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A Methodology Based on Rough Set Theory and Hypergraph for the Prediction of Wart Treatment

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Abstract

Retrieving meaningful information from high dimensional dataset is an important and challenging task. Normally, medical dataset suffers from several issues such as curse of dimensionality problem, massive generation of high-dimensional medical datasets from various biomedical applications, uncertainty, presence of missing values, non-relevant and redundant attributes, etc. All of these issues harden the data analytic process for precise medical diagnosis. This work proposes an efficient feature selection methodology for finding the optimal feature subset which can be devised as a prominent solution to the above-said challenge. The proposed methodology based on rough set theory and hypergraph to identify the optimal feature subset for accurate prediction of wart treatment. In this work we use dataset contains information about wart treatment results of 90 patients using immunotherapy. A rough set with Boolean reasoning discretization algorithm is introduced to discretize the data, then the rough set reduction technique is applied to find all reducts. After that the principles of hypergraph was applied to determine the minimal transversal of reducts. Finally, a set of generalized rules for wart treatment was extracted. The proposed model shows a higher efficiency in terms of reduct size, time complexity and overall accuracy rates as well as generates more compact rules.

Keywords: classification of medical data ; medical diagnosis; Wart Treatment; Hypergraph; Rough set theory; feature selection, Immunotherapy.

1) INTRODUCTION

The advancement of technologies and enrichment in data collection methods have increased the size of the data which led to an enormous information load. The size of real time dataset is increasing day by day in both dimensions (along rows and columns) and also there is high chance of having missing of information. One of the crucial problems with these high dimensional datasets is that all the (column) attributes may not be equally significant for different knowledge discovery or data mining applications [1].

Machine learning and data mining algorithms are utilized to analyze large datasets and discover and extract knowledge from them. They are also employed as a tool in medical sciences [2–4], crime detection, risk assessment, and sales of products. These algorithms can analyze data in order to discover the unknown patterns in large databases. Industries such as banking, insurance, health, and marketing commonly apply them in order to reduce costs, improve the quality of research, and increase the amount of sales.

Attribute (feature) selection [5] is one of the important techniques of dimensionality reduction process to handle the high dimensionality issue. Attribute selection is used to select a subset of relevant attributes from a large attribute space that preserves the semantics of the original content without destroying the underlying meaning of the attributes. In the last few years, significant number of attribute selection methods is proposed by various researchers [6–8] which works in different ways by using arrange of evaluation measures like probability distribution, entropy, correlation, etc. Besides these methods rough set theory (RST) [9,10] is one of the successful approximation based mathematical model to deal the imprecision and uncertainty present in knowledge. Indiscernibility relation of RST is the backbone concept to select minimal representative attribute subset from a dataset. In this regard four main advantages of RST in data analysis may be highlighted as, first, it is based only on the original data and does not require any external input or information; secondly , it assists in identifying and selecting the most information-rich attributes from a dataset and has the capability to return it as a minimal attribute subset; finally, in terms of computational effort, it is highly efficient, as it is based on simple set operations and it can strictly deals with indiscernibility, imprecision and uncertainty. Many heuristic algorithms are proposed based on rough set theory, also numerous approached based on rough set theory and other theories are investigated to extract decision rules and reduce the dimensionality of dataset [11-23].One advantage of the rough set is the creation of readable if-then rules. Such rules have a potential to reveal new patterns in the data material. Thus, the ultimate goal of this work is to present a Methodology based on rough set theory and hypergraph for accurate prediction of wart treatment.

2) HYPERGRAPH

Over the past few decades, graphical representations were widely used by many researchers for the model binary relationships among the objects. A graph is represented as an ordered pair $=\{V,E\}$, where V and E correspond to the vertices and edges, respectively. In a real world scenario, where there exists n-ary relationship among the objects, ordinary graphical representations fail to uncover this kind of relation among the objects. In such cases, hypergraph has proven its efficiency in both defining and describing the n-ary relationships among the objects [24 - 26]. This section discusses basic definitions of the hypergraph and few exciting properties such as vertex linearity and minimal transversal which can be hybridized with RST to identify the optimal feature subset.

