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CLASSIFICATION OF SOME BUTTERFLIES BY USING RULES INDUCTION: CN2 ALGORITHM*

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Abstract

Rule induction is an area of machine learning in which formal rules are extracted from a set of observations. Machine learning is a field of artificial intelligence that uses statistical techniques to give computer systems the ability to "learn" from data, without being explicitly programmed. Machine learning applications are classification, regression, clustering, density estimation and dimensionality reduction. The CN2 algorithm is a classification technique designed for the efficient induction of simple, comprehensible rules of form "if *cond* then predict *class*", even in domains where noise may be present. This research used *zoo* dataset and passed it to CN2 Rule Induction. In this research, classification of some butterflies species by using rules induction with CN2 algorithm system has developed. In this system, there are 29 species of butterflies are classified. In this system, MS Visual Studio 2010 as a programming tool and MS SQL Server as for database development are used.

Keywords: *Machine Learning, Rule Induction, CN2 Algorithm*

Introduction

In artificial intelligence, an expert system is a computer system that follows the decision-making ability of a human expert. Expert systems are designed to solve complex problems by reasoning through bodies of knowledge, represented mainly as if–then rules rather than through conventional procedural code.

The most common form of architecture used in expert and other types of knowledge-based systems is the production system, also called the rule-based system. In computer science, rule-based systems are used as a way to store and manipulate knowledge to interpret information in a useful way. They are often used in artificial intelligence applications and research.

This type of system use knowledge encoded in the form of production rules, that is, if…then rules. Rule have an antecedent or condition part, the left-hand side, and a conclusion of action pert, the right-hand side.

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IF: Condition-1 and Condition-2 and Condition-3 THEN: Take Action-4

The Representative Architectures of Expert System

An expert system is divided into two subsystems: the knowledge base and the interface engine. The knowledge base represents facts and rules. The inference engine applies the rules to the known facts to deduce new facts. Inference engines can also include explanation and debugging abilities.

The architectures of Expert Systems today reflect knowledge engineers understanding of how to represent knowledge and how to perform intelligent decision-making tasks with the support of knowledge base system. The Expert System architecture is independent of specific computer hardware. Determinants for computer hardware selection would include the size of the knowledge database, the desire speed of the system’s responses and the level of sophistication for the user interface.

Figure 1 shows the architecture of a simple Expert System. The architecture of the simple Expert System could be extended. One common extension is to expand the knowledge base into a knowledge database and a domain database. These two databases could be managed by a database management system (DBMS).

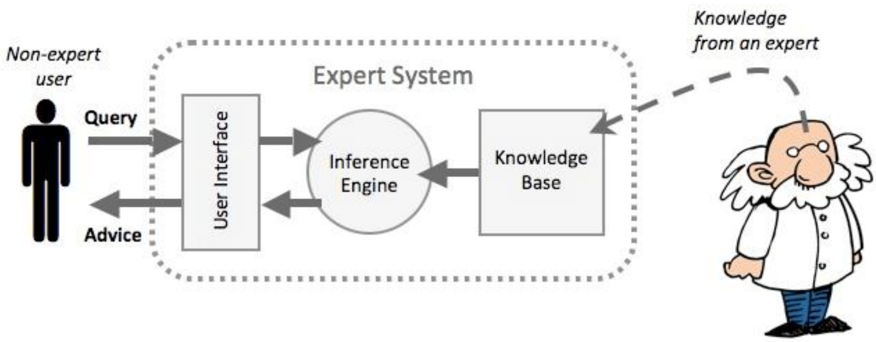


Figure 1: Architecture of a simple Expert System

Building A Knowledge Base

The procedure of building a knowledge base is called knowledge engineering. Investigation of a particular domain, determining what concepts are important in that the domain and creation of a formal representation of the objects and relations in the domain are the role of a knowledge engineer. Often, the knowledge engineer is trained in representation but is not an expert in the domain at hand, be it circuit design, space station mission scheduling or whatever. The knowledge will usually interview the real experts to become educated about the domain and to elicit the required knowledge, in a process called knowledge acquisition.

Architectures of a Rule-Based System

Each rule represents a small piece of knowledge relating to the given domain of expertise. A number of related rules collectively may correspond to a chain of inferences which lead from some initially known facts to some useful conclusions. The inference process is carried out in an interactive mode with the use providing input data needed to complete rule chaining process. Figure 2 shows the architecture of Rule-based system.

