CHAPTER 4

RESULTS

To increase the efficiency of research management in universities, this study developed a research management framework by using CMU as case study. This framework is based on ontology, semantic web technology enabling to enhance capability of search results. The result of study was CMU research ontology commitment. With using this ontology, problem of research information both incomplete and dynamic were solved. Further, predicate logic and inference engine were applied to the ontology for exploring key researchers in complicated condition effectively. Finally CMU research ontology commitment could be used for formulating research strategies and policies reasonably.

This chapter is divided into two parts the first part is results from pilot project working with CMU research team. After that, new framework was built for solving problems from first part. The obtained results are shown in second part.

4.1 First Part: Result from Pilot Project

After all steps in step diagram of Figure 3.5 were done the outputs are as follow:

4.1.1 Explore for *key researchers*

4.1.1.1 Identify *candidate key researcher*s: From interviewing by using heuristic approach the Research Deputy Deans and Research Institute Directors of

CMU from 18 faculties and 3 research institutes, the candidate key researcher list composed of 303 candidate key researchers. The number of candidate key researcher of each discipline is as follow:

a.) Health Sciences: There are 6 faculties and 1 institute. The total number of candidate key researchers of this discipline was 71. Another detail is displayed on table 4.1

Table 4.1 The number of candidate key research from Health Sciences on consent of Research Deputy Deans and Director of The Research Institute for Health Sciences.

Faculty	Number of candidate key researchers
Associated Medical Sciences	4
Dentistry	7
Medicine	21
Pharmacy	13
Nursing	12
Veterinary Medicine	2
The Research Institute for Health Sciences	12
Total	71

b.) Science & Technology: There are 5 faculties and 1 institute. The total number of candidate key researchers of this discipline was 111. Another detail is displayed on table 4.2

Table 4.2 The number of candidate key research from Science & Technology on consent of Research Deputy Deans and Director of Science and Technology Research Institute.

Faculty	Number of candidate key researchers
Agriculture	28
Agro-Industry	10
Architecture	9
Engineering	4
Science	9
Science and Technology Research Institute	57
Total	111*

*There were 6 researchers purposed from Science & Technology Research Institute as same as name purposed by their own faculties.

c.) Social Sciences & Humanities: There are 7 faculties and 1 institute. The total number of candidate key researchers of this discipline was 121. Another detail is displayed on table 4.3

Table 4.3 The number of candidate key research from Social Sciences & Humanities on consent of Research Deputy Deans and Director of The Social Research Institute.

Faculty	Number of candidate key researchers
Business Administration	12
Economics	4
Education	36
Fine Arts	11
Humanities	10
Mass Communication	4
Social Sciences	37
The Social Research Institute	8
Total	121**

** There was 1 researchers purposed from The Social Research Institute was already in his/her faculty.

4.1.1.2 Review candidate key researcher list by CMU research team: After review candidate key researcher list by CMU project team, some names were added to complete the list. Finally the results were 84 researchers in Health Sciences, 109 researcher in Science & Technology, and 122 researchers in Social Sciences & Humanities. Finally, there were a total of 315 candidate key researchers from a total of 2,178 lecturers at the university. Detail of all disciplines is shown in table 4.4, 4.5, and 4.6

Table 4.4 The number of candidate key research from Health Sciences on consent of Research Deputy Deans and Director of Science, Technology Research Institute, and CMU research team.

Faculty	Number of candidate key researchers
Associated Medical Sciences	4
Dentistry	7
Medicine	34
Nursing	12
Pharmacy	13
Veterinary Medicine	2
The Research Institute for Health Sciences	12
Total	84

Table 4.5 The number of candidate key research from Science & Technology on consent of Research Deputy Deans and Director of Science, Technology Research Institute, and CMU research team

Faculty	Number of candidate key researchers
Agriculture	28
Agro-Industry	10
Architecture	9
Engineering	4
Science	9
Science and Technology Research Institute	57
Total	111

Table 4.6 The number of candidate key research from Social Sciences & Humanities on consent of Research Deputy Deans, Director of The social research institute, and CMU research team

Faculty	Number of candidate key researchers
Business Administration	12
Economics	4
Education	36
Fine Arts	11
Humanities	10
Mass Communication	4
Social Sciences	37
The Social Research Institute	8
Total	121

4.1.1.3 Identify *key researcher criteria*: First, CMU research team defined *key researcher criteria* as

a.) Received a distinguished prize or award for research accomplishments.

b.) Created a recognized innovation or patent.

c.) Published a substantial number of papers (ten or more) in a certain period of time (five years).

d.) Had papers published in international journals with a high impact factor (3 or more by Web of Science).

e.) Received an average of 1 million baht in research funding per year.

The criteria above were chosen because they are KPI of CMU and easy to justify key researchers because they can be measured quantitatively.

After review by Research Deputy Deans and Research Institute Directors, they were agreed with these criteria. However they gave some comments as follows.

a.) Researcher who passed at least one item of those criteria should be considered as key researcher.

b.) Some criteria were suitable for only researchers in Health Sciences and Science & Technology areas. But for Social Sciences & Humanities some criteria such as criteria c) and d) might not be appropriate.

Further, Research Deputy Deans and Research Institute Directors suggested more criteria.

a.) Recognized by others.

b.) Be able to do research with many people.

c.) Be able to do research with researchers from other disciplines.

d.) Submit dissertation on time and have high quality.

e.) Have project management skill.

f.) Do research regularly and realize research importance.

g.) Be the example and inspiration for other researchers.

h.) Have social services.

i.) Have systematic working.

j.) Have working enthusiastic.

k.) Have high research skills.

l.) Have vision, positive attitude and open mind.

m.) Have research etiquettes.

However, some of them were subjective and not significant enough. Therefore, CMU research team chose some criteria that could be measured quantitatively to decrease the conflict of the key researchers' identifying. Any subjective criterion, team expected to use another method to organized in the next phase of the project.

After revised *key researcher criteria* with the recommend above, *key researcher criteria* were divided into two groups, the first one for Health Sciences and Science & Technology, and the other one for Social Sciences & Humanities. They were

a.) Criteria for Health Sciences and Science & Technology

1. Received at least one national or international research award and in case of recipient of honorably mentioned award at national or institutional levels justification shall be made on such additional criteria as the (significance of) research grant or

2. Created a recognized innovation or patent or

3. Published a substantial number of papers (ten or more), in a certain period of time (five years), in international journals with high impact factor (3 or more by ISI Web of Science) or received a substantial number of citations or

4. Received at least 1 million baht of research funding on the average per year

b.) Criteria for Social Sciences & Humanities

1. Received at least one national or international research award and in case of recipient of honorably mentioned award at national or institutional levels justification shall be made on such additional criteria as the (significance of) research grant or

2. Published at least one article in international scientific journal that has impact factor or

3. Received at least 1 million baht of research funding on the average per year or

4. Received book points which are translated from composed academic books, at least 3 points for English and 15 points for Thai publication

Criteria for Social Sciences & Humanities were as same as criteria of Health Sciences and Science & Technology except criteria items number 3 and 4. Actually, administrators suggested one more criteria for Social Sciences & Humanities, number of attend conferences both national and international conference. However, CMU research team could not find any good sources given correct and complete information. Finally team did not use it in this project.

4.1.1.4 Collect research information of *candidate key researchers:* In this step, research information of candidate key researchers was collected from many sources as follow:

a.) Questionnaires: With using Skandia Model as a frame, questionnaire was designed by analysis intellectual capital in research domain into each subgroup of Skandia Model, as shown in Figure 4.1. This model presents value perception from stakeholder of CMU. Detail of questionnaire is shown in Appendix A.

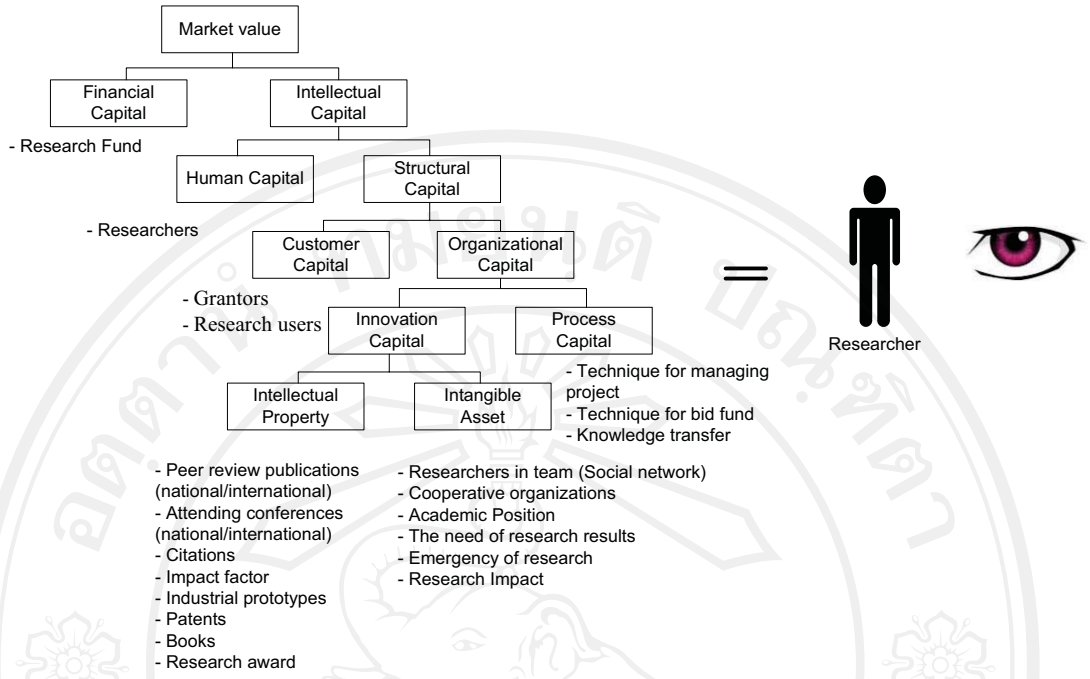

Figure 4.1 Analysis IC of Research with Skandia Model

From direct collecting information via questionnaires found that all 296 questionnaires was returned only 104, equal 35%. In addition, some information received from questionnaires was not correct and incomplete because some researchers did not remember the exact Figure or some misunderstood the questions such as research funding per year or number of papers per year.

b.) Other sources: Due to lack of direct information via questionnaires, CMU research team planed to use other sources to collect information indirectly. These sources were personal record in MIS of all faculties, CMU internal documents, electronic databases (Scopus and ISI Web of Science), CMUL OPAC. The information concerned are

1.) Research awards.

2.) Patents.

3.) International paper details.

4.) Impact factor of journals researchers published.

5.) Citation of researcher papers.

6.) Research funding.

From gathering information, there were 2,422 papers, which had an impact factor between 0 and 35.046, 47 patents, 49 awards, and 1,422 books.

4.1.1.5 Database design

Results of database system design were four parts -- Tables (Appendix B), relationship among tables (Appendix C), database system layout (Appendix D), and queries (Appendix E). Query was designed by using key research criteria.

4.1.1.6 After processing query and reviewing by CMU project team, key researchers consisted of

a.) Health Sciences : 51 key researchers.

b.) Science & Technology : 35 key researchers.

c.) Social Sciences & Humanities : 29 key researchers

Detail of each discipline is shown in Table 4.7-4.9. List of key researchers' name is shown in Appendix F.

Table 4.7 The number of key research from Health Sciences.

Faculty	Number of key researchers
Associated Medical Sciences	3
Dentistry	3
Medicine	24
Nursing	6
Pharmacy	6
Veterinary Medicine	1
The Research Institute for Health Sciences	8
Total	51

Table 4.8 The number of key research from Science & Technology.

Faculty	Number of key researchers
Agriculture	12
Agro-Industry	1
Architecture	2
Science	12
Engineering	8
Total	35

Table 4.9 The number of key research from Social Sciences & Humanities

Faculty	Number of key researchers
Business administration	2
Economics	3
Education	6
Fine arts	3
Humanities	3
Mass communication	-
Social Sciences	9
The Social Research Institute	3
Total	29

4.1.1.7 Public hearing with representative of *key researchers*

From public hearing to verify methodology of the first part, representative of key researchers suggested some comment divided into three groups of discipline as follow:

1) Health Sciences

In analysis, vocabularies and keywords of researchers should be gathered from analysis system of electronic databases such as ISI Web of Science because it provides the standard keywords. Additional, the collected keywords should be interesting keywords such as hot issue, trend of academic society, or niche of CMU. The other way to finding keywords was collecting from Thailand Research Fund's database.

2) Sciences and Technology

The chosen electronic databases should include PubMed and Elsevier. Patent should be distinguished between patents registered in Thai and aboard.

3) Social Sciences & Humanities

About key researcher criteria, publication should be national paper more than international paper. Number of published book should be concerned as same as recognition of researchers. The recognition could be defined by Delphi technique, peer review among key researchers. In review, it should consider on potential of researchers and impact of their research with society.

For all three disciplines, the meeting of public hearing suggested more comments as follow.

- Key researcher criteria should be defined by universities administrators for over all image
- Collecting research information should be the responsibility of all faculties, which were done under CMU control
- If every subject used the same Impact Factor criteria, some subjects such as economic, engineering, and mathematics could not identify key researchers. This is due to the maximum Impact Factor of those subjects are very low. Therefore if researchers in those subject could publish even in national journal that enough to count.
- Each subject has very different characteristics, so electronic databases should be used more than one.
- Key researcher should be the leader of research in his/her discipline. Thus most of researchers in his/her discipline should recognize him/her. Key researcher should create and give chance to young researcher as well. Otherwise social network could not be done if key researchers did not have moral and ethic.

All suggestions above were used to modify key researcher criteria as already shown in 4.1.1.3.

4.1.2 Identifying expertise and research directions of the key researchers

After collected all keywords (Appendix G) explaining the expertise and research direction of *key researchers* from both questionnaire and called by phone, card sorting was implemented. This step produces some results as follow.