According to [27] consider U be a finite set of non-empty elements. If $E=\left((E_i)_{i\in j}\neq\{\ \}\right)$ and $\bigcup E_i=V, i\in j$ then $H=(V,E)$ is an hypergraph as shown in fig. 1, where $V=\{v_1,v_2,v_3,......\}$ and $E=\{e_1,e_2,e_3,......\}$ represent the vertices and edges, respectively. Hyperedges of H are represented by $e_i=\{e_{i1},e_{i2},e_{i3},.....e_{ij}\}(i\in j; j=1,2,3,....n)$

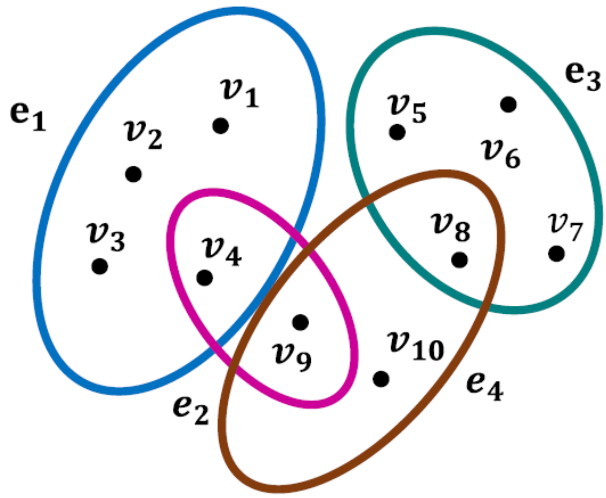

Fig. 1: Hypergraph structure

According to [28] $H=(V,E)$ for $k\in V$, then set of hyperedges that contain k is known as star of H which is represented as $H(k)$ and degree of k is the cardinality of star $H(k)$ denoted as $k_d=Card(H(k))$. From Fig.1 $V=\{v_1,v_2,v_3,v_4,v_5,v_6,v_7,v_8,v_9,v_{10}\}$; set of hyperedges $e_1=\{v_1,v_2,v_3,v_4\}$, $e_2=\{v_4,v_9\}$, $e_3=\{v_5,v_6,v_7,v_8\}$, $e_4=\{v_8,v_9,v_{10}\}$; the star centered on v_8 is $H(k_8)=\{e_3,e_4\}$ and $k_{8d}=2$; the star centered on v_4 is $H(k_4)=\{e_1,e_2\}$ and $k_{4d}=2$.

According to [28, 29]:

a) $H=(V,E)$ be a simple (Sperner family) only for every $E_a,E_b\in E$; if $E_a\not\subset E_b$, it implies $a\neq b$. The set of $H\subseteq V$ is known as transversal of H only when it intersects every hyperedge of H.

b) The transversal hypergraph T_H^r of hypergraph H is a set of all minimal transversals of H.

3) PROBLEM FORMULATION

In medical research, one of the most important fields is skin disease, and among the skin diseases wart treatment. Warts are non-cancerous (benign) skin growths that develop on different parts of the body and come in various forms. They are caused by caused by the human papillomavirus (HPV) viruses. Warts are contagious and very common: Most people will have one at some point in their lives. Although they can affect people at any age, warts are most common among children and teenagers. Most warts are harmless and will go away on their own within a few weeks or months. But they can be bothersome and unattractive, and some people feel ashamed. There are a number of different treatments that can make warts go away more quickly – but they don't always work. Most warts don't cause any bothersome symptoms. Some may cause itching, tightness or a feeling of pressure. Warts might be painful too, particularly those on the soles of your feet. Some warts have small black or brownish dots caused by clotted blood that has leaked from capillaries (very fine blood vessels) in the skin. Warts may appear alone or in groups, which may then cover larger areas of skin. The main types of warts are shown in Fig. 2. There are two methods for treatment, cryotherapy method and immunotherapy method. A number of medical studies have been done to compare these two treatment methods.

