different families showed very close values of topological indices but insects from different orders i.e. Hymenoptera, Diptera, and Hemiptera showed significant difference in the values of estimated topological indices.

Table 2: Wings and wing graphs of studied insect species

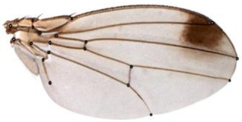
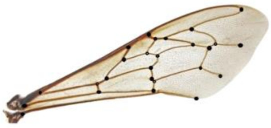
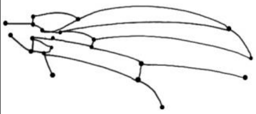
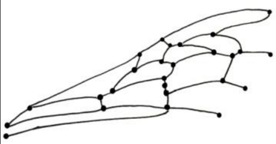
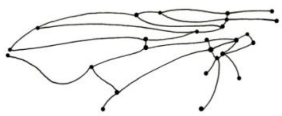
	Drosophila spp	Cicada spp	Apis spp	Musca spp
Photos of Wings				
Wing Graphs				

Table 3: Estimated values of different topological indices of wing venation of different insect species

	Drosophila spp	**Cicada spp**	**Apis spp**	**Musca spp**
Insect wings				
M-Polynomial	$5xy^3 + 6x^2y^3 + 14x^3y^3$	$4x^2y^3 + 37x^3y^3 + 4x^3y^4$	$2xy^3 + 2xy^4 + 6x^2y^3 + 22x^3y^3 + 2x^3y^4$	$4xy^3 + xy^4 + 2xy^5 + x^2y^2 + 2x^2y^3 + x^2y^4 + x^2y^5 + 11x^3y^3 + 7x^3y^4 + x^3y^5 + x^4y^4 + x^4y^5$
I-Zagreb Index (M_1G)	134	270	191	200
II-Zagreb Index (M_2G)	177	405	272	294

Modified II-Zagreb Index (mM_2G)	4.2222	5.1111	4.7777	4.776388
Redefined Zagreb Index ($ReZG_3$)	996	2454	1600	1932
Harmonic Index H(G)	9.5666	15.0761	12.1047	5.6873
Inverse Index	31.95	64.3571	46.7285	46.225

1. Topological indices for Drosophila species

The graph D of bee Drosophila consist 21 vertices and 25 edges. There are 5 vertices of 1 degree, 3 vertices of 2 degree and 13 vertices of 3 degree.

Theorem 1. The M-Polynomial of wings graph of Drosophila is

$$f(x,y) = 5xy^3 + 6x^2y^3 + 14x^3y^3$$

Proof:

$$f(x,y) = \sum_{1 \le i \le j \le 3} d_{i,j} x^i y^j$$

$$= d_{1,3}xy^3 + d_{2,3}x^2y^3 + d_{3,3}x^3y^3$$

$$= 5xy^3 + 6x^2y^3 + 14x^3y^3$$

The 3D plots of M-Polynomials of wing graphs of Drosophila species showed different patterns (Table 4).

Theorem 2. The degree based topological indices of wings graph of Drosophila are

1. First Zagreb Index: $M_1(D) = 134$
2. Second Zagreb Index: $M_2(D) = 177$
3. Modified Second Zagreb Index: $M_2(D) = 4.2222$
4. Redefined Zagreb Index: $ReZ(D) = 996$
5. Harmonic Index: $H(D) = 9.56666$
6. Inverse sum Indeg Index: $ISI(D) = 31.95$