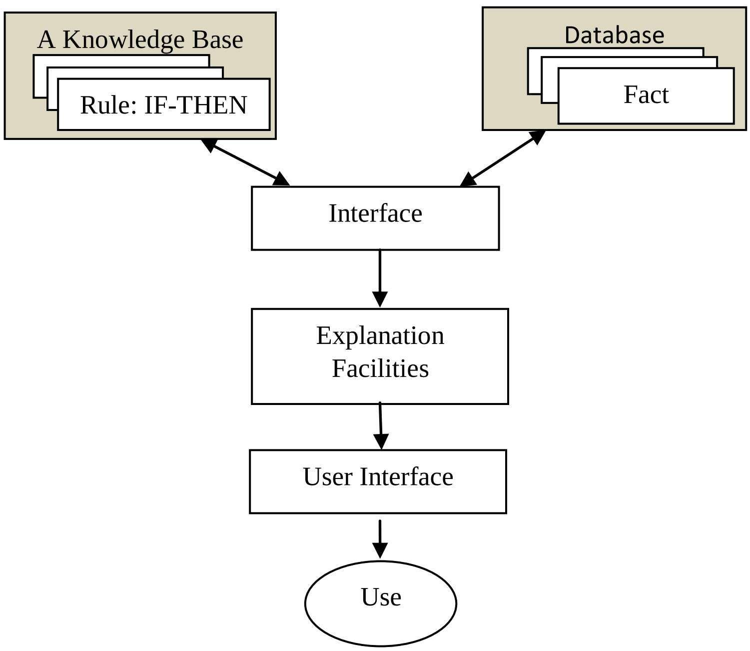


Figure 2: Architecture of Rule-Based System

A typical rule-based system consists of the following components are:

knowledge base : contains the rules embodying expert knowledge about the problem domain

database : contains the set of known facts about the problem currently being solved

inference engine : carries out the reasoning process by linking the rules with the known facts to find a solution

explanation facilities : provides information to user about the reasoning steps that are being followed

user interface : communication between the user and the system

In this research, rule induction with CN2 was used for classification of butterfly that is the simplest setting for classification.

Rule Induction

The rule induction system can create rule that fit the example cases. The rule can then be used to access other cases the outcome is not known. The heart of a rule induction system is an algorithm, which is used to induce the rules from the examples.

Induction methods use various algorithms to convert a knowledge matrix of attributes, values, and selections to rules. Some well-known rule learning algorithms are AQ, CN2, FOIL, RIPPER AND OPUS.

Rule Induction with CN2

The **CN2 induction algorithm** is a learning algorithm for rule induction. It is designed to work even when the training data is imperfect. It is based on ideas from the AQ algorithm to produce rules and combine decision tree learning (such as C 4.5, ID3) to handle noise. As a consequence it creates a rule set like that created by AQ but is able to handle noisy data like ID3.

Materials and Methods

In this research, keys of butterflies are used as materials or zoological data set and rule induction with CN2 algorithm is used as rule indention method.

Identifying Keys of the Butterfly

Butterflies are the most well-known of all insects. They are among the most beautiful creatures on Earth. They are popular among nature lovers as well as a subject for scientific study. Figure 3 shows the external features of the butterfly that are used in the scientific classification.

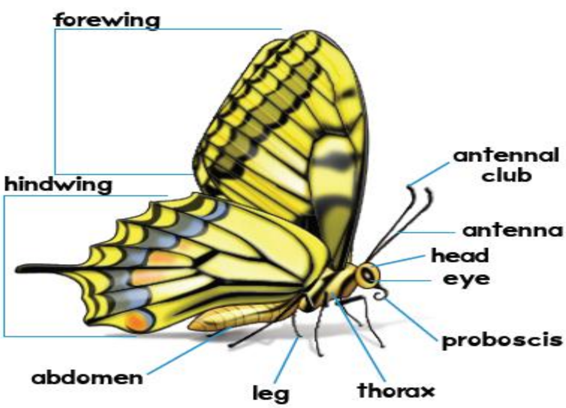


Figure 3: External Features of Butterfly

Butterflies and moths are insects that make up the order Lepidoptera, derived from the Greek words *lepidos* for scaly and *ptera* for wings. Four wings are present. The wings are membranous, with veins or nervures running longitudinal form base to the wing margins. The pattern formed by these veins (wing venation) is of primary importance in the classification of Lepidoptera. Wings of all the butterflies' families showed considerable variations in shapes and vein patterns reflecting their specific nature. Figure 4 shows the parts of wings and venation pattern of butterflies.