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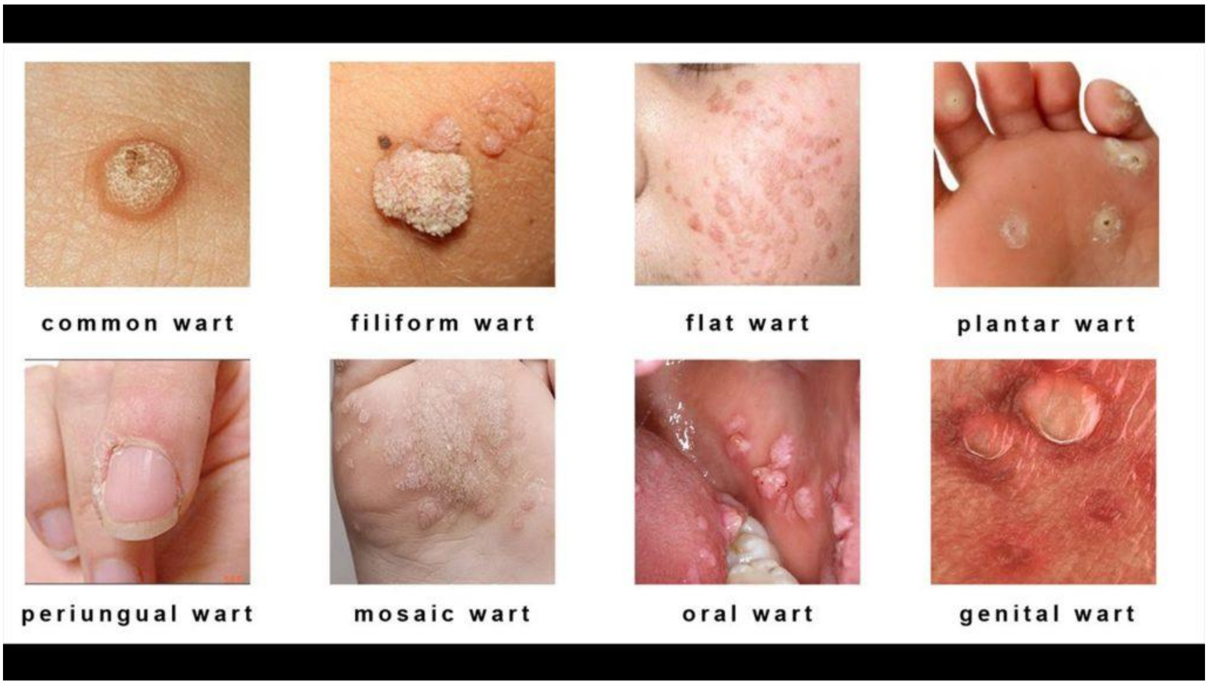

Fig. 2: Types of Warts

The main goal of this work is to present Methodology based on rough set theory and hypergraph for generating classification to predict the response of wart treatment. The data set is taken from the UCI machine learning repository [30, 31]. This dataset contains information about wart treatment results of 90 patients using immunotherapy. We consider the Response to treatment as the decision variable. The attributes that play major wart treatment are presented in the decision table shown in Table 2, where to write it in a simple form and to make our analysis simple we used the coding shown in table 1.

Table 1. Coding system for the Symptoms and decision attribute

attribute	**Attribute code**	**Attribute value**
Gender	A	1-Man 2- woman
Age (year)	B	15–56
Time elapsed before treatment (month)	C	0–12
The number of warts	E	1–19
Surface area of the warts(mm2)	F	6–900
Induration diameter of initial test(mm)	G	5–70
Types of wart	H	1– Common 2– Plantar 3– Both
Response to treatment	D	Yes or No

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Table 2. Decision table for wart treatment

U	A	B	C	E	F	G	H	D
X1	1	22	2.25	14	3	51	50	1
X2	1	15	3	2	3	900	70	1
X3	1	16	10.5	2	1	100	25	1
X4	1	27	4.5	9	3	80	30	1
X5	1	20	8	6	1	45	8	1
X6	1	15	5	3	3	84	7	1
X7	1	35	9.75	2	2	8	6	1
X8	2	28	7.5	4	1	9	2	1
X9	2	19	6	2	1	225	8	1
X10	2	32	12	6	3	35	5	0
X11	2	33	6.25	2	1	30	3	1
X12	2	17	5.75	12	3	25	7	1
X13	2	15	1.75	1	2	49	7	0
X14	2	15	5.5	12	1	48	7	1
X15	2	16	10	7	1	143	6	1
X16	2	33	9.25	2	2	150	8	1
X17	2	26	7.75	6	2	6	5	1
X18	2	23	7.5	10	2	43	3	1
X19	2	15	6.5	19	1	56	7	1
X20	2	26	6.75	2	1	6	6	1
X21	1	22	1.25	3	3	47	3	1
X22	2	19	2.25	2	1	60	7	1
X23	2	26	10.5	6	1	50	9	0
X24	1	25	5.75	2	1	300	7	1
X25	2	17	11.25	4	3	70	7	1
X26	1	27	5	2	1	20	5	1
X27	2	24	4.75	10	3	30	45	1
X28	1	15	11	6	1	30	25	0
X29	2	34	11.5	12	1	25	50	0
X30	2	20	7.75	18	3	45	2	1
X31	2	38	2.5	1	3	43	50	1
X32	1	23	3	2	3	87	70	1
X33	2	48	10.25	7	1	50	25	1
X34	2	24	4.25	1	1	174	30	1
X35	2	33	8	3	1	502	8	1
X36	1	34	5	7	3	64	7	0
X37	2	41	11	11	2	21	6	0
X38	1	29	8.75	3	1	504	2	1
X39	2	22	8.5	5	1	99	8	1