Proof: From equation, The M-Polynomial of graph Drosophila is

$$f(x,y) = 5xy^3 + 6x^2y^3 + 14x^3y^3$$

Then, using notations

$$D_x f(x,y) = 5xy^3 + 12x^2y^3 + 42x^3y^3$$

$$D_y f(x,y) = 15xy^3 + 18x^2y^3 + 42x^3y^3$$

$$D_x + D_y f(x,y) = 20xy^3 + 30x^2y^3 + 84x^3y^3$$

$$D_x D_y f(x,y) = 5xy^3 + 36x^2y^3 + 126x^3y^3$$

$$D_x D_y (D_x + D_y) f(x,y) = 60xy^3 + 180x^2y^3 + 756x^3y^3$$

$$S_y f(x,y) = \frac{5}{3}xy^3 + \frac{6}{3}x^2y^3 + \frac{14}{3}x^3y^3$$

$$S_x S_y f(x,y) = \frac{5}{3}xy^3 + x^2y^3 + \frac{14}{9}x^3y^3$$

$$Jf(x,y) = 5x^4 + 6x^5 + 14x^6$$

$$S_xJf(x,y) = \frac{5}{4}x^4 + \frac{6}{5}x^5 + \frac{14}{6}x^6$$

$$S_xJD_xD_yf(x,y) = \frac{15}{4}x^4 + \frac{36}{5}x^5 + \frac{126}{6}x^6$$

1. First Zagreb Index is

$$M_1(D) = [D_x + D_y f(x,y)]_{x=y=1} = 134$$

2. Second Zagreb Index:

$$M_2(D) = [D_xD_y f(x,y)]_{x=y=1} = 177$$

3. Modified Second Zagreb Index:

$$M_2(D) = [S_xS_y f(x,y)]_{x=y=1} = 4.22222$$

4. Redefined Zagreb Index:

$$ReZ(D) = \left[D_xD_y(D_x + D_y)f(x,y)\right]_{x=y=1} = 996$$

5. Harmonic Index:

$$H(D) = [S_xJf(x,y)]_{x=1} = 9.5666$$

6. Inverse sum Indeg Index:

$$ISI(D) = [S_xJD_xD_yf(x,y)]_{x=1} = 31.95$$

2. Topological Indices for Cicada species

The wing graph C of Cicada insect consist 31 vertices and 45 edges. There are 1 vertex of 4 degree, 2 vertex of 2 degree and 28 vertices of 3 degree.

Theorem 3. The M-Polynomial of wing graph of Cicada insect is

$$f(x,y) = 4x^2y^3 + 37x^3y^3 + 4x^3y^4$$

Proof:

$$f(x,y) = \sum_{2\le i\le j\le 4} d_{i,j}x^iy^j$$

$$= d_{2,3}x^2y^3 + d_{3,3}x^3y^3 + d_{3,4}x^3y^4$$

$$= 4x^2y^3 + 37x^3y^3 + 4x^3y^4.$$

The 3D plots of M-Polynomials of wing graphs of Cicada species showed different patterns (Table 4).

Theorem 4. The degree based topological indices of wing graph Cicada species are

1. First Zagreb Index: $M_1(C) = 270$
2. Second Zagreb Index: $M_2(C) = 405$
3. Modified Second Zagreb Index: $M_2(C) = 5.1111$
4. Redefined Zagreb Index: $ReZ(C) = 2454$
5. Harmonic Index: $H(C) = 15.0761$
6. Inverse sum Indeg Index: $ISI(C) = 64.3571$

Proof: From equation, The M-Polynomial of wing graph Cicada species is

$$f(x,y) = 4x^2y^3 + 37x^3y^3 + 4x^3y^4$$

Then, using notations

$$D_x f(x,y) = 8x^2y^3 + 111x^3y^3 + 12x^3y^4$$

$$D_y f(x,y) = 12x^2y^3 + 111x^3y^3 + 16x^3y^4$$

$$D_x + D_y f(x,y) = 20x^2y^3 + 222x^3y^3 + 28x^3y^4$$

$$D_x D_y f(x,y) = 24x^2y^3 + 333x^3y^3 + 48x^3y^4$$

$$D_x D_y (D_x + D_y) f(x,y) = 120x^2y^3 + 1998x^3y^3 + 336x^3y^4$$

$$S_y f(x,y) = \frac{4}{3}x^2y^3 + \frac{37}{3}x^3y^3 + x^3y^4$$

$$S_x S_y f(x,y) = \frac{4}{6}x^2y^3 + \frac{37}{9}x^3y^3 + \frac{1}{3}x^3y^4$$

$$Jf(x,y) = 4x^5 + 37x^6 + 4x^7$$

$$S_x J f(x,y) = \frac{4}{5}x^5 + \frac{37}{6}x^6 + \frac{4}{7}x^7$$

$$S_x J D_x D_y f(x,y) = \frac{24}{5}x^5 + \frac{333}{6}x^6 + \frac{48}{7}x^7$$

The proof follows the same pattern as the proof of the Theorem 2

3. Topological Indices for Apis species

The wing graph H of Honey Bee (Apis species) consist 26 vertices and 34 edges. There are 4 vertices of 1 degree, 3 vertices of 2-degree, 18 vertices of 3-degree and 1 vertex of 4-degree.