4.1.2.1 With using Card Sorting, key researchers classified into 10 groups as below:

a.) Nanomaterial Science

- Nanomaterial
- Nonopharmacology
- Electron microscope
- X-Ray machine
- Ceramics

b.) Sustainable conservation and use of nature and environment

- Tourism
- Conservation
- Natural resources
- Geographic Information System
- Environment

c.) Quality of Thai society

- Tourism
- Management

- Rural community development
- Politics and government
- Education
- Resources
- Applied economics
- Public health
- Environment
- Human rights
- Media

d.) Biotechnology

- Health
- Microorganism
- Plant
- Food
- Instrument

e.) Local history and tourism

- Tourism
- Local architectural conservation
- Archeology
- Local histories
- Philosophy and Religion
- Language and literature
- Local arts and culture
- Sociology and anthropology

f.) Infections disease

- HIV
- Malaria
- Epidemiology
- Causes (Microorganism)

g.) Non – infections disease

- Heart disease
- Cancer
- Trematodes/Fluke

h.) Environment

- Management
- Air pollution
- Agriculture and biodiversity
- Tools

i.) Information technology

- GIS
- Model
- Program

j.) Economic plant and animal

- Economic animal
- Vegetables and fruits
- Rice
- Flower
- Soil

- Herb
- Food safety

Ontology Commitment of CMU composed of research clusters and vocabularies or keywords of researchers in each cluster. The ontology commitment is shown in Appendix F.

4.1.2.2 The example of card sorting in biotech cluster shown in Figure 4.2

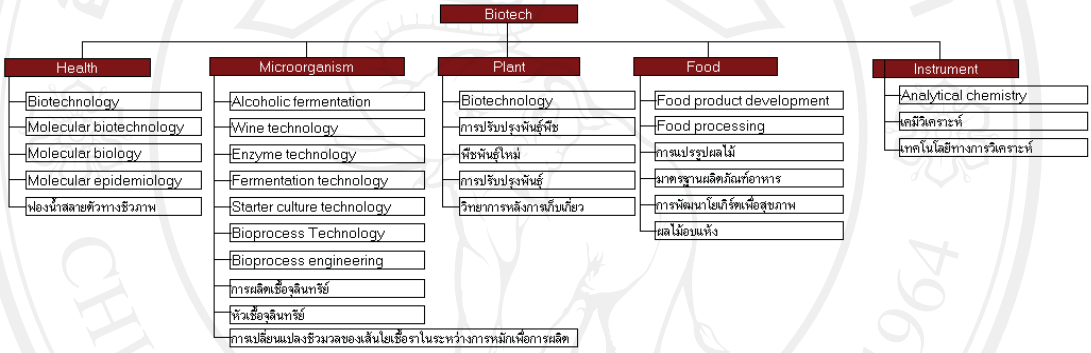

Figure 4.2 Example of card sorting: Biotechnology cluster

4.1.2.3 Use *river diagram* to identify research direction and researcher potential: This step used river diagram to identify research direction and researcher potential for developing research results in the level of faculties and university. Doing this had to use research clusters from step 4.1.2.2

1.) Expertise and research direction of faculties: Building expertise graphs of each faculty were done by using researchers' performance such as number of publications, number of researcher award. Then classified them by research clusters and calculated in term of percentage as the example is shown in Figure 4.3

and Figure 4.4. After that, this information was used to draw expertise graph as shown the example in Figure 4.5 and Figure 4.6.

The example of expertise and research direction of Faculty of Sciences is shown in Figure 4.4

Research cluster	Publication (%)	Impact Factor (%)	Citation (%)	Award (%)	No of Patent (%)	Budget (%):	No of researcher (%)
Nanomaterial Science	16.17	16.93	7.13	21.05		11.36	50.00
Sustainable conservation and use of nature and environment	25.06	27.69	27.73	26.32		29.55	12.50
Quality of Thai Society	25.06	27.69	27.73	26.32		29.55	12.50
Biotechnology	33.71	27.69	37.42	26.32		29.55	25.00

Figure 4.3 Research performance of candidate key researchers separate by research clusters in faculties of Sciences

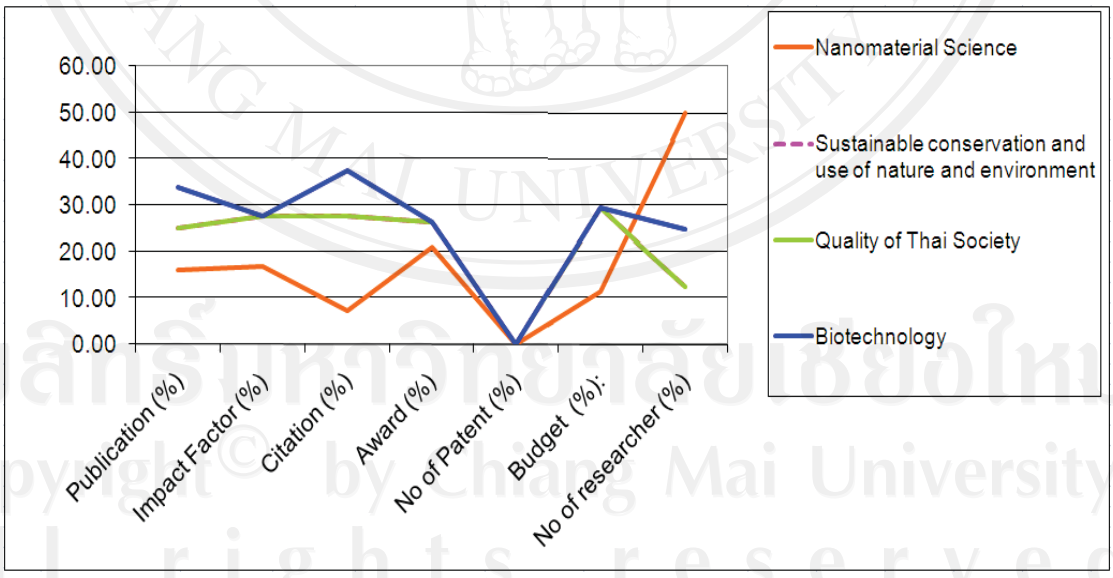

Figure 4.4 River diagram of faculty of Science

From river diagram in Figure 4.4 found that faculty of Sciences had many research clusters. Even though most of researchers researched in Nanomaterial Science but the cluster published many papers was Biotechnology cluster.

The example of expertise and research direction of Faculty of Medicine is shown in Figure 4.5

Research Cluster	Pulbication (%)	Impact Factor (%)	Citation (%)	Award (%)	Patent (%)	Budget (%):	No. of Researcher (%)
Non - infections disease	13.60	30.92	23.37	100.00			15.38
Quality of Thai Society	4.41	13.00	5.10			28.90	7.69
Biotechnology	5.15	13.00	14.00			11.60	7.69
Local history and tourism	4.41	13.00	5.10			28.90	7.69
Economic plant and animal	25.37	8.46	12.81		100.00	19.00	23.08
Infections disease	25.74	14.44	29.18			11.60	23.08
Environment	21.32	7.19	10.44				15.38

Figure 4.5 Research performance of candidate key researcher separate by subject in faculty of Medicine

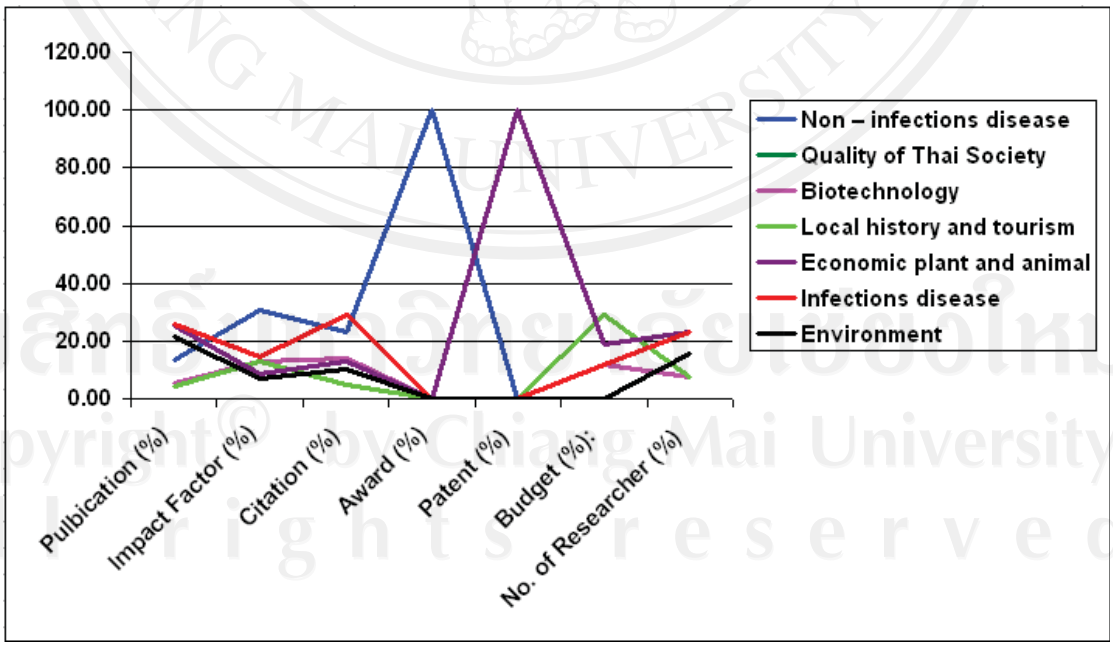

Figure 4.6 River diagram of faculty of Medicine

From river diagram in Figure 4.6 found that most of researchers researched in Infections disease cluster and Economic plant and animal cluster (Herbs). There were many research results in these clusters i.e. number of published papers, and high number of citation. Anyway research results were also high in non-infection disease as well.

2.) Expertise and research direction of CMU: Building expertise graphs of CMU were done by using researchers' performance such as number of publications, number of researcher award. Then classified them by faculties and calculated in term of percentage as the example shown in Figure 4.7 and Figure 4.9. The example of CMU expertise graph is shown in Figure 4.8 and Figure 4.10.

The example of expertise and research direction of CMU in Biotechnology cluster.

Faculty	Publication (%)	Impact Factor (%)	Citation (%)	Award (%)	Patent (%)	Budget (%):	No. of Researcher (%)
Agriculture	5.51	11.35	1.49	50.00	15.38	70.01	18.18
Dentistry	3.54	14.19	21.81			1.62	9.09
Associated Medical Science	14.96	11.14	9.95		38.46	15.60	9.09
Medicine	5.51	10.03	9.78			0.88	9.09
Phamacy	9.45	7.95	4.39		38.46	1.27	18.18
Science	58.27	11.09	46.10	50.00		6.45	18.18
Research Institute for Health Science	2.36	32.11	6.38			1.31	9.09
Agro-Industry	0.39	2.13	0.08		7.69	2.87	9.09

Figure 4.7 Researcher performance of biotechnology cluster of CMU

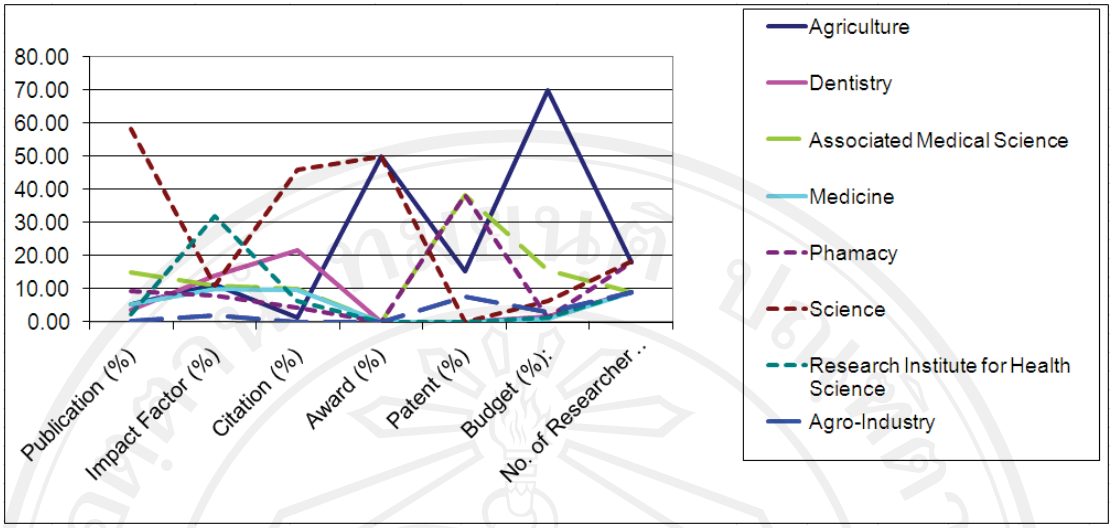

Figure 4.8 Researcher performance of biotechnology cluster of CMU in graph.

From river diagram in Figure 4.8 found that research of Biotechnology is done in many faculties. However faculty of Sciences was the faculty published the most number of publications. Faculty of Associated Medical Sciences and faculty of Pharmacy were the faculty registered the most number of patents. From this information, CMU administrators should formulate some policies to reduce gap of research performance by transferring knowledge from high potential faculties to others faculties.

The example of expertise and research direction of CMU in Infections disease cluster.

Faculty	Pulbication (%)	Impact Factor (%)	Citation (%)	Award (%)	No. of Patent (%)	Budget (%):	No. of Researcher (%)
Dentistry	7.03	20.69	37.20			3.68	11.11
Associated Medical Sciences	29.69	16.24	16.97		100.00	35.49	11.11
Nursing						30.31	22.22
Medicine	54.69	16.24	34.79			1.99	33.33
The Research Institute for Health Sciences	8.59	46.82	11.03			28.53	22.22

Figure 4.9 Researcher performance of Infection Disease cluster of CMU.

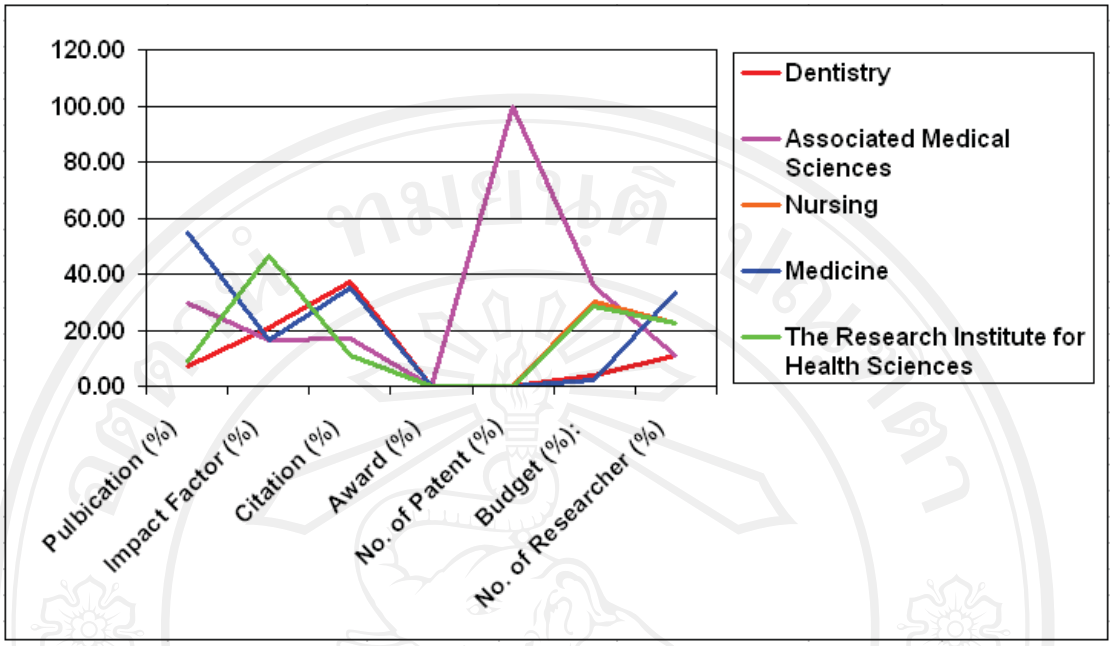

Figure 4.10 Research performance of Infections Disease cluster of CMU in graph.