X40	1	45	11.25	4	1	72	5	0
X41	2	22	8.25	9	1	352	3	1
X42	1	35	8.75	10	2	69	7	1
X43	2	34	8.5	1	2	163	7	0
X44	1	49	4.5	2	1	33	7	0
X45	2	19	11	5	2	51	6	1
X46	1	21	8	3	1	17	8	1
X47	1	26	7.75	13	2	13	5	1
X48	1	51	8.75	2	2	57	3	1
X49	1	19	7.75	6	1	32	7	1
X50	1	38	12	14	1	87	6	0
X51	2	36	1.75	10	3	45	3	1
X52	2	52	2.25	5	1	63	7	1
X53	2	49	9	4	2	14	9	1
X54	1	23	5.75	2	1	43	7	1
X55	1	45	10	8	1	58	7	1
X56	1	54	7.5	13	3	43	5	1
X57	2	47	5.25	3	3	23	45	1
X58	2	53	10	1	2	30	25	1
X59	2	56	11.75	7	1	31	50	0
X60	1	27	11.25	3	2	37	2	1
X61	2	47	3.75	14	2	67	50	1
X62	2	19	2.25	8	2	42	70	1
X63	2	33	8	5	1	63	25	1
X64	2	15	4	12	1	72	30	1
X65	1	17	8.5	2	1	44	8	1
X66	1	29	5	12	3	75	7	1
X67	1	27	11.75	8	1	208	6	0
X68	2	51	6	6	1	80	2	1
X69	1	35	6.75	4	3	41	8	1
X70	2	47	10.75	8	1	57	5	0
X71	1	43	8	1	1	59	3	1
X72	1	15	4	4	3	25	7	1
X73	1	33	1.75	7	2	379	7	0
X74	2	51	4	1	1	65	7	1
X75	1	45	6.5	9	2	49	6	1
X76	2	47	9.25	13	2	367	8	1
X77	1	18	11.75	5	2	13	5	1
X78	2	46	7.75	8	1	40	3	1
X79	1	43	11	7	1	507	7	1
X80	2	28	11	3	3	91	6	0

X81	1	30	1	2	1	88	3	1
X82	2	16	2	11	1	47	7	1
X83	2	42	8.75	8	2	73	9	0
X84	2	15	8	1	1	55	7	1
X85	2	53	7.25	6	1	81	7	1
X56	1	40	5.5	8	3	69	5	1
X87	1	38	7.5	8	2	56	45	1
X88	1	46	11.5	4	1	91	25	0
X89	1	32	12	9	1	43	50	0
X90	2	23	6.75	6	1	19	2	1

4) ANALYSIS

In this section, we will discuss the proposed rough sets and hypergraph scheme to analyze, mining and generating classification rules for predict the response of wart treatment. The main stages will be done with the aid of software called ROSETTA which is an RST analysis toolkit. First, rough sets with Boolean reasoning discretization algorithm is introduced to discretize the data, second step, the rough set reduction technique is applied to find all reducts of the data which contains the minimal subset of attributes that are associated with a class label for classification as shown in table 3.

Table 3. Reducts of Table 2.