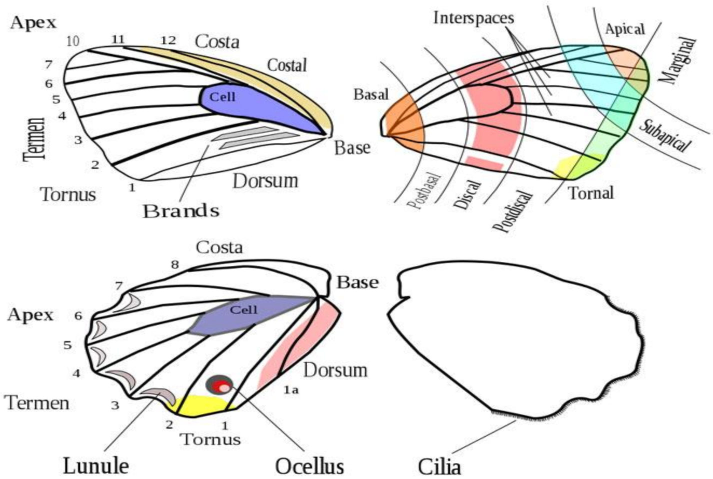


Figure 4 : Parts of Wings and Venation Pattern of Butterfly

Exploring the Rule Induction with CN2 Algorithm

Rule induction is a popular method that automates the knowledge acquisition process when knowledge is expressed in terms of rules in classification-type problems. Rule induction examines historical cases and generates the rules that were used to arrive at certain recommendations. Rule induction can be used by a system engineer, an expert, or any other system builder. Another advantage is that the builder does not have to be a knowledge engineer. He or she can be the expert or a system analyst. This is not only saves time and money, but it also solves the difficulties of dealing with the knowledge engineer who is an outsider unfamiliar with the domain.

CN2 is designed for the efficient induction of simple, comprehensible production rules in domains where problems of poor description language and/or noise may be present. CN2 based on the ID3 (Quinlan, 1983) and AQ (Michalski, 1969) algorithms. The ID3 algorithm provides itself to such modification by the nature of its general-to-specific search. The AQ algorithm's dependence on specific training examples during search makes it less easy to modify. CN2 was designed to modify the AQ algorithm itself in ways that removed this dependence on specific examples and increased the space of rules searched. CN2, a new induction algorithm combines the efficiency and ability to cope with noisy data of ID3 with the if-then rule form and flexible search strategy of the AQ family. Figure 5 shows the CN2 induction algorithm.

Let E be a set of classified examples.
Let SELECTORS be the set of all possible selectors.
    Procedure CN2(E)
    Let RULE-LIST be the empty list.
    Repeat until BEST.CPX is nil or E is empty:
    Let BEST.CPX be Find-Best.Complex(E).
        If BEST.CPX is not nil,
        Then let E' be the examples covered by
    BEST.CPX.
    Remove from E the examples E' covered by
BEST.CPX.
    Let C be the most common class of examples in E'.
    Add the rule 'If BEST.CPX then the class is C'
    to the end of RULE-LIST.
    Return RULE-LIST.

Figure 5: CN2 Induction Algorithm

Proposed System for Classification of Classification of Some Butterflies by Using Rules Induction: CN2 Algorithm

In this research, the proposed system contributed in system flow diagram, selected item for classification and implementation main form of proposed system.