From river diagram in Figure 4.10 found that only faculty of Associated Medical Sciences registered patent. This means administrators should encourage researchers in this cluster register patent much more. Faculty of Medicine enables to publish many of papers and they also have high number of citation more than others faculties. In this case, administrations should be planed to reduce this gap by setting up knowledge transfer activity among faculties. This could be done to the case of Impact Factor of The Research Institute for Health Sciences as well.

4.1.2.4 Find academic social network among researchers

This step used researchers' name co-published in journal to generate graph of *social network*. After extract researchers' names from papers by coding Perl language and generating graph with Cytoscape version 2.2, the results were social networks of

key researchers, which were represented some multi-disciplines research groups. The examples of social network are shown in Figure 4.11 and 4.14.

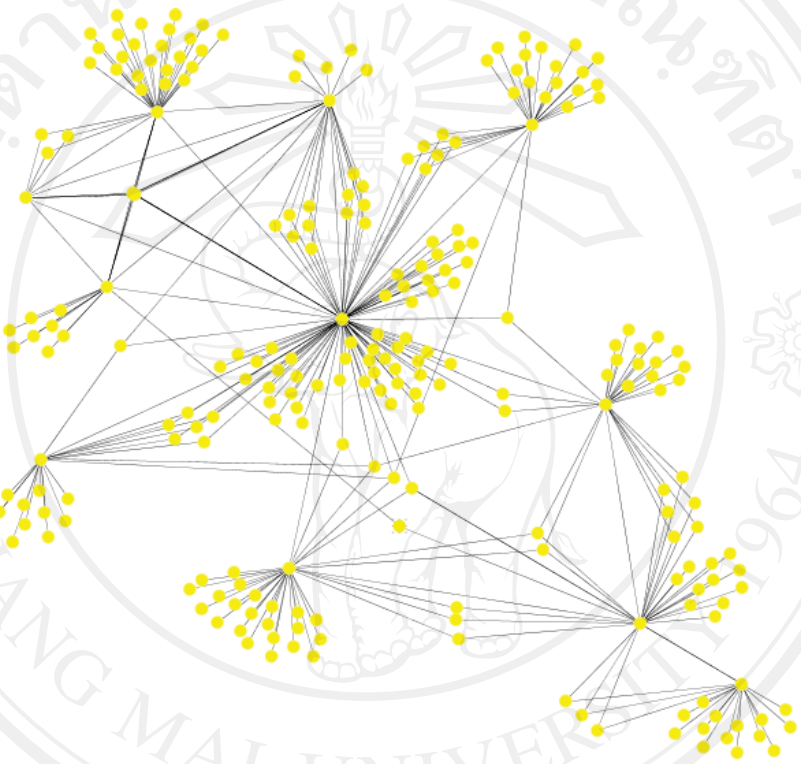

Figure 4.11 Example of social network - Nanomaterial Science

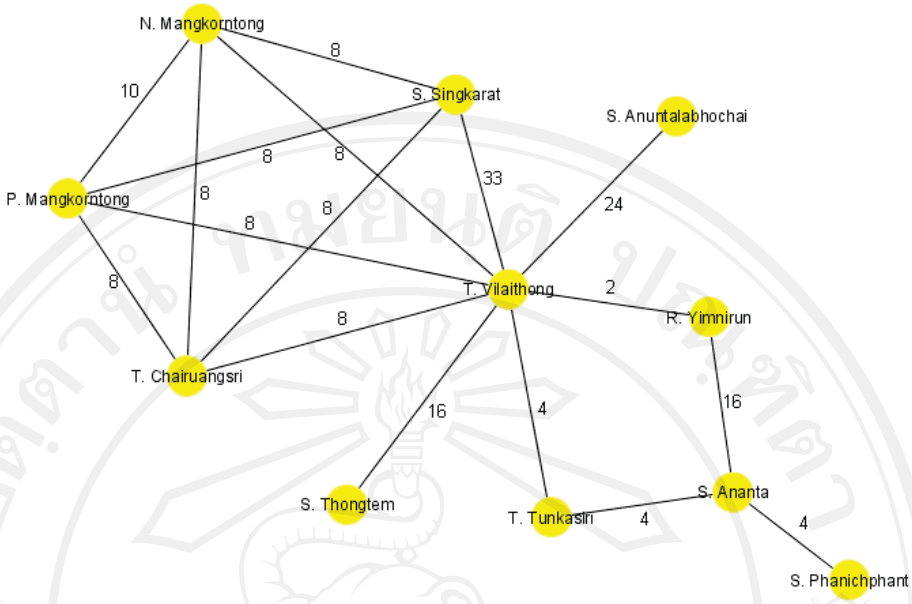

Figure 4.12 Example of social network - Nanomaterial Science

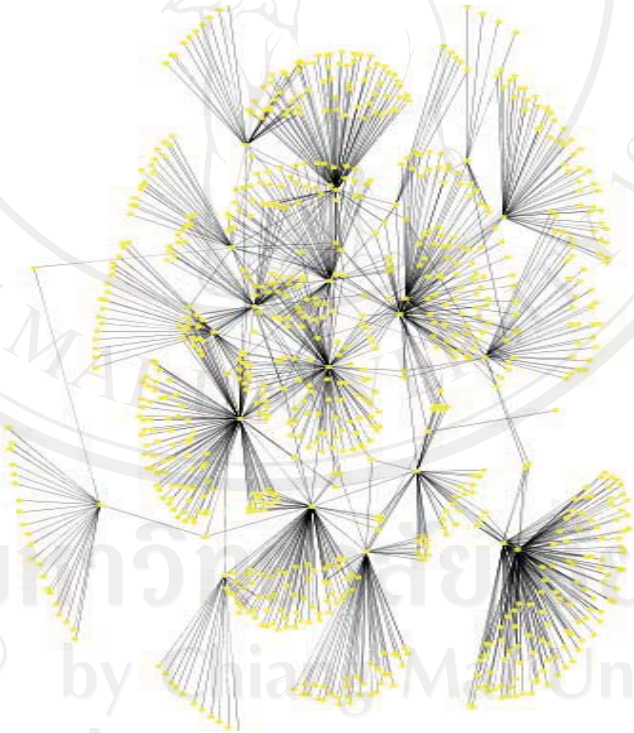

Figure 4.13 Example of social network: Immunology – Toxicology - Biochemistry

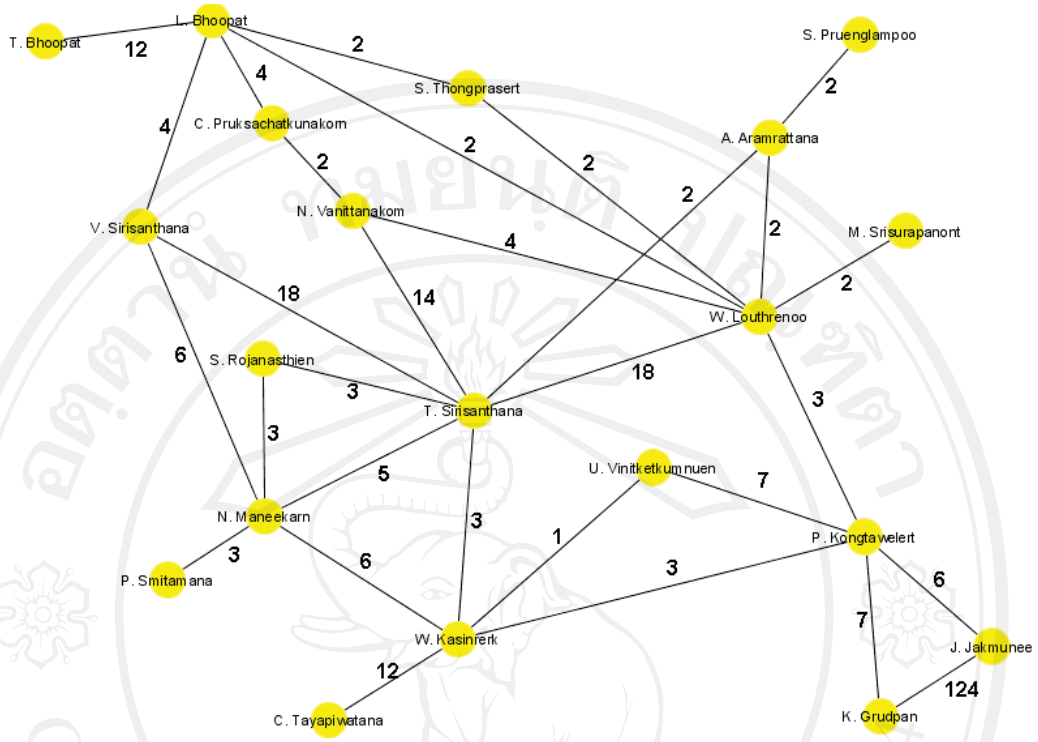

Figure 4.14 Example of social network: Immunology – Toxicology - Biochemistry

Figure 4.11 and 4.12 show social network of Nanomaterial Science and Figure 4.13 and 4.14 show social network of Immunology – Toxicology – Biochemistry. The center nodes in graphs are researchers of CMU and leave nodes are both researchers in CMU and researchers from other organizations.

The numbers on arcs are the number of papers published together. They show how strength of the connection between two researchers. If any researcher had many arcs point out, that means the researcher has strength recognition with many researchers. Addition the graphs show the opportunity of CMU to building research cluster to increase the competitiveness of CMU.

4.1.3 Establishing research clusters

From the result in 4.1.2, CMU research team enabled to identify key researchers in each cluster as shown in Table 4.10 – 4. 18

Table 4.10 Research cluster of Nanomaterial Science

Order	Faculty	Researchers' Name
1.	Agriculture	Assoc. Prof. Dr. Adisorn Krasaechai
2.	Pharmacy	Assoc. Prof. Dr. Aranya Manosroi
3.	Pharmacy	Assoc. Prof. Dr. Jiradej Manosroi
4.	Science	Assist. Prof. Dr. Rattikorn Yimnirun
5.	Science	Assoc. Prof. Dr. Supon Ananta
6.	Science	Prof. Dr. Tawee Tunkasiri
7.	Science	Assist. Prof. Dr. Torranin Chairuangsri

Table 4.11 Research cluster of Sustainable conservation and use of nature and environment.

Order	Faculty	Researchers' Name
1.	Architecture	Assist. Prof. Vitul Lieorungruang
2.	Economics	Prof. Dr. Mingsarn Kaosa-ard
3.	Education	Assoc. Prof. Dr. Anurak Panyanuwat
4.	Science	Prof. Dr. Kate Grudpan
5.	Social Sciences	Chira Prangkio
6.	Social Sciences	Assist. Prof. Dr. Pong-In Rakariyatham
7.	Social Sciences	Prof. Dr. Anan Ganjanapan
8.	Social Sciences	Prof. Dr. Manat Suwan
9.	Social Sciences	Prof. Dr. Yos Santasombat
10.	Veterinary medicine	Assoc. Prof. Dr. Suvichai Rojanasthien

Order	Faculty	Researchers' Name
11.	The Social Research Institute	Dr. Duongchan Apavatjrut Charoenmuang
12.	The Social Research Institute	Suree Boonyanupong

Table 4.12 Research cluster of Quality of Thai society

Order	Faculty	Researchers' Name
1.	Agriculture	Assoc. Prof. Dr. Aree Wiboonpongse
2.	Business administration	Assoc. Prof. Chaiyos Santiwong
3.	Business administration	Assoc. Prof. Sirikiat Ratchusanti
4.	Education	Assoc. Prof. Dr. Anurak Panyanuwat
5.	Education	Assoc. Prof. Dr. Cherdla Soontornvipart
6.	Education	Assoc. Prof. Dr. Kittiporn Punyapinyophol
7.	Education	Assoc. Prof. Dr. Phasin Tangchuang
8.	Economics	Prof. Dr. Mingsarn Kaosa-ard
9.	Economics	Assoc. Prof. Dr. Satiean Sriboonruang
10.	Economics	Dr. Songsak Sriboonchitta
11.	Humanities	Dr. Chuchai Smithikrai
12.	Medicine	Assoc. Prof. Prasit Tharavichitkul
13.	Nursing	Assoc. Prof. Wilawan Senaratana
14.	Science	Prof. Dr. Kate Grudpan
15.	The Social Research Institute	Dr. Duongchan Apavatjrut Charoenmuang
16.	The Social Research Institute	Suree Boonyanupong
17.	Social Sciences	Assist. Prof. Dr. Kobkul Rayanakorn
18.	Social Sciences	Assoc. Prof. Taipesrinivat Bhakdikul
19.	Social Sciences	Assoc. Prof. Dr. Thanet Chareanmuang
20.	Social Sciences	Assist. Prof. Dr. Pong-In Rakariyatham
21.	Social Sciences	Prof. Dr. Manat Suwan

Order	Faculty	Researchers' Name
22.	Social Sciences	Assoc. Prof. Virada Somswasdi
23.	Social Sciences	Prof. Dr. Anan Ganjanapan

Table 4.13 Research cluster of Biotechnology

Order	Faculty	Researchers' Name
1.	Agriculture	Prof. Dr. Benjavan Rerkasem
2.	Agriculture	Assoc. Prof. Dr. Somporn Choonluchanon
3.	Agro-Industry	Assoc. Prof. Dr. Pairote Wiriyacharee
4.	Associated medical sciences	Assoc. Prof. Dr. Watchara Kasinrerk
5.	Dentistry	Assoc. Prof. Dr. Suttichai Krisanaprakornkit
6.	Medicine	Assoc. Prof. Dr. Niwat Maneekarn
7.	Pharmacy	Assoc. Prof. Dr. Jiradej Manosroi
8.	Pharmacy	Assist. Prof. Dr. Phuriwat Leesawat
9.	Science	Dr. Jaroon Jakmunee
10.	Science	Prof. Dr. Kate Grudpan
11.	The Research Institute for Health Sciences	Dr. Jiraprapa Wipasa