Theorem 5. The M-Polynomial of wing graph Honey Bee (Apis species**)** is

$$f(x,y) = 2xy^3 + 2xy^4 + 6x^2y^3 + 22x^3y^3 + 2x^3y^4$$

Proof:

$$f(x,y) = \sum_{1 \le i \le j \le 4} d_{i,j} x^i y^j$$

$$= d_{1,3}xy^3 + d_{1,4}xy^4 + d_{2,3}x^2y^3 + d_{3,3}x^3y^3 + d_{3,4}x^3y^4$$

$$= 2xy^3 + 2xy^4 + 6x^2y^3 + 22x^3y^3 + 2x^3y^4$$

The 3D plots of M-Polynomials of wing graphs of Apis species showed different patterns (Table 4).

Theorem 6. The degree based topological indices of graph Honey Bee (Apis species) are

1. First Zagreb Index: $M_1(H) = 194$
2. Second Zagreb Index: $M_2(H) = 272$
3. Modified Second Zagreb Index: $MM_2(H) = 4.7777$
4. Redefined Zagreb Index: $ReZ(H) = 1600$
5. Harmonic Index: $H(H) = 12.1047$
6. Inverse sum Indeg Index: $ISI(H) = 46.7285$

Proof: From equation, The M-Polynomial of wing graph of Honey Bee is

$$f(x,y) = 2xy^3 + 2xy^4 + 6x^2y^3 + 22x^3y^3 + 2x^3y^4$$

Then, using notations

$D_x f(x,y) = 2xy^3 + 2xy^4 + 12x^2y^3 + 66x^3y^3 + 6x^3y^4$

$D_y f(x,y) = 6xy^3 + 8xy^4 + 18x^2y^3 + 66x^3y^3 + 8x^3y^4$

$(D_x + D_y) f(x,y) = 8xy^3 + 10xy^4 + 30x^2y^3 + 132x^3y^3 + 14x^3y^4$

$D_x D_y f(x,y) = 6xy^3 + 8xy^4 + 36x^2y^3 + 198x^3y^3 + 24x^3y^4$

$D_x D_y (D_x + D_y) f(x,y) = 24xy^3 + 40xy^4 + 180x^2y^3 + 1188x^3y^3 + 168x^3y^4$

$S_y f(x,y) = \frac{2}{3}xy^3 + \frac{2}{4}xy^4 + \frac{6}{3}x^2y^3 + \frac{22}{3}x^3y^3 + \frac{2}{4}x^3y^4$

$S_x S_y f(x,y) = \frac{2}{3}xy^3 + \frac{2}{4}xy^4 + x^2y^3 + \frac{22}{9}x^3y^3 + \frac{2}{12}x^3y^4$

$Jf(x,y) = 2x^4 + 8x^5 + 22x^6 + 2x^7$

$S_x J f(x,y) = \frac{1}{2}x^4 + \frac{8}{5}x^5 + \frac{22}{6}x^6 + \frac{2}{7}x^7$

$S_x J D_x D_y f(x,y) = \frac{3}{2}x^4 + \frac{44}{5}x^5 + \frac{198}{6}x^6 + \frac{24}{7}x^7$

The proof follows the same pattern as the proof of the Theorem 2

4. Topological Indices for Musca species (House fly)

The wing graph M of Musca species consist 26 vertices and 33 edges. There are 7 vertices of 1-degree, 3 vertices of 2-degree, 12 vertices of 3-degree, 3 vertices of 4-degree and 1 vertex of 5-degree.

Theorem 7. The M-Polynomial of wing graph Musca species is

$$f(x,y) = 4xy^3 + xy^4 + 2xy^5 + x^2y^2 + 2x^2y^3 + x^2y^4 + x^2y^5 + 11x^3y^3 + 7x^3y^4 + x^3y^5 + x^4y^4 + x^4y^5$$

Proof:

$$f(x,y) = \sum_{1 \le i \le j \le 5} d_{i,j} x^i y^j = d_{1,3}xy^3 + d_{1,4}xy^4 + d_{1,5}xy^5 + d_{2,2}x^2y^2 + d_{2,3}x^2y^3 + d_{2,4}x^2y^4 + d_{2,5}x^2y^5 + d_{3,3}x^3y^3 + d_{3,4}x^3y^4 + d_{3,5}x^3y^5 + d_{4,4}x^4y^4 + d_{4,5}x^4y^5$$

$$= 4xy^3 + xy^4 + 2xy^5 + x^2y^2 + 2x^2y^3 + x^2y^4 + x^2y^5 + 11x^3y^3 + 7x^3y^4 + x^3y^5 + x^4y^4 + x^4y^5$$

The 3D plots of M-Polynomials of wing graph of Musca species showed different patterns (Table 4).