System Flow Diagram

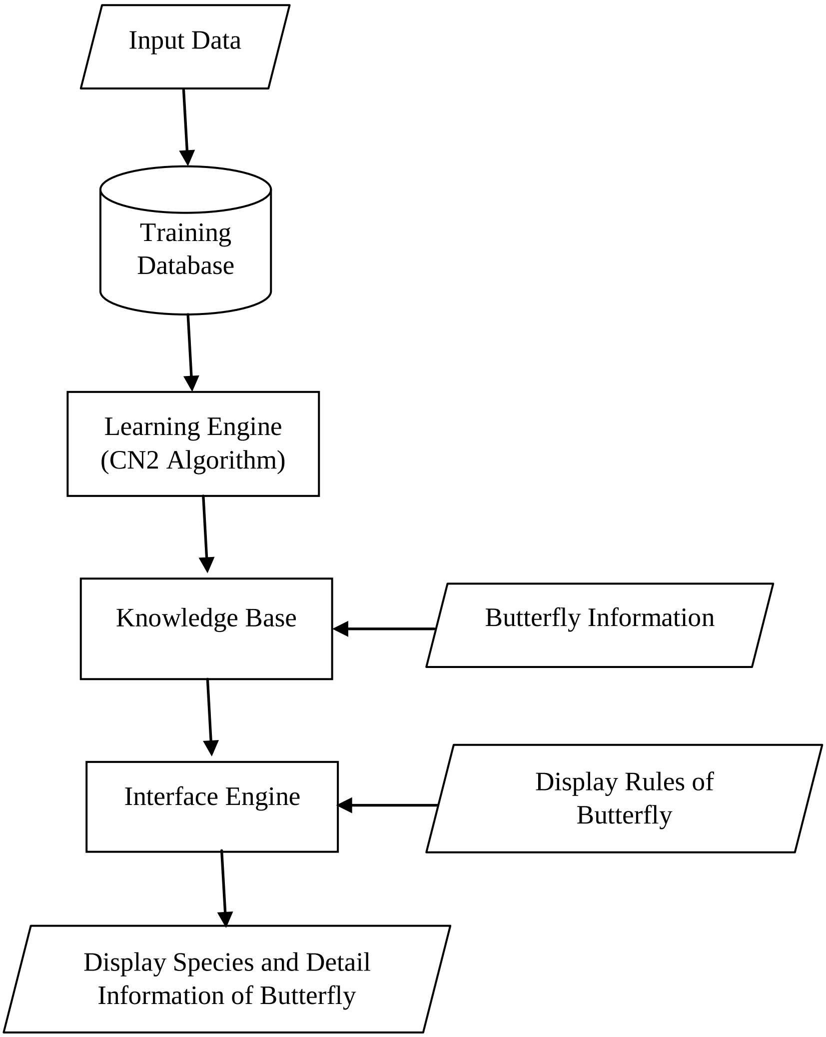


Figure 6: System Flow Diagram

Selected Item for Classification

A dichotomous key is a tool that can be used to classify objects. Dichotomous means "divided in two parts" or "binary classification". Therefore, this key uses a series of yes or no questions to place objects into groups. Butterflies are classified in the Kingdom: Animalia, Phylum: Arthropoda, and Order: Lepidoptera.

Kingdom	**Animalia** (animals)
Phylum	**Arthropoda** (arthropods, invertebrate animals with an exoskeleton, a segmented body, and jointed legs)
Class	**Insecta** (insects, arthropods with 6 legs, 2 antennae, and a 3-part body)
Order	**Lepidoptera** (butterflies and moths)

The butterflies are entirely depending upon their habitat. So, there are 29 butterflies were collected in Yangon Division for classify. The classification was made for the following procedure. First select an item as sample for classify and then classify the following keys. Figure 7 shows the selected item for classification.

Figure 7: Selected item for classification from Collected Butterfly

Key to the Families of Butterflies

1	A.	Antennae approximate at base, hind tibiae with only a terminal pair of spurs, one or more of the veins in the fore wing forked or coincident beyond the cell…………………………….....**2**
	B.	Antennae wide apart at base, hind tibiae generally with a medial as well as a terminal pair of spurs, all the veins in the fore wing from base or from cell, none forked or coincident beyond……………..….**Hesperiidae**
2	a.	Precostal nervure in hind wing present ………….......…..…….**3**
	b.	Precostal nervure in hind wing absent……….........**Lycaenidae**
3	a1.	Front pair of legs imperfect in one or both sexes……………**..4**
	b1.	Front pair of legs perfect in both sexes………………….......…**5**
4	a2.	Front pair of legs perfect in both sexes………………. …..**Nymphalidae**
	b2.	Front pair of legs imperfect in male, perfect in female............... .... **Nemeobidae**
5	a2.	Vein 1a in hind wing wanting, claws simple……… …..….**Papilionidae**
	b2.	Vein 1a in hind wing present, claws bifid……………………. …**Pieridae**

By using the rule induction with CN2 algorithm and identification key of family of butterfly, the following rule can be developed for rule 1. There will be four steps to produce rule 1.