Table 4.14 Research cluster of Local history and tourism

Order	Faculty	Researchers' Name
12.	Architecture	Assist. Prof. Vitul Lieorungruang
13.	Economics	Prof. Dr. Mingsarn Kaosa-ard
14.	Education	Assist. Prof. Dr. Phetcharee Rupavijetra
15.	Education	Assoc. Prof. Somchote Ongsakul
16.	Fine arts	Prof. Suraphon Damrikul
17.	Fine arts	Assist. Prof. Woraran Boonyasurat
18.	Humanities	Assoc. Prof. Dr. Attachak Sattayanurak

Order	Faculty	Researchers' Name
19.	Humanities	Prof. Dr. Udom Roongruangsri
20.	The Social Research Institute	Dr. Hans Penth
21.	Medicine	Assoc. Prof. Prasit Tharavichitkul
22.	Social Sciences	Prof. Dr. Anan Ganjanapan
23.	Social Sciences	Assist. Prof. Dr. Kobkul Rayanakorn
24.	Social Sciences	Prof. Dr. Manat Suwan
25.	Social Sciences	Prof. Dr. Yos Santasombat
26.	The Social Research Institute	Dr. Duongchan Apavatjrut Charoenmuang
27.	The Social Research Institute	Suree Boonyanupong

Table 4.15 Research cluster of Infections disease

Order	Faculty	Researchers' Name
1.	Associated medical sciences	Assoc. Prof. Dr. Watchara Kasinrerk
2.	Dentistry	Assoc. Prof. Dr. Suttichai Krisanaprakornkit
3.	Nursing	Assoc. Prof. Dr. Warunee Fongkaew
4.	Nursing	Assoc. Prof. Wilawan Senaratana
5.	Medicine	Assoc. Prof. Dr. Niwat Maneekarn
6.	Medicine	Assoc. Prof. Dr. Nopporn Sittisombut
7.	Medicine	Assoc. Prof. Wej Choochote
8.	The Research Institute for Health Sciences	Apinun Aramrattana
9.	The Research Institute for Health Sciences	Dr. Jiraprapa Wipasa

Table 4.16 Research cluster of Non-Infections disease.

Order	Faculty	Researchers' Name
1.	Dentistry	Assoc. Prof. Dr. Anak Iamaroon
2.	Medicine	Dr. Nipon Chattipakorn
3.	Medicine	Assoc. Prof. Dr. Usanee Vinitketkumnuen

Table 4.17 Research cluster of Environment

Order	Faculty	Researchers' Name
1.	Agriculture	Assoc. Prof. Benchaphun Ekasingh
2.	Agriculture	Prof. Dr. Benjavan Rerkasem
3.	Agriculture	Dr. Kanok Rerkasem
4.	Economics	Prof. Dr. Mingsarn Kaosa-ard
5.	Education	Assoc. Prof. Dr. Anurak Panyanuwat
6.	Medicine	Assoc. Prof. Dr. Usanee Vinitketkumnuen
7.	Medicine	Assoc. Prof. Wej Choochote
8.	Science	Dr. Jaroon Jakmunee
9.	Science	Prof. Dr. Kate Grudpan
10.	Social Sciences	Prof. Dr. Manat Suwan

Table 4.18 Research cluster of Information technology

Order	Faculty	Researchers' Name
1.	Agriculture	Assoc. Prof. Dr. Aree Wiboonpongse
2.	Agriculture	Assoc. Prof. Dr. Attachai Jintrawet
3.	Agriculture	Assoc. Prof. Benchaphun Ekasingh
4.	Architecture	Dr. Ekkachai Mahaek
5.	Architecture	Assist. Prof. Vitul Lieorungruang
6.	Economics	Dr. Songsak Sriboonchitta
7.	Humanities	Prof. Dr. Udom Roongruangsri

Order	Faculty	Researchers' Name
8.	Social Sciences	Chira Prangkio
9.	Social Sciences	Prof. Dr. Manat Suwan
10.	The Social Research Institute	Dr. Duongchan Apavatjrut Charoenmuang

Table 4.19 Research cluster of Economic plant and animal

Order	Faculty	Researchers' Name
1.	Agriculture	Assoc. Prof. Dr. Adisorn Krasaechai
2.	Agriculture	Assoc. Prof. Dr. Attachai Jintrawet
3.	Agriculture	Prof. Dr. Benjavan Rerkasem
4.	Agriculture	Dr. Kanok Rerkasem
5.	Agriculture	Assist. Prof. Dr. Pittaya Sruamsiri
6.	Agriculture	Assoc. Prof. Dr. Somporn Choonluchanon
7.	Agriculture	Assoc. Prof. Dr. Suchon Tangtaweewipat
8.	Agriculture	Assoc. Prof. Dr. Tavatchai Radanachaless
9.	Dentistry	Assoc. Prof. Dr. Suttichai Krisanaprakornkit
10.	Medicine	Assoc. Prof. Dr. Prachya Kongtawelert
11.	Medicine	Assoc. Prof. Wej Choochote
12.	Medicine	Assoc. Prof. Dr. Usanee Vinitketkumnuen
13.	Pharmacy	Assoc. Prof. Dr. Aranya Manosroi
14.	Pharmacy	Assoc. Prof. Dr. Boonsom Liawruangrath
15.	Pharmacy	Assist. Prof. Chadarat Duangrat
16.	Economics	Prof. Dr. Mingsarn Kaosa-ard
17.	Veterinary medicine	Assoc. Prof. Dr. Suvichai Rojanasthien

The result of assessment CMU clusters with TCM to find direction synergized CMU key researchers is show in Table 4.20

Table 4.20 Result of assessment CMU clusters with TCM

Order	Research Cluster	Business Group	TCM Group
1.	Nanomaterial Science	Electrical Machinery	Question Mark lean to Opportunity
		Chemical	Opportunity
		Healthcare	New Wave
2	Sustainable Conservation and Use of Nature and Environment	Travel & Tourism	Star
3	Quality of Thai society	This cluster is not business so it cannot use TCM to assess	
4	Biotechnology	Vegetable	Opportunity
		Processed Fruit & Vegetable	Falling Star
		Other Food	Opportunity lean to Question Mark
		Healthcare	New Wave
5	Local History and Tourism	Travel & Tourism	Star
6	Infections Disease	Healthcare	New Wave
7	Non- Infections Disease	Healthcare	New Wave
8	Environment	This cluster is not business so it cannot use TCM to assess	
9	Information technology	This cluster can support all business groups so it hard to use TCM to assess	
10	Economic plant and animal	Meat & Poultry	Star
		Vegetable	Opportunity
		Other Food	Opportunity lean to Question Mark
		Healthcare	New Wave

Order	Research Cluster	Business Group	TCM Group
		Processed Fruit & Vegetable	Falling Star
		Rice & Grain	Falling Star

From table 4.20, all CMU research clusters could be analyzed as follow:

1) Cluster in *Star region* was Sustainable Conservation and Use of Nature and Environment and Local History and Tourism, which could be promoted because they are the competitiveness of Thailand.

About Economic Plant and Animal cluster, it quite hard to judge because this cluster matched with six business group of TCM, which were in different regions. Thus this cluster should be considered on each business group one by one.

2) Cluster in *Opportunity region*: This cluster is required from world market but the competition of Thailand was in medium level. This is because of there were some problems in value chain. Thus Thailand should analyze these problems and improve the value chain. For example Nanomaterial Science cluster falling in the *Opportunity region* should be developed the quality and quantity of its products and search for some chance in competitiveness. This cluster should be supported more for developing to *Star region* in the future.

3) Cluster in *New Wave region*: This group has high requirement of world market but level of the competitiveness of the cluster is low. For this case creating new knowledge is important. Since new knowledge is basis of long time competitiveness. Research in this group should be encouraged. Anyway it takes time to archive this target.

4) Cluster in *Falling Star region*: Research in this group has low level of requirement in contrast Thailand had high level in competition. For this region, Thailand should find a new chance in new market continually. This kind of research should be supported constantly because it is CMU niche e.g. Rice & Grain. However for this cluster, research of its market should be done in parallel. The other way was applied it in other business group, which was still growing for example applied rice research in Health Care.

5) Cluster in *Question Mark region*: This group still ambiguous, CMU might finding new chance like *Falling Star* or stop doing it.

6) Cluster in *Trouble region*: research in this group should be stopped or considered it again in next time because market value might be change when time goes by.

7.) Some cluster is not involving business they could not use TCM to assess.

4.1.4 Formulate strategies and policies to develop research management of CMU

From establishing research clusters, there were 10 groups of research clusters. These clusters were divided into two research groups.

4.1.4.1 Research group classified by subjects of research

a.) High potential research group in specific subject.

1.) Nanomaterial Science

2.) Biotechnology

3.) Infections Disease

4.) Non-Infection Disease

5.) Information Technology

b.) Research group of niche and advantage in area, environment, and culture.

1.) Sustainable Conservation and Use of Nature and Environment.

2.) Local history and Tourism.

3.) Environment.

c.) New trend group or group corresponding to government's requirement i.e. Economic plant and animal.

4.1.4.2 Research group classified by co-publishing.

a.) Nanotechnology

b.) Immunology – Toxicology - Biochemistry

However CMU research team had been preparing the master plan for improving research affair in many points of view such as research database development, budget formation, and budget management. In addition, hot issues that research management center of CMU should process parallel with the master plan are

1.) Setting the suitable key researcher criteria.

2.) Developing researcher database

3.) Uupdating publishing information of researchers automatically

Further, CMU team plan to support research by setting targeted research corresponding with Thailand's Development Strategies, and Educational Development

Plan phase 10th in 2007-2011 of Chiang Mai University. Then they designed to support research clusters, which had characteristic as follow:

1.) The cluster already having potential and strength in specialized research areas, and well-recognized in the research circle. Researchers in this cluster can be mentor to new researchers excellently. Besides these clusters can be run to be Center of Excellence finally.
2.) The cluster having its own niche from geographic, environmental and cultural advantages because Chiang Mai University is located in the North of Thailand.
3.) The cluster dealing with new trend to answer the government policies and modern technology.
4.) The research social network is in which all co-authoring researchers had joint research. Further, keyword of researchers in this network could be synergy and transformed to be new clusters ex. Immunology - Toxicology - Biochemistry. Such kind of these clusters can be mobilized new knowledge and bid more budgets readily in the future.

Anyway this result was analyzed from only questionnaire returned to CMU research team. That is only 35% of all. There are many key researchers did not return questionnaires back. Though CMU research team tried to correct more data from other sources but it did not guarantee that all information was correct and up-to-date. Actually result of this project was the suitable methodology using in surveying expertise and research direction of CMU including demonstrated research network of CMU more clearly. If CMU could develop any system to collect researchers' information automatically and more efficiency, this methodology would enable to

apply in formulating CMU research strategies and research directions, and setting up multi-disciplines research more efficiency and effectiveness.

From research in first part, 115 CMU key researchers were identified (51 from Health Sciences, 35 from Science & Technology, and 29 from Social Sciences & Humanities). This was done by querying research database, which is storing all intellectual capital of researchers in research aspect. Further, research clusters was identified by using card sorting technique with CMU ontology commitment, which indicates expertise and research direction of CMU researcher. After that administrators used all information to formulate strategic and policies for CMU research management.

4.2 Second Part: Result from New Research Management Framework

In this part, only processes modified in new research management framework were focused. These processes are composed of four steps; develop CMU ontology commitment instead of database, identify key researchers by using predicate logic and inference step instead of query, setup research clusters using ontology, card sorting technique, and SPARQL instead of using only card sorting, analyze interesting of each research cluster by using TCM and SPAQL instead of using only TCM.

4.2.1 Develop CMU ontology commitment by discourse analysis to ontology

All collected information was represented by ontology in form of a directed graph with labels on each node and each edge. Nodes can be referred to as classes or subclasses. On the other hand, edges can be referred to as a relationship between the classes. Ontologies serve to provide a convenient representation for the semantics of some particular domain. To specify an ontology in this study, an ontology language was employed; the OWL Web Ontology Language is defined by W3C (Heflin, 2004).

Based on normalized the collected information, it was found that the relevant entities for the research ontology consist of 12 classes: *Researcher, Patent, No of Team, Budget, Year, Academic Title, Award, Award Partition, Citation, Impact Factor, Level of IF,* and *Prototype*. The ontology was designed for representing CMU research ontology commitment. The structure of CMU research ontology commitment is shown in Figure 4.15.

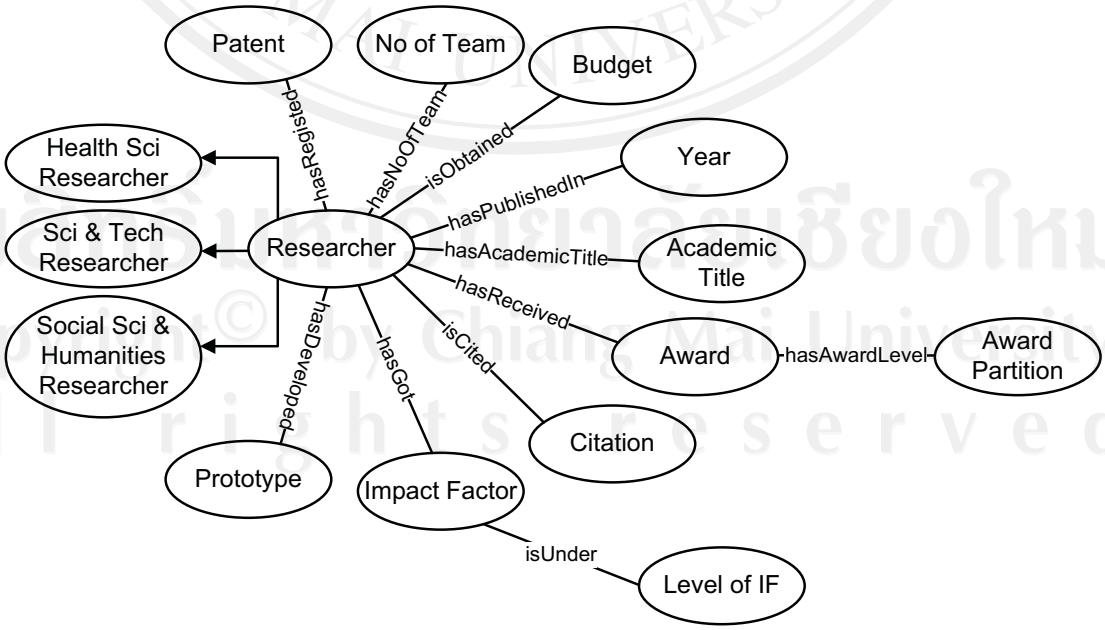

Figure 4.15 CMU Ontology Commitment

The *Researcher* class describes candidate key researchers in a university. The *Patent* class describes patent recognized by candidate key researchers. The *No of Team* class describes the maximum number of team in candidate key researchers' research projects. The *Budget* class describes the research budget received by candidate key researchers. The *Year* class describes the publication year of that paper published by the candidate key researchers. The *Academic* Title class describes academic title of each candidate key researchers. The *Award* class describes research awards received by candidate key researchers. The *Award Partition* class describes level of research award. The *Citation* class describes the citation number for each paper published by candidate key researchers. The *Impact Factor* class describes the impact factor number of journals, which were published by the candidate key researchers. The *Level of IF* class describes minimum number of impact factors accepted for identifying key researchers. This class has two subclasses *High IF* and *Low IF*. Members of *High IF* are impact factor numbers that are more than or have an equal impact factor number defined in the criteria. Members of *Low IF* are impact factor numbers that are less than impact factor number defined in the criteria. The *Prototype* class describes name of prototypes developed by candidate key researchers.