	Reduct	**Support**	**Length**
1	$\{A,B,C,E,G\}$	100	5
2	$\{A,B,C,E,F\}$	100	5
3	$\{A,B,C,E,H\}$	100	5
4	$\{A,B,C,F,G,H\}$	100	6

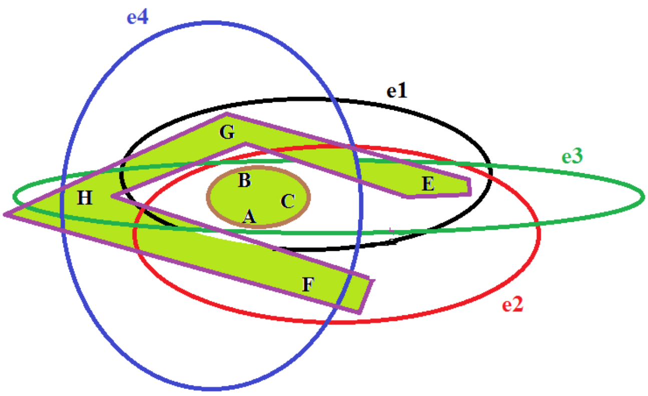

Fig. 3: Hypergraph with minimal transversal property

The next stage is applying the hypergraph principles to determine the minimal transversal of reducts. Consider the hypergraph $H=(V,E)$ where $V=\{A,B,C,E,F,G,H\}$, $E=\{e_1,e_2,e_3,e_4\}$; set of hyperedges $e_1=\{A,B,C,E,G\}$, $e_2=\{A,B,C,E,F\}$, $e_3=\{A,B,C,E,H\}$, $e_4=\{A,B,C,F,G,H\}$; the minimal transversal of H hypergraph is $\{\{A,B,C\},\{E,F,G,H\}\}$ as shown in Fig. 3. Finally, the rough sets dependency rules are generated directly as shown in table 4.

CONCLUSION

This paper introduced a methodology for predicting the response of wart treatment based on rough set theory and hypergraph. The proposed methodology hybridizes the benefits of RST and Sperner hypergraph properties. The minimal transversal properties of hypergraph were exploited on the reducts obtained from RST to identify the informative feature subset for health-care applications. The proposed technique has been simplified logic-based rules required to building knowledge. Also it was observed that this system can greatly and effectively reduce both the time and cost of treatment for patients. an extension work of using rough sets with other intelligent systems like neural networks, genetic algorithms, fuzzy approaches, and so forth, will be considered in the future work.

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Table 4. The generated rules to predict the response of wart treatment