Rule 1 (For Family)	**Family Name**
A (a) (a1) (a2)	Nymphalidae

Key to the Subfamilies of the Nymphalidae

1	A.	Discoidal cell in both fore and hind wing closed…….………..**2**
	B.	Discoidal cell open, or if closed, lower disco-cellular very slender, inconspicuous.
2	a.	Vein 1 in fore wing forked at base……………..……..***Danainae***
	b.	Vein 1 in fore wing not forked at base.

By using the rule induction with CN2 algorithm and identification key of subfamily of butterfly, the following rule can be developed for rule 2. There will be two steps to produce rule 2.

Rule 2 (For SbFamily)	**SubFamily Name**
A (a)	Danainae

Key to the Genera of the Danainae

1	A.	Claws furnished with paronychia and pulvilli.
	B.	Claws without paronychia or pulvilli…………………………………..……***Danais***

By using the rule induction with CN2 algorithm and identification key of genus of butterfly, the following rule can be developed for rule 3. There will be only one step to produce rule 3.

Rule 3 (For Genus)	**Genus Name**
B	Danais

Key to the Species of Dannis

1	A.	Fore wing tawny, with black margins and white spots; larva with three pairs of fleshy tentacula…………………… ……………**2**
	B.	Fore wing fuliginous black, with subhyaline streaks and spots of bluish white; larva so far as known, with two pairs of fleshy tentacula.
2	a.	Middle discocellular in hind wing slightly curved inwards; veins in both wings conspicuously bordered with black.
	b.	Middle discocellular in hind wing bent inwards at almost a right angle in the middle; veins in wings not conspicuously bordered with black………………………………...……..……………**3**
3	a1.	Apical third of fore wing black above, with a preapical obliquely-placed row of elongate white spots……………… …………….**4**
	b1.	Apex of fore wing with narrow even margin only, of black spotted with white; preapical row of white spots quite obsolete.
4	a2.	Discoidal cell and disc of hind wing entirely tawny.................. ***chrysippus***
	b2.	Discoidal cell and disc of hind wing more or less marked with white………………………………………………***alcipppus***

By using the rule induction with CN2 algorithm and identification key of species of butterfly, the following rule can be developed for rule 4. There will be four steps to produce rule 4.

Rule 4 (For Species)	**Species Name**
A (b) (a1) (a2)	chrysippus
A (b) (a1) (b2)	plexippus

Classification of the butterfly applying rule induction with CN2 also gives the result of scientific name. In the scientific name, the genus name and species name are called together. Therefore, the selected item is ***Danais chrysippus***.

Implementation Main Form of Proposed System

In the proposed system, there are seven parts. Among them, View, Searching and Detail Information are portion of the knowledge base and Classification is the portion of learning engine for CN2 algorithm and Rules is the output of the research. Figure 8 shows the main form of proposed system.

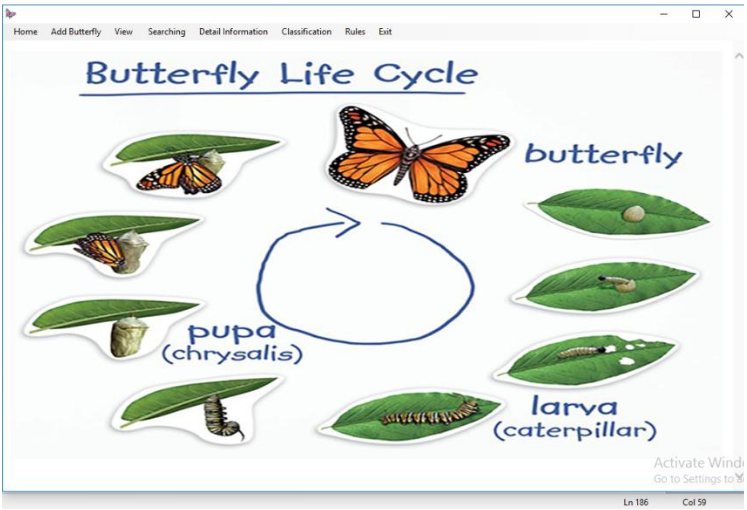


Figure 8 : Main Form of Proposed System

Result and Discussion

After classification by using rule induction with CN2 algorithm, the **family rule** for butterfly (**Rule 1**), the **subfamily rule** for butterfly (**Rule 2**), the **genus rule** for butterfly (**Rule 3**) and the **species rule** for butterfly (**Rule 4**) respectively come out as the result.