The Researcher class has nine relationships to the others nine classes i.e. *Patent, No of Team, Budget, Year, Academic Title, Award, Citation, Impact Factor, Prototype*. The names of relationships are *hasRegisted, hasNoOfTeam, isObtained, hasPublishedIn, hasAcademicTitle, hasReceived, isCited, hasGot,* and *hasDevloped* respectively. The *Award* class also has a relationship to the *Award Partition* class named *hasAwardLevel*. The *Impact Factor* class has a relationship to *Level of IF* named *isUnder*.

In addition, the *Researcher* class has three subclasses. Researcher class has Health Science Researcher, Science & Technology Researcher, and Social Sciences & Humanities Researcher as subclasses. These subclasses were used for identifying key researchers in each subclass with different criteria.

4.2.2 Identify key researchers

In the first part, the CMU research team found many problems in identifying key researcher phase. First of all, when the CMU research project team defined the number of impact factor for evaluating key researchers more than or equal 3, some head of departments said that number was impossible or too high for their departments such as department of Mathematics. However, they still want to know who the key researchers in their department are. Since these key researchers were the one who can help young researchers to improve their research skill. Second, Social Sciences & Humanities researchers claimed that many researchers in their disciplines published papers in many journals without any impact factor but they are still recognized by others. So impact factor is not good criteria in their disciplines. Finally, mathematics researchers and engineering researchers said they cannot use the same criteria as Science & Technology candidate key researchers use. That's because in their subjects, the average impact factor is around 0.6 for mathematics journals and 0.8 for engineering journals, whereas the average impact factor in biochemistry is around 3.2

From the information above, key researcher criteria are dynamic depend on three different situations as follow:

1. Difference in management level, i.e. university, faculties, and departments

2. Difference in disciplines, i.e. Health Sciences, Science & Technology, and Social Sciences & Humanities

3. Difference in subjects e.g. biochemistry, mathematic, and engineering

This means criteria of Impact Factor should be defined more than one set for serving all levels of administration.

For this problem to be solved, sets of criteria was entered in *Protégé*. Those set of criteria is in terms of *predicate logic* or called as *restriction* in Protégé. Predicate logic is one type of logic used for representing types of assertions using in Expert System (Nikolopoulos, 1997).

Subsequently, an *inference step* or *a reasoning process*, a common technique in expert system used for solving the problem (Giarratano, & Riley, 1993), was run by using predicate logics CMU ontology commitment. The result of the inference is new knowledge. In this study the new knowledge was the list of key researchers. The number of sets of key researchers' list was depended on the number of predicate logics entered. Each list could support the different requirements of each management level, discipline, and subject.

4.2.2.1 The example of identifying key researchers by ontology

In Figure 4.16 shows the diagram of inference step by using the second criterion stated that *key researchers have to create a recognized innovation or patent*. The input of the process was CMU ontology commitment. Classes used in this process were two classes i.e. *Researcher* class and *Patent* class. The *Researcher* Class has three subclasses; *Health Science Researcher, Science & Technology Researcher, and*

Social Sciences & Humanities Researcher. These three subclasses the candidate key researchers name to be members. The *Researcher* class has a relationship with *a Patent* class named *hasRegistered*. The *Patent* class has all the patents' name registered by candidate key researchers to be instances or members.

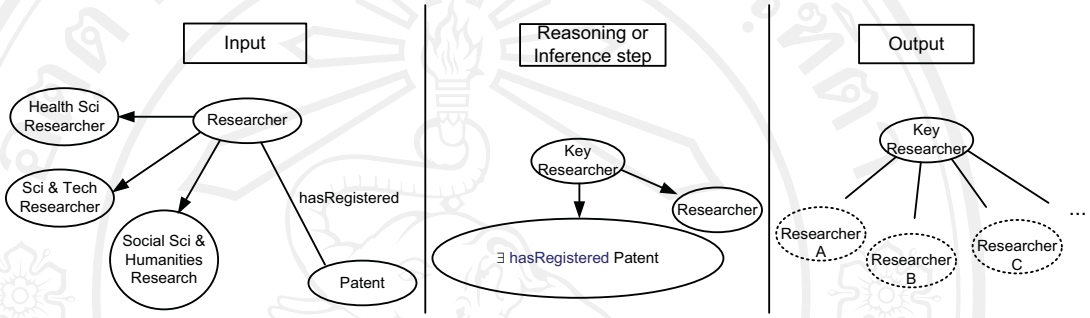

Figure 4.16 Diagram of inference step for identifying key researchers by using patent information.

From the criteria above new class was created named *Key Research* class. This class was specified the restriction with predicate logic. Predicate logic was written for generating the list of candidate key researchers who registered one or more patents. Those candidate key researchers were recognized as key researchers. The written predicate logic was

$\exists$ *hasRegistered Patent*

When wrote this predicated logic in the restrict panel of Protégé, it changed to

hasRegistered some Patent

On implementation in Protégé, there are two classes – *Patent* class and *Researcher* class were created. In *Researcher* class, there are three subclasses – *Health_Sci_Researcher*, *Sci_Researcher*, and *Social_Sci_Researcher* as shown in Figure 4.17

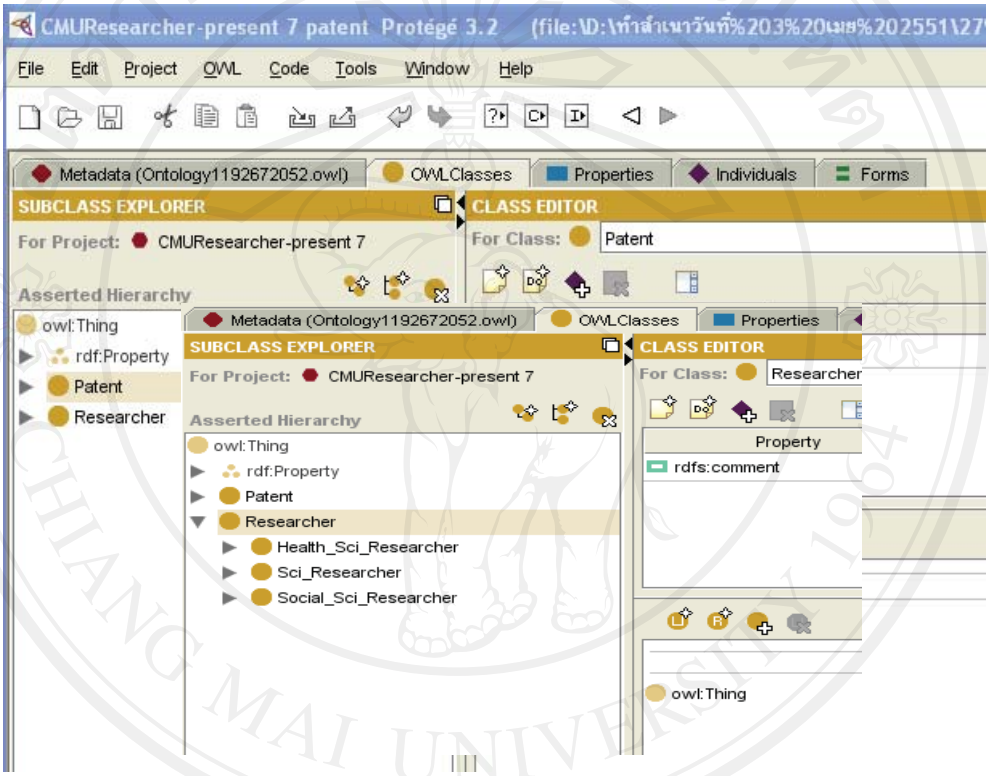

Figure 4.17 Class and subclass of Researcher Class in Protégé

After that relationship between *Patent* class and *Researcher* class was built. Relationship from *Researcher* class to *Patent* class was *hasRegistered* setting domain and range as shown in Figure 4.18 and relationship from *Patent* class to *Researcher* class was *isRegistered*. Both relationships inverted to each other by set in *inverse box*.

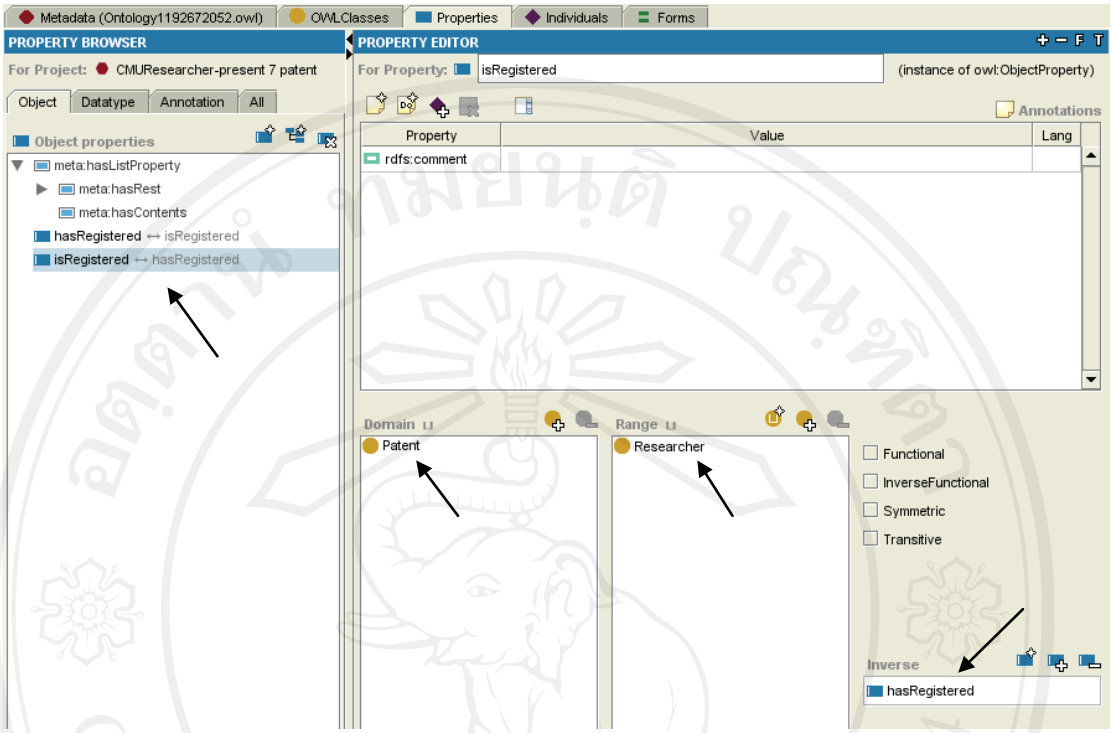

Figure 4.18 Relationship between Patent class and Researcher class

In this example, Assoc. Prof. Watchara Kasinrerk is one researcher in Health Science Discipline. He registered one patent named *Three color reagent for measuring of CD4 positive lymphocytes by flow cytometry*. From this condition, when implement in Protégé , *Watchara Kasinrerk* was input as subclass of Health_Sci_Researcher Class so his restriction input in *Asserted Conditions* panel was

Health_Sci_Researcher

hasRegisted some Three_color_reagent_for_measurement_of_CD4_positive_lymphocytes_by_flow_cytometry

The result on implementing is shown in Figure 4.19

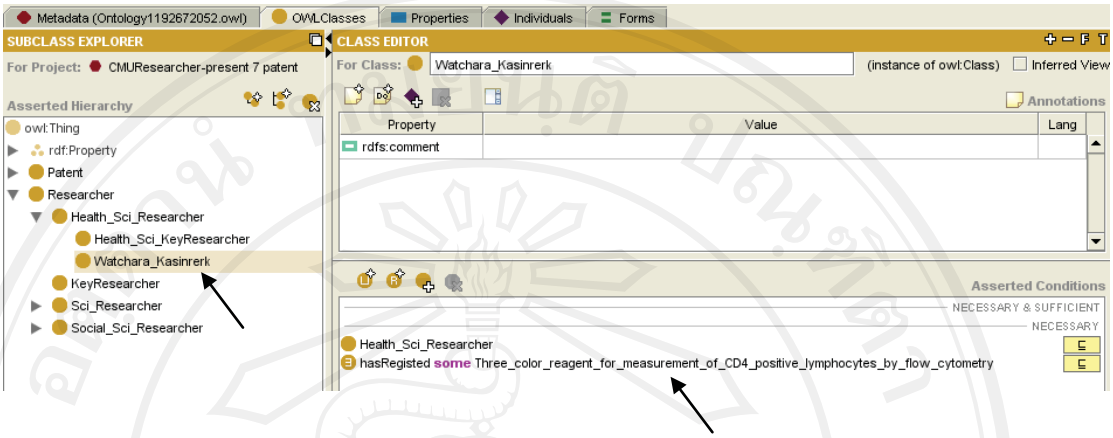

Figure 4.19 The example of patent condition in Protégé

For identifying key researcher who registered patent one or more, the *Key_researcher* class was created. Its condition designed above was input into Asserted Condition by click on created restriction as shown in Figure 4.20