Theorem 8. The degree based topological indices of wing graph Musca species are

1. First Zagreb Index: $M_1(M) = 200$
2. Second Zagreb Index: $M_2(M) = 294$
3. Modified Second Zagreb Index: $MM_2(M) = 4.7763888$
4. Redefined Zagreb Index: $ReZ(M) = 1932$
5. Harmonic Index: $H(M) = 5.6873$
6. Inverse sum Indeg Index: $ISI(M) = 46.225$

Proof: From equation, The M-Polynomial of wing graph Musca species is

$$f(x,y) = 4xy^3 + xy^4 + 2xy^5 + x^2y^2 + 2x^2y^3 + x^2y^4 + x^2y^5 + 11x^3y^3 + 7x^3y^4 + x^3y^5 + x^4y^4 + x^4y^5$$

Then, using notations

$$D_x f(x,y) = 4xy^3 + xy^4 + 2xy^5 + 2x^2y^2 + 4x^2y^3 + 2x^2y^4 + 2x^2y^5 + 33x^3y^3 + 21x^3y^4 + 3x^3y^5 + 4x^4y^4 + 4x^4y^5$$

$$D_y f(x,y) = 12xy^3 + 4xy^4 + 10xy^5 + 2x^2y^2 + 6x^2y^3 + 4x^2y^4 + 5x^2y^5 + 33x^3y^3 + 28x^3y^4 + 5x^3y^5 + 4x^4y^4 + 5x^4y^5$$

$$(D_x + D_y) f(x,y) = 16xy^3 + 5xy^4 + 12xy^5 + 4x^2y^2 + 10x^2y^3 + 6x^2y^4 + 7x^2y^5 + 66x^3y^3 + 49x^3y^4 + 8x^3y^5 + 8x^4y^4 + 9x^4y^5$$

$$D_x D_y f(x,y) = 12xy^3 + 4xy^4 + 10xy^5 + 4x^2y^2 + 12x^2y^3 + 8x^2y^4 + 10x^2y^5 + 99x^3y^3 + 84x^3y^4 + 15x^3y^5 + 16x^4y^4 + 20x^4y^5$$

$$D_x D_y (D_x + D_y) f(x,y) = 48xy^3 + 20xy^4 + 60xy^5 + 16x^2y^2 + 60x^2y^3 + 48x^2y^4 + 70x^2y^5 + 594x^3y^3 + 588x^3y^4 + 120x^3y^5 + 128x^4y^4 + 180x^4y^5$$

$$S_y f(x,y) = \frac{4}{3}xy^3 + \frac{1}{4}xy^4 + \frac{2}{5}xy^5 + \frac{1}{2}x^2y^2 + \frac{2}{3}x^2y^3 + \frac{1}{4}x^2y^4 + \frac{1}{5}x^2y^5 + \frac{11}{3}x^3y^3 + \frac{7}{4}x^3y^4 + \frac{1}{5}x^3y^5 + \frac{1}{4}x^4y^4 + \frac{1}{5}x^4y^5$$

$$S_x S_y f(x,y) = \frac{4}{3}xy^3 + \frac{1}{4}xy^4 + \frac{2}{5}xy^5 + \frac{1}{4}x^2y^2 + \frac{1}{3}x^2y^3 + \frac{1}{8}x^2y^4 + \frac{1}{10}x^2y^5 + \frac{11}{9}x^3y^3 + \frac{7}{12}x^3y^4 + \frac{1}{15}x^3y^5 + \frac{1}{16}x^4y^4 + \frac{1}{20}x^4y^5$$

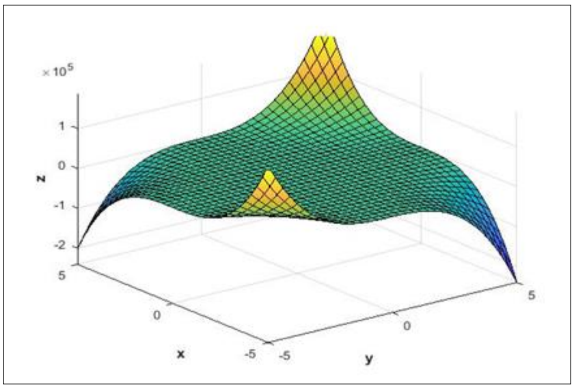
$$Jf(x,y) = 5x^4 + 3x^5 + 14x^6 + 8x^7 + 2x^8 + x^9$$

$$S_x J f(x,y) = \frac{5}{4}x^4 + \frac{3}{5}x^5 + \frac{14}{6}x^6 + \frac{8}{7}x^7 + \frac{2}{8}x^8 + \frac{1}{9}x^9$$