Rule for Family of Butterfly: Rule 1

Table 1 shows the results of the rules for butterfly family. There are sex families all together but five family are comes out for 29 butterflies.

Table 1: Rule for Family of Butterfly

Sr.No	Family Name	Rule for Family (Family Key)
1	Nymphalidae	A (a) (a1) (a2)
2	Nemeobidae	A (a) (a1) (b2)
3	Papilionidae	A (b) (a1) (a2)
4	Pieridae	A (b) (a1) (b2)
5	Lycaenidae	A (b)
6	Hesperidae	B

Rule for SubFamily of Butterfly: Rule 2

In the collected five families, the family Nymphalidae has three subfamilies: Danainae, Satyrinae and Nymphalinae; the family Papilionidae has one subfamily: Papilio and the family Lycaenidae has one subfamily: Lycaeninae. The family Nemobidae and Pieridae have not subfamily.

Rule for SubFamily of Nymphalidae

Table 2(a) shows the results of the rules for subfamily of family Nymphalidae. There are three subfamilies in Nymphalidae contain in the 29 butterflies.

Table 2(a): Rule for SubFamily of Nymphalidae

Sr.No	SubFamily Name	Rule for SubFamily (SubFamily Key)
1	Danainae	A (a)
2	Satyrinae	A (b) (a1)
3	Nymphalinae	B (b)

Rule for SubFamily of Papilionidae

Table (4.2(b)) shows the results of the rules for subfamily of family Papilionidae. There has one subfamily in Papilionidae contain in the 29 butterflies.

Table 2(b): Rule for SubFamily of Papilionidae

Sr.No	SubFamily Name	Rule for SubFamily (SubFamily Key)
1	Papilio	A

Rule for SubFamily of Lycaenidae

Table 2(c) shows the results of the rules for subfamily of family Lycaenidae. There has one subfamily in Lycaenidae contain in the 29 butterflies.

Table 2(c): Rule for SubFamily of Papilionidae

Sr.No	SubFamily Name	Rule for SubFamily (SubFamily Key)
1	Lycaeninae	B (b) (a1) (a2)

Rule for Genus of Butterfly: Rule 3

There are 13 genus contain in the five family of 29 butterflies which are collected in Yangon Division.

Rule for Genus of Danainae

Table 3(a) shows the results of the rules for genus of subfamily Danainae. There are only one genus in Danainae contain in the 29 butterflies.

Table 3(a) Rule for Genus of Danainae

Sr.No	Genus Name	Rule for Genus (Genus Key)
1	Dannis	B

Rule for Genus of Satyrinae

Table 3(b) shows the results of the rules for genus of subfamily Satyrinae. There are three genus in Satyrinae contain in the 29 butterflies.

Table 3(b): Rule for Genus of Satyrinae

Sr.No	Genus Name	Rule for Genus (Genus Key)
1	Mycalesis	A (a) (a1)
2	Orsotriaena	B (a)
3	Cyllogenes	B (b)

Rule for Genus of Nymphalinae

Table 3(c) shows the results of the rules for genus of subfamily Nymphalinae. There are only one genus in Nymphalinae contain in the 29 butterflies.

Table 3(c): Rule for Genus of Nymphalinae

Sr.No	Genus Name	Rule for Genus (Genus Key)
1	Euthalia	A (a)

Rule for Genus of Nemeobidae

Table 3(d) shows the results of the rules for genus of family Nemeobidae. There are only one genus in Nemeobidae contain in the 29 butterflies.

Table 3(d): Rule for Genus of Nemeobidae

Sr.No	Genus Name	Rule for Genus (Genus Key)
1	Abisara	A (b)

Rule for Genus of Papilio

Table 3(e) shows the results of the rules for genus of subfamily Papilio. There are two genus in Papilio contain in the 29 butterflies.