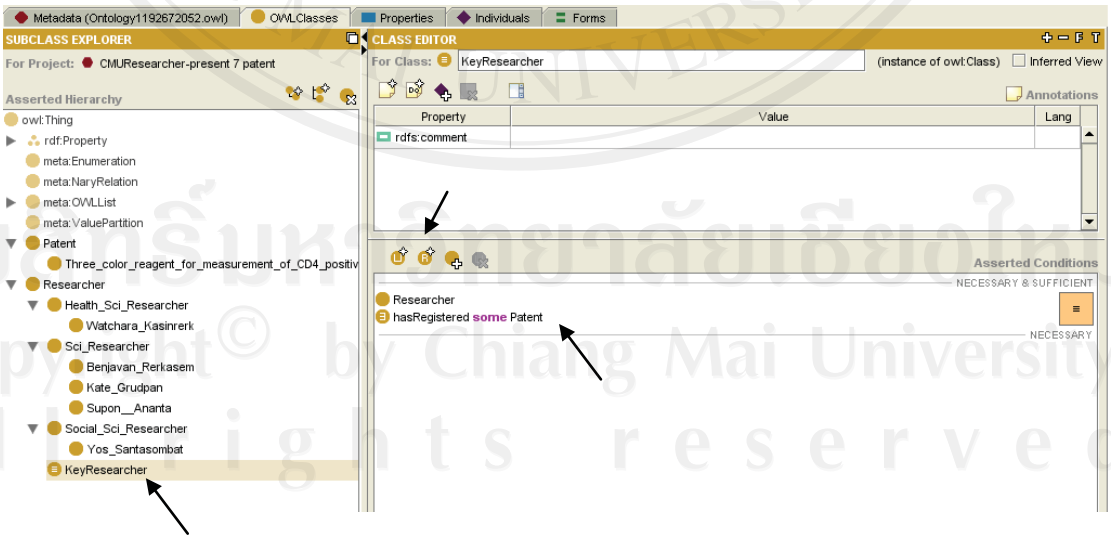

Figure 4.20 Condition of patent in Protégé

After that move all condition up to *Necessary & Sufficient* part as shown in Figure 4.21

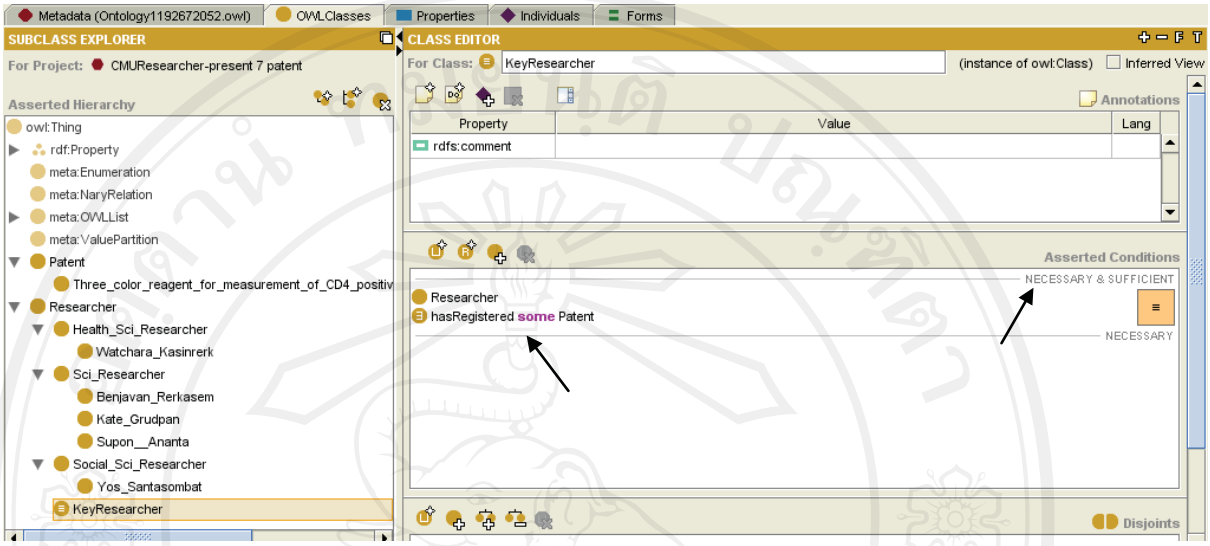

Figure 4.21 Creating key researcher's condition in NESSESSARY & SUFFICIENT part

In Figure 4.21, *KeyResearcher* class did not have its own member but its member had been generated after running inference step. Such kind of class can be called *equivalence* class. In this study, *RacerPro* program was used to inference CMU research ontology commitment by pressing bottom C (Classify taxonomy) in Figure 4.22. After run this step candidate key researchers who registered one or more patents were the member of *KeyResearcher* class as show in Figure 4.22

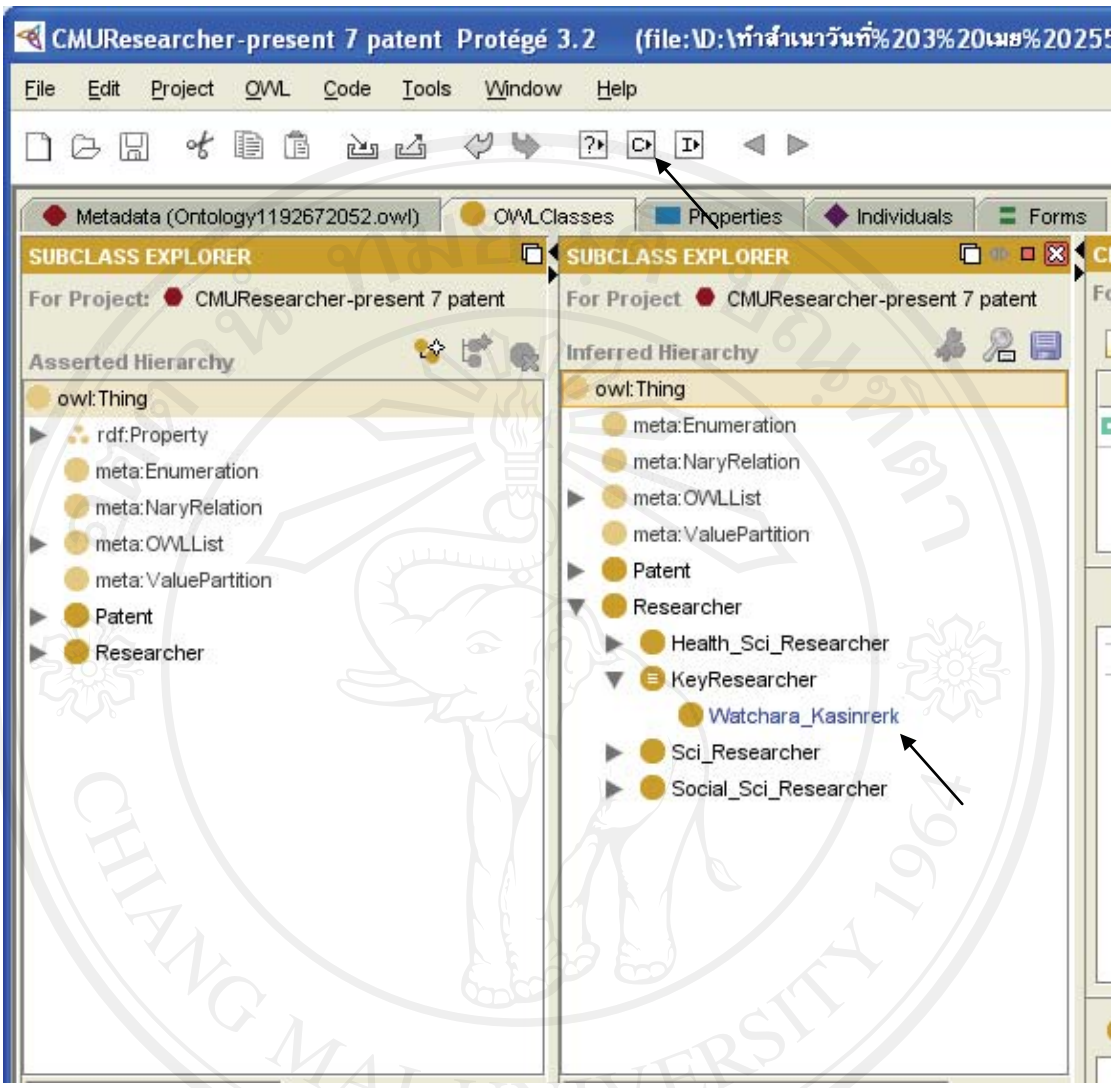

Figure 4.22 The member of *KeyResearcher* class from inference step

4.2.2.2 The example of identifying key researchers in more complicated predicate logic

The second example is more complicated. The chosen item of criteria is *Key researchers are researchers who received a recognized prize or awarded for research accomplishments*. Classes used in this process are three classes i.e. *Researcher* class, *Award* class, and *Award Level* class as shown in Figure 4.23. The Research class also

has a relationship with an *Award* class named *hasRecieved.* The *Award* class has the names of researchers' award to be members. At the same time, the *Award* class has a relationship with *the Award Level* Class. Each award will be classified in one of three levels; *High, Medium,* and *Low*, which are subclasses of *Award Level* class.

From the criteria above, predicate logic was written for generating a new equivalence class contained a list of key researchers' name who received research awards sorted in high level and medium level. The written predicate logic is

$$\exists\, hasReceived\ (Award \cap ((hasAwardLevel\ some\ High) \cup (\exists\ hasAwardLevel\ Medium)))$$

When written in the restrict box of Protégé, it will be changed to

(hasReceived some (Award and ((hasAwardLevel some High) or (hasAwardLevel some Medium))))

The output of inference step was one of the members of *Key researcher* class. These were researchers who have received research awards that are classified in high level or medium level.

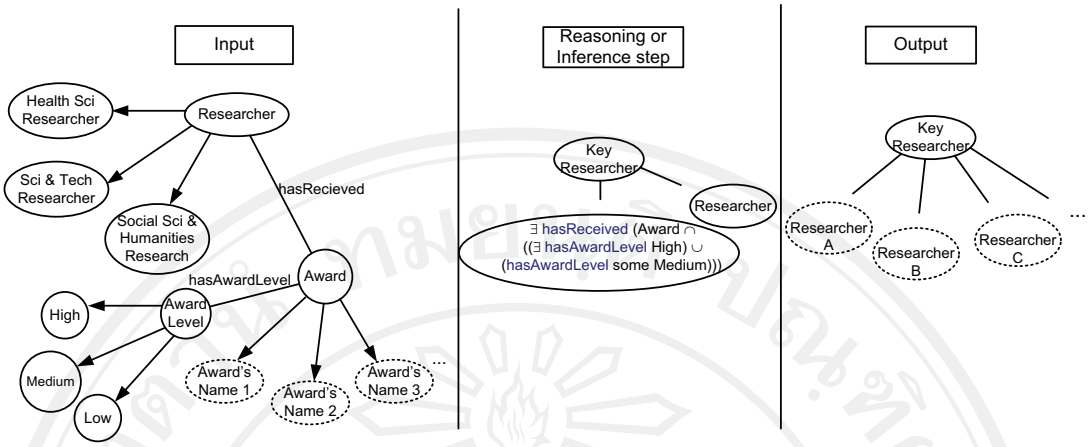

Figure 4.23 Diagram of inference step for identifying key researcher by using award information.

From the two examples of criteria, two predicate logic statements were written. In practical, criteria may be composed of more than one concurrently. Thus both predicate logics have to be combined into one statement.

It is *(∃ hasRegistered Patent) or (∃ hasReceived (Award ∩ ((hasAwardLevel some High) ∪ (∃ hasAwardLevel Medium))))*

It means the key researchers who were registered as one or more patents or had received research awards classified in high level or medium level. When written in the restrict box of Protégé, it was changed to

(hasRegisted some Patent) or (hasReceived some (Award and ((hasAwardLevel some High) or (hasAwardLevel some Medium))))

On implementation in Protégé, *Award* class was created. All research awards' names were the members of this class. The example is shown in Figure 4.24

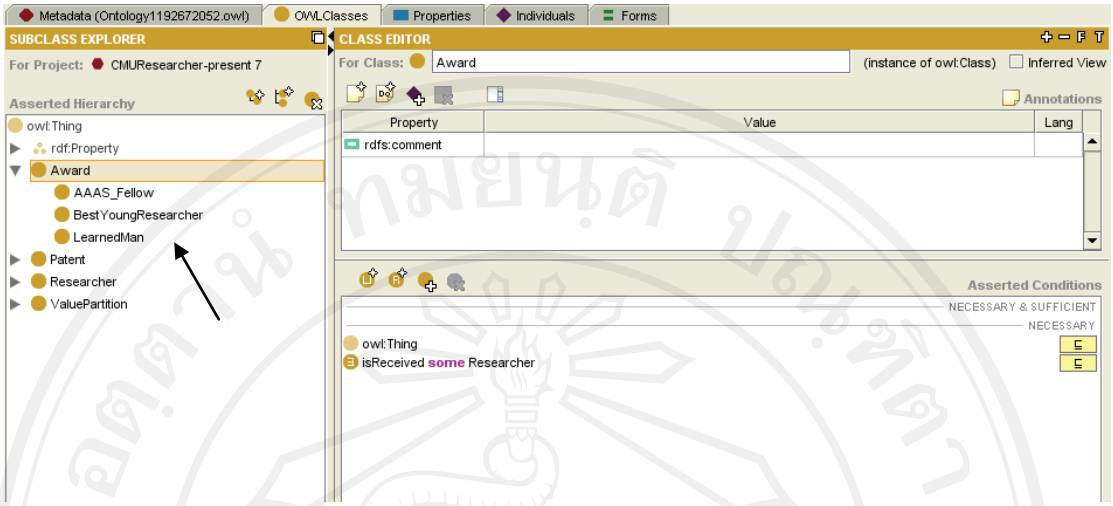

Figure 4.24 Class and subclass of researcher in Protégé

After that relationship between *Award* class and *Researcher* class was built. Relationship from *Researcher* class to *Award* class was *hasReceived* setting domain and range identified as shown in Figure 4.25 and relationship from *Award* class to *Researcher* class was *isReceived*. Both relationships inverted to each other by set in *inverse box*.