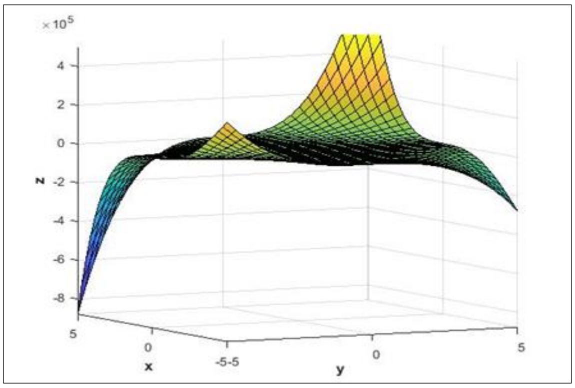
$$S_x J D_x D_y f(x,y) = \frac{16}{4}x^4 + \frac{16}{5}x^5 + \frac{117}{6}x^6 + \frac{94}{7}x^7 + \frac{31}{8}x^8 + \frac{20}{9}x^9$$

The proof follows the same pattern as the proof of the Theorem 2.

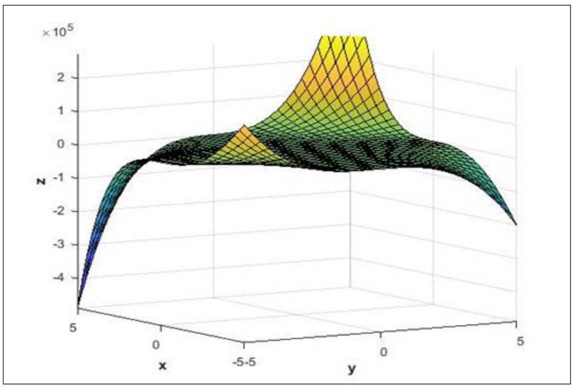
Table 4: The 3D plots of M-polynomials of wing graphs of different insect species



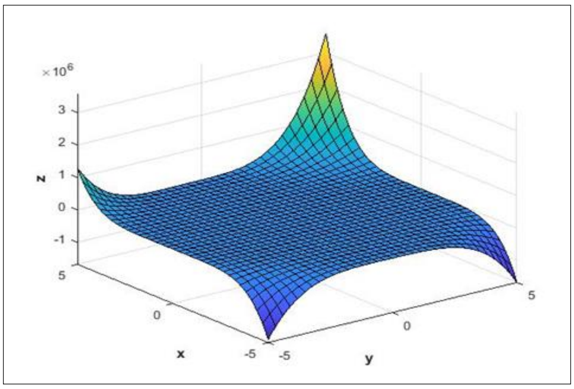
Drosophila spp



Cicada spp



Apis spp



Musca spp

The 3D graphical presentation of M-Polynomial of different type of wings of studied insects is shown in the table. This has been plotted by using MATLAB. These plots show different behaviour corresponding changing the parameters x and y.

Discussion

All the sexually reproducing animals show diversity on gene level hence show variations and differentiation at the all levels of body organization, morphology, behaviour and ecology etc. Venation pattern in the wings of all insects showed different morphometric parameters like venation pattern, distribution and distance between vertices, so it is considered that by calculating topological indices for wings insect orders can be identified and different insects can be distinguished on the basis of topological indices. Morphological parameters and wings pattern were used for long time to identified different insect species [1]. In the present study first time topological indices have been applied in the identification of insect orders and to differentiate insects belonging to different species. The value of I-Zagreb index was estimated 134, 270, 194 and 200 for Drosophila species, Cicada species, Apis species and Musca species respectively which showed variations as per different species. Similarly, the value of II-Zagreb index, Modified II-Zagreb index, Redefined Zagreb index values estimated different as per different species of insects which is showing the importance and capability of topological indices to differentiate insects. Identification of insects by molecular techniques is being recently used for the confirmatory test but the technique is very costly but estimation of morphological analysis is an easy method and no specific costly instruments required which made this technique important [14, 15]. In the past research, wings were analyzed by estimating Cubital index of fore wing of bee species [11]. Cubital and Discoidal indices of wing analysis have been frequently used in the morphometric analysis from many decades.

Conclusion

Study revealed the power of wing geometry in differentiating insects of different orders of insecta class of Arthropoda phylum. By estimating topological indices different insects can be distinguished from each other. This study opened a new way of interdisciplinary study between entomology and mathematics.

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