Table 3(e): Rule for Genus of Papilio

Sr.No	Genus Name	Rule for Genus (Genus Key)
1	memnon	A
2	polytes	B

Rule for Genus of Pieridae

Table 3(f) shows the results of the rules for genus of family Pieridae. There are four genus in Pieridae contain in the 29 butterflies.

Table 3(f) : Rule for Genus of Pieridae

Sr.No	Genus Name	Rule for Genus (Genus Key)
1	Delias	A (a) (b1)
2	Appias	B (a) (a1)
3	Hebomoia	B (b)
4	Catopsilia	A (a) (b1)

Rule for Genus of Lycaeninae

Table 3(g) shows the results of the rules for genus of subfamily Lycaeninae. There are only one genus in Lycaeninae contain in the 29 butterflies.

Table 3(g): Rule for Genus of Lycaeninae

Sr.No	Genus Name	Rule for Genus (Genus Key)
1	Abisara	B (b)

Rule for Species of Butterfly: Rule 4

There were 29 species for 29 butterflies were classified by using the rule induction with CN2 algorithm.

Rule for Species of Dannis

Table 4(a) shows the results of the rules for species of genus Dannis. There are two species in Dannis contain in the 29 butterflies.

Table 4(a): Rule for Species of Dannis

Sr.No	Species Name	Rule for Species (Species Key)
1	chrysippus	A (b) (a1) (a2)
2	alcippus	A (b) (a1) (b2)

Rule for Species of Mycalesis

Table 4(b) shows the results of the rules for species of genus Mycalesis. There are only one species in Mycalesis contain in the 29 butterflies.

Table 4(b): Rule for Species of Mycalesis

Sr.No	Species Name	Rule for Species (Species Key)
1	gotama	B (b)

Rule for Species of Orsotriaena

Table 4(c) shows the results of the rules for species of genus Orsotriaena. There are only one species in Orsotriaena contain in the 29 butterflies.

Table 4(c): Rule for Species of Orsotriaena

Sr.No	Species Name	Rule for Species (Species Key)
1	meda	Keys

Rule for Species of Cyllogenes

Table 4(d) shows the results of the rules for species of genus Cyllogenes. There are only one species in Cyllogenes contain in the 29 butterflies.

Table 4(d): Rule for Species of Melanitis

Sr.No	Species Name	Rule for Species (Species Key)
1	suradeva	A

Rule for Species of Euthalia

Table 4(e) shows the results of the rules for species of genus Euthalia. There are three species in Euthalia contain in the 29 butterflies.

Table 4(e): Rule for Species of Euthalia

Sr.No	Species Name	Rule for Species (Species Key)
1	lubentina	B (a)
2	phemius	B (b) (a1)
3	acontius	B (b) (b1) (c2)

Rule for Species of Abisara

Table 4(f) shows the results of the rules for species of genus Abisara. There are two species in Abisara contain in the 29 butterflies.

Table 4(f): Rule for Species of Abisara

Sr.No	Species Name	Rule for Species (Species Key)
1	fylla	A
2	echerius	B

Rule for Species of Memnon

Table 4(g) shows the results of the rules for species of genus Memnon. There are three species in Memnon contain in the 29 butterflies.

Table 4(g): Rule for Species of Memnon

Sr.No	Species Name	Rule for Species (Species Key)
1	agenor	A (a)
2	polymnestoroides	A (b)
3	mayo	B

Rule for Species of Polytes

Table 4(h) shows the results of the rules for species of genus Polytes. There are two species in Polytes contain in the 29 butterflies.

Table 4(h): Rule for Species of Polytes

Sr.No	Species Name	Rule for Species (Species Key)
1	polyts	A
2	pitmani	B

Rule for Species of Delias

Table 4(i) shows the results of the rules for species of genus Delias. There are two species in Delias contain in the 29 butterflies.

Table 4(i): Rule for Species of Delias

Sr.No	Species Name	Rule for Species (Species Key)
1	eucharis	A
2	hierta	B

Rule for Species of Appias

Table 4(j) shows the results of the rules for species of genus Appias. There are four species in Appias contain in the 29 butterflies.