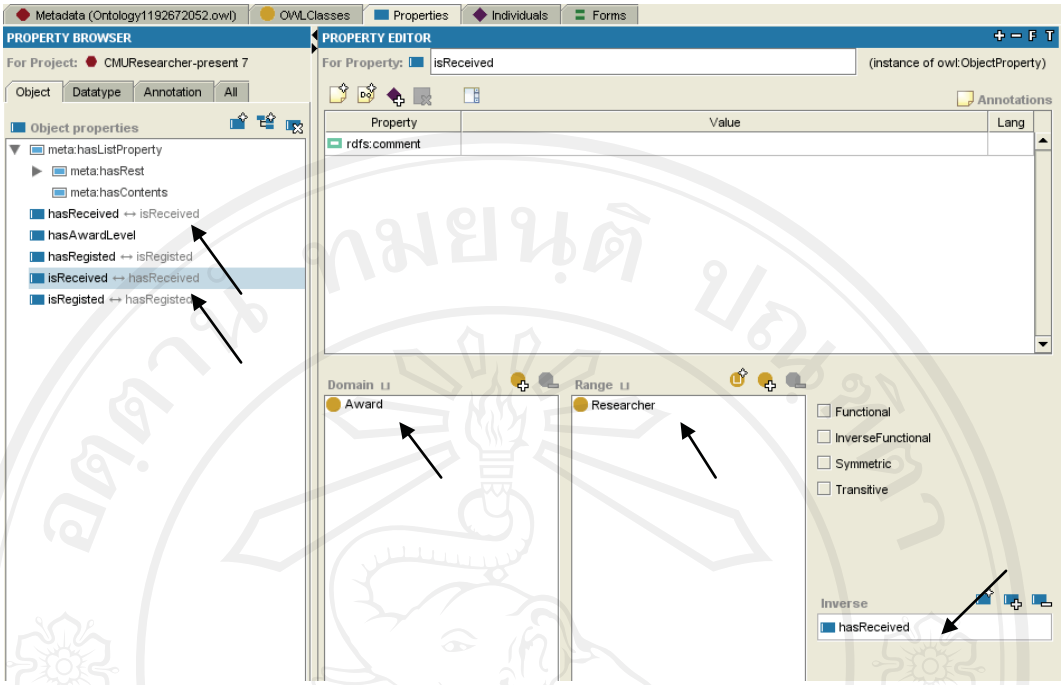

Figure 4.25 Relationship between Award class and Researcher class

In this example, the condition was more complicate so other class was added. It was *AwardPartition* class. This class was used to classify the level of award (High, Medium, and Low). The output is shown in Figure 4.26

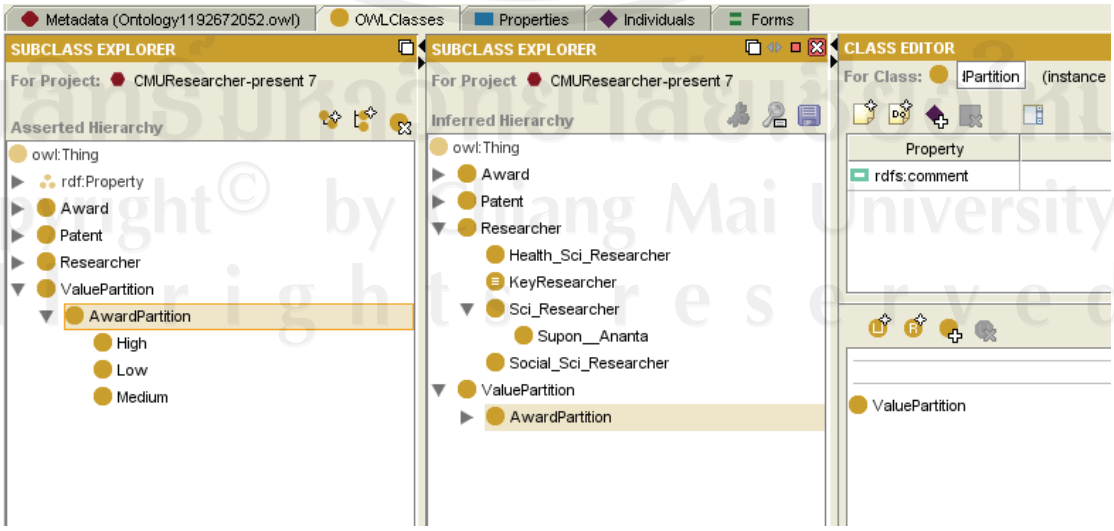

Figure 4.26 AwardPartition Class using for classifying level of award

Each award had to set its own level. For example AAAS Fellow was set in *High* level, Leaned man was set in *Medium* level, and the best of young researcher was set in *Low* level. The output of this idea is shown in Figure 4.27

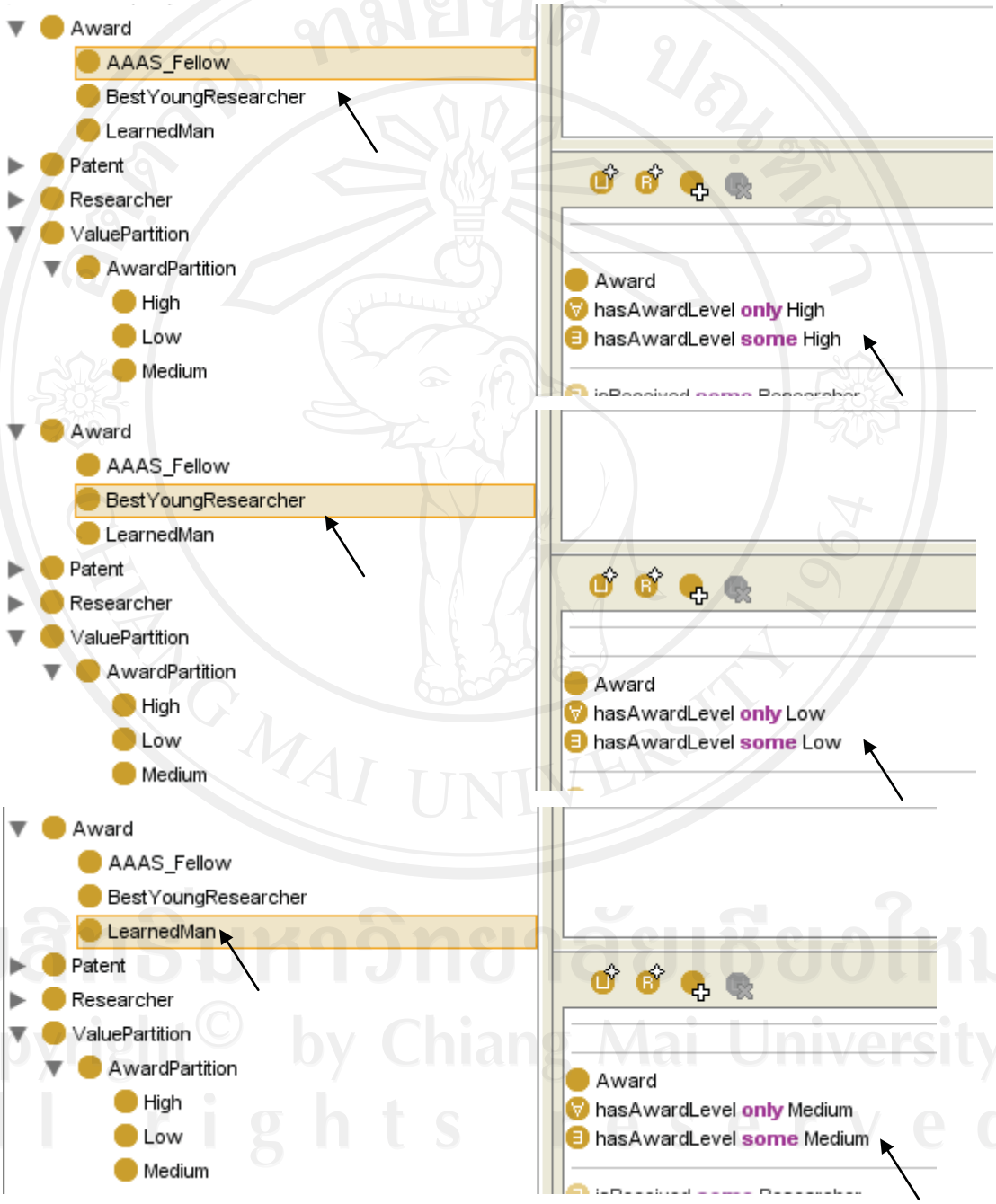

Figure 4.27 Award level of each award

Prof. Dr. Benjavan Rerkasem is one researcher in Science & Technology Discipline and she received two awards – AAAS fellow award and Learned Man award which were in high and medium level respectively. From this condition, when implement in Protégé , *Benjavan_Rerkasem* was input as subclass of *Sci_Researcher* so her restriction was input in *Asserted Conditions* panel as

Sci_Researcher

hasReceived some AAAS_Fellow

hasReceived some LearnedMan

The result on implementing is shown in Figure 4.28.

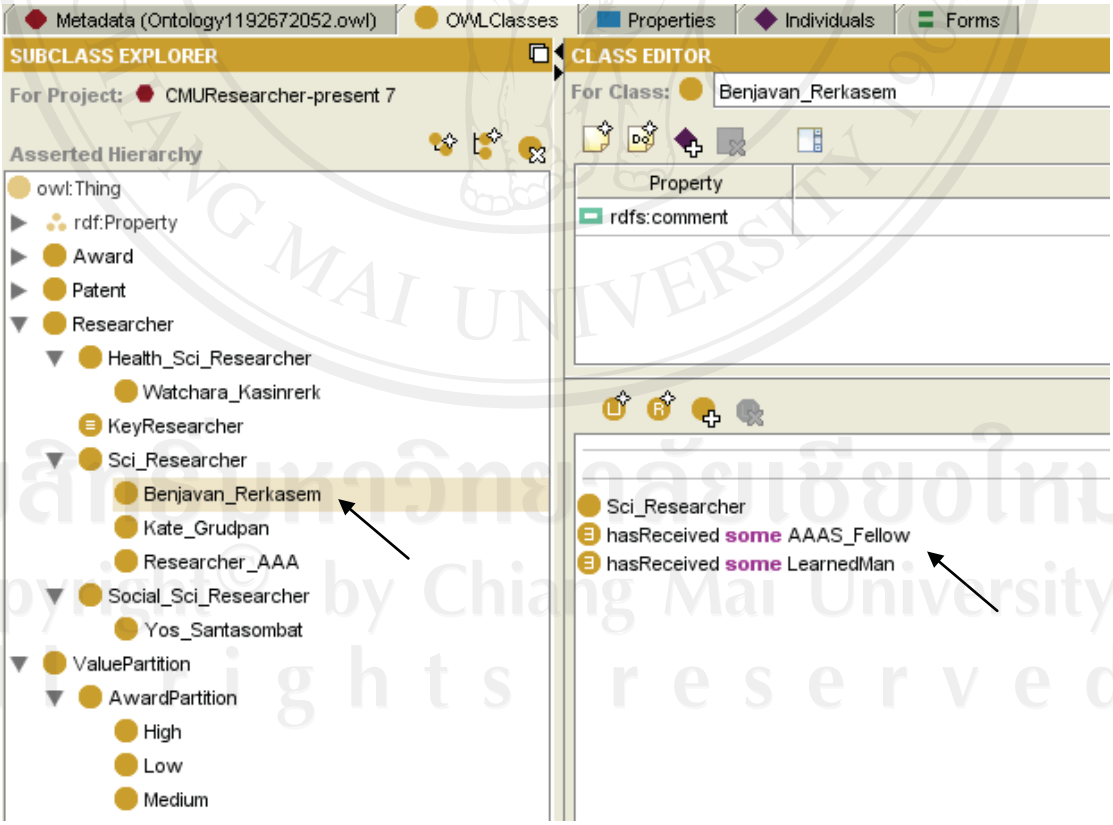

Figure 4.28 The example of award condition in Protégé

Suppose that Resarcher_AAA (anonymous) is one researcher in Science & Technology Discipline who was received one award, the best one researcher. That award was set in Low level award. Thus *Resarcher_AAA* subclass was input in *Sci_Researcher* class and the restriction was

Sci_Research

hasReceived some BestYoungResearcher

The result on implementing is shown in Figure 4.29

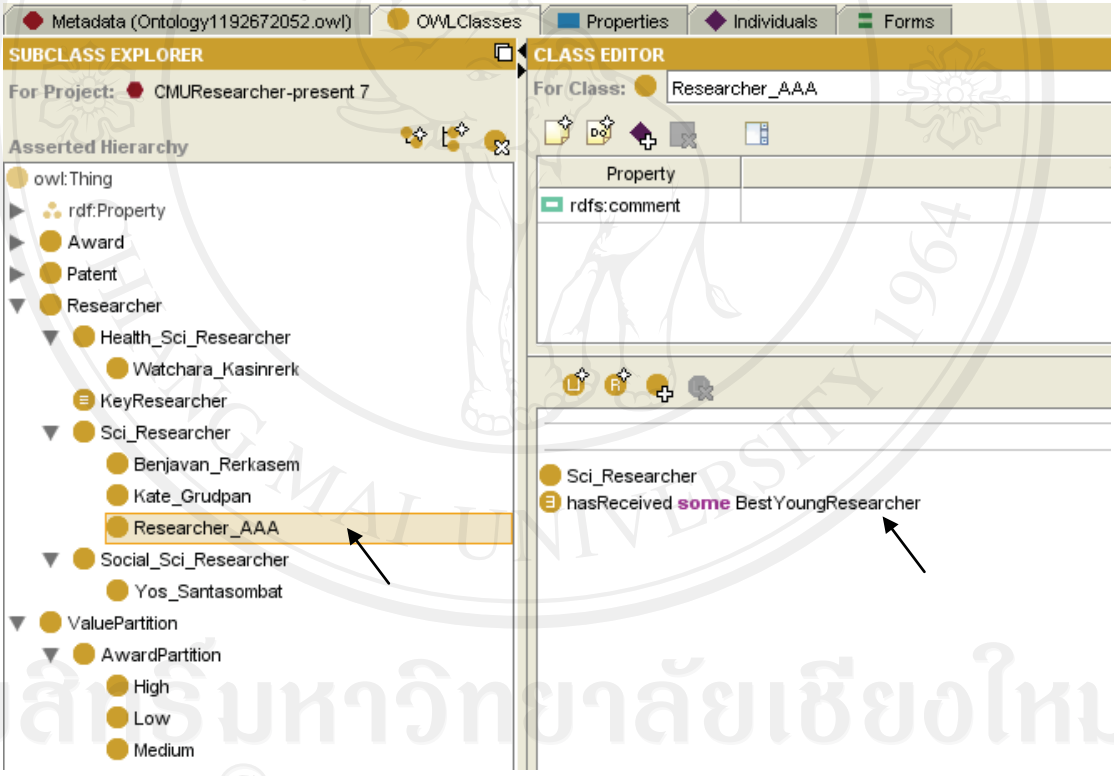

Figure 4.29 The example of award condition in Protégé

When combined award condition to patent condition, *Asserted Condition* of the *Key_researcher* class was changed as shown in Figure 4.30