	Rule	LHS Support	RHS Support	RHS Accuracy	LHS Coverage	RHS Coverage
1	A([*, 2)) AND B([*, 26)) AND C([5.13, 10.38)) AND F(1) AND G([*, 64)) AND H(8) => D(1)	3	3	1.0	0.033333	0.042254
2	A([2, *)) AND B([*, 26)) AND C([5.13, 10.38)) AND F(1) AND G([*, 64)) AND H(7) => D(1)	3	3	1.0	0.033333	0.042254
3	A([*, 2)) AND B([*, 26)) AND C([5.13, 10.38)) AND F(1) AND G([*, 64)) AND H(7) => D(1)	2	2	1.0	0.022222	0.028169
4	A([*, 2)) AND B([*, 26)) AND C([*, 5.13)) AND F(3) AND G([64, *)) AND H(70) => D(1)	2	2	1.0	0.022222	0.028169
5	A([2, *)) AND B([*, 26)) AND C([*, 5.13)) AND F(1) AND G([*, 64)) AND H(7) => D(1)	2	2	1.0	0.022222	0.028169
6	A([2, *)) AND B([*, 26)) AND C([5.13, 10.38)) AND F(1) AND G([64, *)) AND H(8) => D(1)	2	2	1.0	0.022222	0.028169
7	A([2, *)) AND B([*, 26)) AND C([*, 5.13)) AND F(1) AND G([64, *)) AND H(30) => D(1)	2	2	1.0	0.022222	0.028169
8	A([*, 2)) AND B([*, 26)) AND C([*, 5.13)) AND F(3) AND G([*, 64)) AND H(50) => D(1)	1	1	1.0	0.011111	0.014085
9	A([*, 2)) AND B([*, 26)) AND C([10.38, *)) AND F(1) AND G([64, *)) AND H(25) => D(1)	1	1	1.0	0.011111	0.014085
10	A([*, 2)) AND B([26, 31)) AND C([*, 5.13)) AND F(3) AND G([64, *)) AND H(30) => D(1)	1	1	1.0	0.011111	0.014085
11	A([*, 2)) AND B([*, 26)) AND C([*, 5.13)) AND F(3) AND G([64, *)) AND H(7) => D(1)	1	1	1.0	0.011111	0.014085
12	A([*, 2)) AND B([31, 43)) AND C([5.13, 10.38)) AND F(2) AND G([*, 64)) AND H(6) => D(1	1	1	1.0	0.011111	0.014085
13	A([2, *)) AND B([26, 31)) AND C([5.13, 10.38)) AND F(1) AND G([*, 64)) AND H(2) => D(1	1	1	1.0	0.011111	0.014085
14	A([2, *)) AND B([31, 43)) AND C([10.38, *)) AND F(3) AND G([*, 64)) AND H(5) => D(0)	1	1	1.0	0.011111	0.052632
15	A([2, *)) AND B([31, 43)) AND C([5.13, 10.38)) AND F(1) AND G([*, 64)) AND H(3) => D(1	1	1	1.0	0.011111	0.014085
16	A([2, *)) AND B([*, 26)) AND C([5.13, 10.38)) AND F(3) AND G([*, 64)) AND H(7) => D(1)	1	1	1.0	0.011111	0.014085
17	A([2, *)) AND B([*, 26)) AND C([*, 5.13)) AND F(2) AND G([*, 64)) AND H(7) => D(0)	1	1	1.0	0.011111	0.052632
18	A([2, *)) AND B([*, 26)) AND C([5.13, 10.38)) AND F(1) AND G([64, *)) AND H(6) => D(1)	1	1	1.0	0.011111	0.014085
19	A([2, *)) AND B([31, 43)) AND C([5.13, 10.38)) AND F(2) AND G([64, *)) AND H(8) => D(1	1	1	1.0	0.011111	0.014085
20	A([2, *)) AND B([26, 31)) AND C([5.13, 10.38)) AND F(2) AND G([*, 64)) AND H(5) => D(1	1	1	1.0	0.011111	0.014085
21	A([2, *)) AND B([*, 26)) AND C([5.13, 10.38)) AND F(2) AND G([*, 64)) AND H(3) => D(1)	1	1	1.0	0.011111	0.014085
22	A([2, *)) AND B([26, 31)) AND C([5.13, 10.38)) AND F(1) AND G([*, 64)) AND H(6) => D(1	1	1	1.0	0.011111	0.014085
23	A([*, 2)) AND B([*, 26)) AND C([*, 5.13)) AND F(3) AND G([*, 64)) AND H(3) => D(1)	1	1	1.0	0.011111	0.014085
24	A([2, *)) AND B([26, 31)) AND C([10.38, *)) AND F(1) AND G([*, 64)) AND H(9) => D(0)	1	1	1.0	0.011111	0.052632
25	A([*, 2)) AND B([*, 26)) AND C([5.13, 10.38)) AND F(1) AND G([64, *)) AND H(7) => D(1)	1	1	1.0	0.011111	0.014085
26	A([*, 2)) AND B([26, 31)) AND C([*, 5.13)) AND F(1) AND G([*, 64)) AND H(5) => D(1)	1	1	1.0	0.011111	0.014085
27	A([2, *)) AND B([*, 26)) AND C([*, 5.13)) AND F(3) AND G([*, 64)) AND H(45) => D(1)	1	1	1.0	0.011111	0.014085
28	A([*, 2)) AND B([*, 26)) AND C([10.38, *)) AND F(1) AND G([*, 64)) AND H(25) => D(0)	1	1	1.0	0.011111	0.052632
29	A([2, *)) AND B([31, 43)) AND C([10.38, *)) AND F(1) AND G([*, 64)) AND H(50) => D(0)	1	1	1.0	0.011111	0.052632
30	A([2, *)) AND B([*, 26)) AND C([5.13, 10.38)) AND F(3) AND G([*, 64)) AND H(2) => D(1)	1	1	1.0	0.011111	0.014085
31	A([2, *)) AND B([31, 43)) AND C([*, 5.13)) AND F(3) AND G([*, 64)) AND H(50) => D(1)	1	1	1.0	0.011111	0.014085
32	A([2, *)) AND B([43, *)) AND C([5.13, 10.38)) AND F(1) AND G([*, 64)) AND H(25) => D(1)	1	1	1.0	0.011111	0.014085
33	A([2, *)) AND B([31, 43)) AND C([5.13, 10.38)) AND F(1) AND G([64, *)) AND H(8) => D(1	1	1	1.0	0.011111	0.014085
34	A([*, 2)) AND B([31, 43)) AND C([*, 5.13)) AND F(3) AND G([64, *)) AND H(7) => D(0)	1	1	1.0	0.011111	0.052632

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