Table 4(j): Rule for Species of Appias

Sr.No	Species Name	Rule for Species (Species Key)
1	nero	A
2	libythea	B (a)
3	leis	B (b) (a1)
4	wardi	B (b) (b1)

Rule for Species of Hebomoia

Table 4(k) shows the results of the rules for species of genus Hebomoia. There are two species in Hebomoia contain in the 29 butterflies.

Table 4(k): Rule for Species of Hebomoia

Sr.No	Species Name	Rule for Species (Species Key)
1	glaucippe	A
2	roepstorff	B

Rule for Species of Catopsilia

Table 4(l) shows the results of the rules for species of genus Catopsilia. There are four species in Catopsilia contain in the 29 butterflies.

Table 4(l): Rule for Species of Catopsilia

Sr.No	Species Name	Rule for Species (Species Key)
1	crocale	A (a)
2	scylla	A (b)
3	pyranthe	B (a)
4	florella	B (b)

Rule for Species of Castalius

Table 4(m) shows the results of the rules for species of genus Castalius. There are two species in Castalius contain in the 29 butterflies.

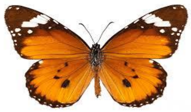
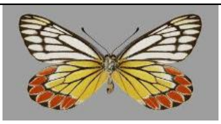
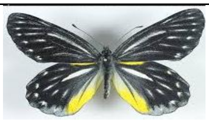
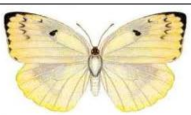
Table 4(m): Rule for Species of Castalius

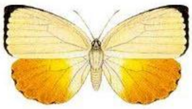
Sr.No	Species Name	Rule for Species (Species Key)
1	ananda	A
2	rosimon	B

Scientific Name of Butterflies

Table (4.5) shows the results of the scientific names of the collected butterflies by using rule induction with CN2 algorithm. For the zoologist and the users who have knowledge in classification in zoology are able to acquire more exposure knowledge. The results can also give the scientific name, that is the genus name and species name are called together.

Table 5 : Classified Butterfly with their Scientific Name

			
1. *Danaus chrysippus*	2. *Danaus alcippus*	3. *Mycalesis gotama*	4. *Orsotriaena meda*
			
5. *Cyllogenes suradeva*	6. *Euthalia lubentina*	7. *Euthalia phemius*	8. *Euthalia acontius*
			
9**.** *Abisara fylla*	10. *Abisara echerius*	11. *Papilio memnon agenor*	12. *Papilio memnon polymnestoroides*
			
13. *Papilio mayo*	14. *Papilio polytes polyts*	15. *Papilio polytes pitmani*	16. *Delias eucharis*
			
17. *Delias hierta*	18. *Appias nero*	19. *Appias libythea*	20. *Appias leis*
			
21. *Appias wardi*	22. *Hebomoia glaucippe*	23. *Hebomoia roepstorff*	24. *Catopsilia crocale*

			
25. *Catopsilia Scylla*	26. *Catopsilia pyranthe*	27. *Catopsilia florella*	28. *Castalius ananda*
			
29. *Castalius rosimon*			

Rule induction can be used by a system engineer, an expert, or any other system builder. The classification of butterfly by using rule induction with CN2 was simple, clear and useful for the researcher. But the steps of the procedure for classification were not the same. Some species of the butterfly were classified four steps and the others up to 10. The largest group is the family Papilionidae and the classification steps are more other family.

Conclusion

This research paper has introduced the idea of inducing rules from sets of examples in order to speed up the development of knowledge bases in expert systems. The rule induction with CN2 algorithm is the best technique for classification of biological dataset. The results give rules for classification and the implemented system is easy to use and understand for biologist; who is willing to classify the butterflies by computerization. A big advantage of the rule induction is that it enhances the thinking process of the expert. Butterflies are the best-known and best group of insects for examining pattern of terrestrial biotic diversity and distribution. The whole world takes an interest in the beautiful, exotic and colorful butterfly and many countries have established butterfly parks and organized special butterfly watching safaris for enthusiasts and eco-tourists in order to earn foreign exchange. In addition, children in schools are being encouraged to study the life and habit of butterflies and in this way come to appreciate the beauty of the natural environment and become involved in efforts for its conservation. So, this research will meet the aim of correct, easy, fast, simple and useful than traditional manual methods. As a future work, the evaluation of the classification method with rule induction will be carried out.

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