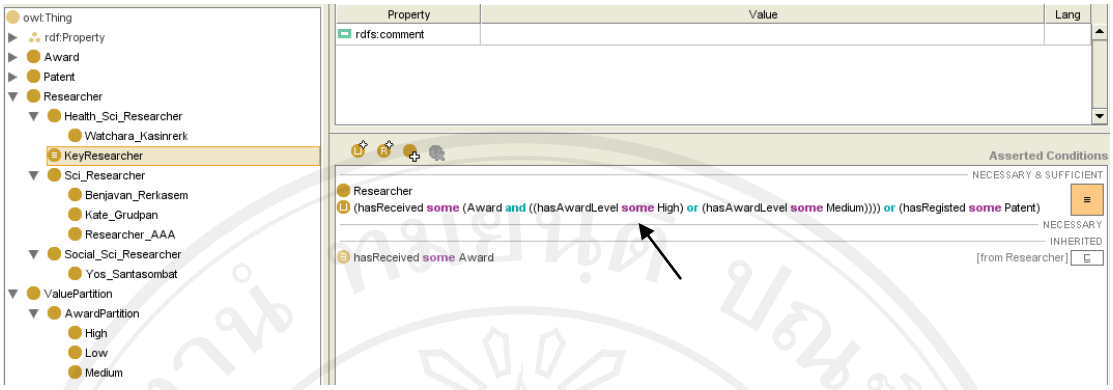

Figure 4.30 Condition of patent and award in Protégé

After run inference step, candidate key researchers who registered one or more patents were the member of *KeyResearcher* class as show in Figure 4.31

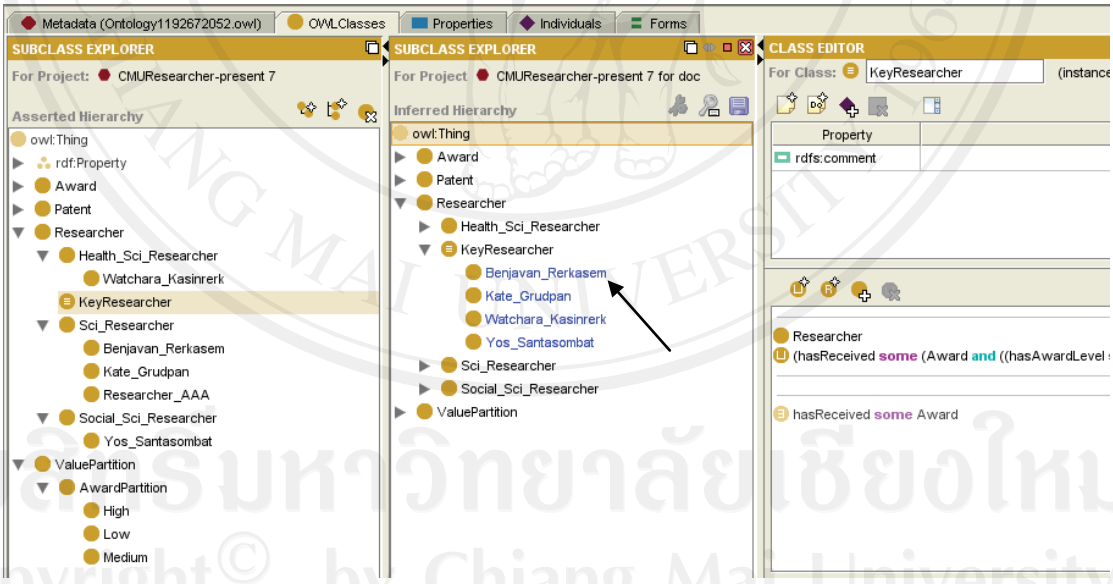

Figure 4.31 The member of Key researcher from inference step using award and patent condition

Notice that in Figure 4.31 Prof. Dr. Benjavan Rerkasem was classified to *KeyResearcher* class but Researcher_AAA did not.

4.2.2.3 The example of identifying key researchers by using mathematical condition.

In some mathematical case, the ontology cannot be served. For example, the item of criteria is *Key researchers are researchers who have published a substantial number of papers (ten or more), in a certain period of time (five years)*. From the experiment, the suitable predicate logic for checking both, 10 or more papers in last five years could not be found. The way used in this study was entering only papers published in the last five years in CMU ontology and then employed the inference step as shown in Figure 4.32. Thus the *Year* class contained years of publications, which researchers published their papers. The written predicate logic is

hasPublishedIn Year >= 10

When wrote in the restrict box of Protégé, it was changed to

hasPublishedIn min 10

After inference, the obtained output was the members of *Key researcher* class. These are name of researchers who have published at least ten papers in last five years.

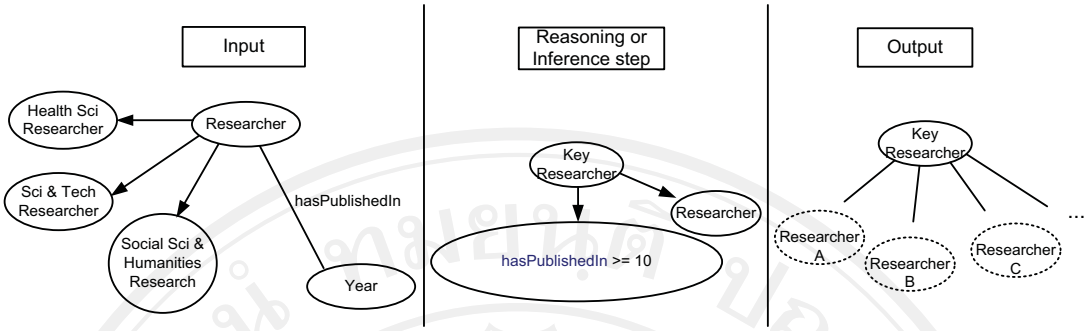

Figure 4.32 Diagram of inference step for identifying key researcher by using publication information.

On implementation in Protégé, *Year* class was created. All publication years of researcher's papers were added to be the members of this class. Then each year was input to be members of *Year* class one by one such as *Year_2001, Year_2002.* However researchers might publish papers more than one paper per year so running number was add to be suffix of those members. For example, if in 2003 researcher published 3 papers, then Year_2003_1, Year_2003_2, and Year_2003_3 were added to *Year* class. Thus members of *Year* class were defined as shown in Figure 4.33

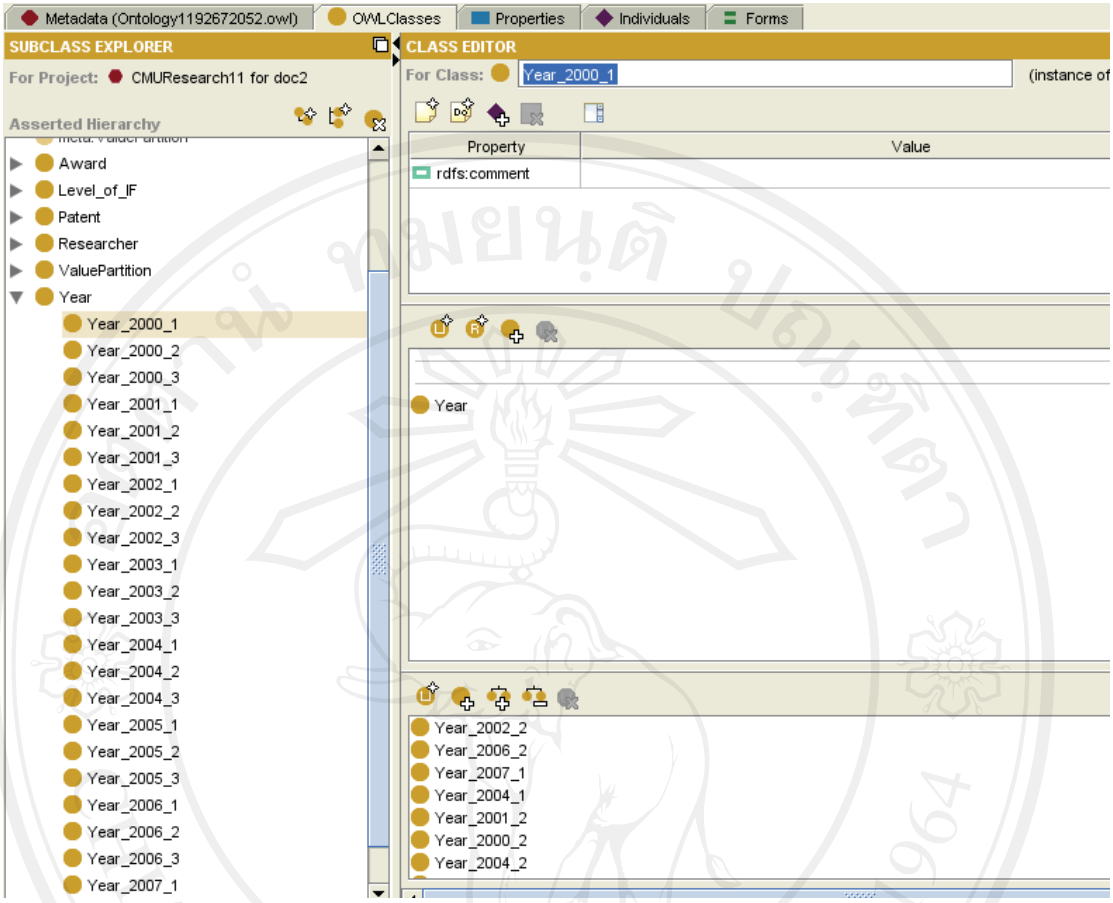

Figure 4.33 The member of Year class

Each researcher had to set publishing year of his/her papers. For example Researcher_B in Science & Technology discipline published one paper in 2000 (out of concerned range so did not input to Protégé), two papers in 2001, two papers in 2002, two papers in 2003, two papers in 2004, and two papers in 2005. Predicate logic of this were

hasPublishedIn some Year_2001_1

hasPublishedIn some Year_2001_2

hasPublishedIn some Year_2002_1

hasPublishedIn some Year_2002_2

hasPublishedIn some Year_2003_1

hasPublishedIn some Year_2003_2

hasPublishedIn some Year_2004_1

hasPublishedIn some Year_2004_2

hasPublishedIn some Year_2005_1

hasPublishedIn some Year_2005_2

The output in Protégé is shown in Figure 4.34

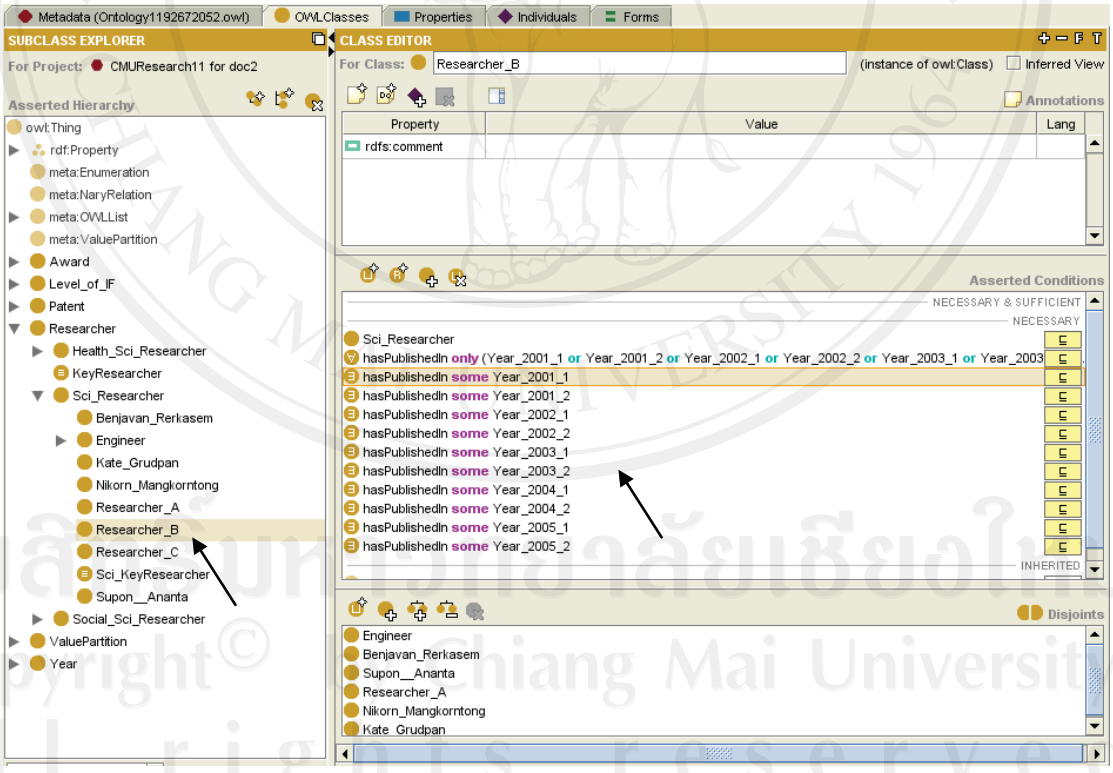

Figure 4.34 The example of published years of researcher in Protégé

When combine condition of publication to award and patent condition, *Asserted Condition* of the *KeyResearcher* class was changed as shown in Figure 4.35

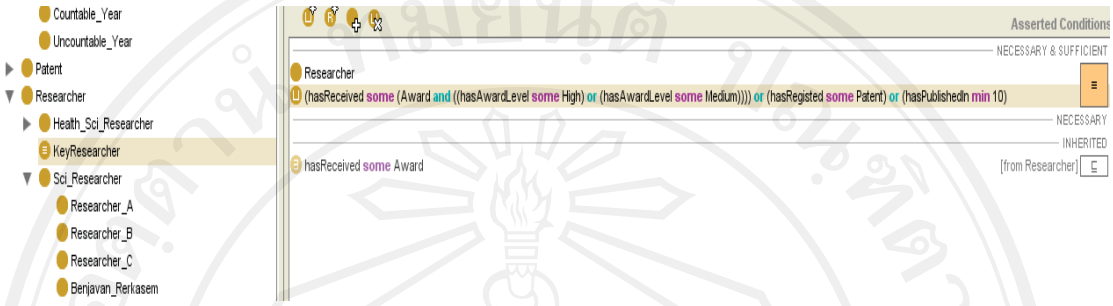

Figure 4.35 Key researcher condition with patent, award, and publication in Protégé.

After run inference step, candidate key researchers who are qualified with all three conditions are show in Figure 4.36

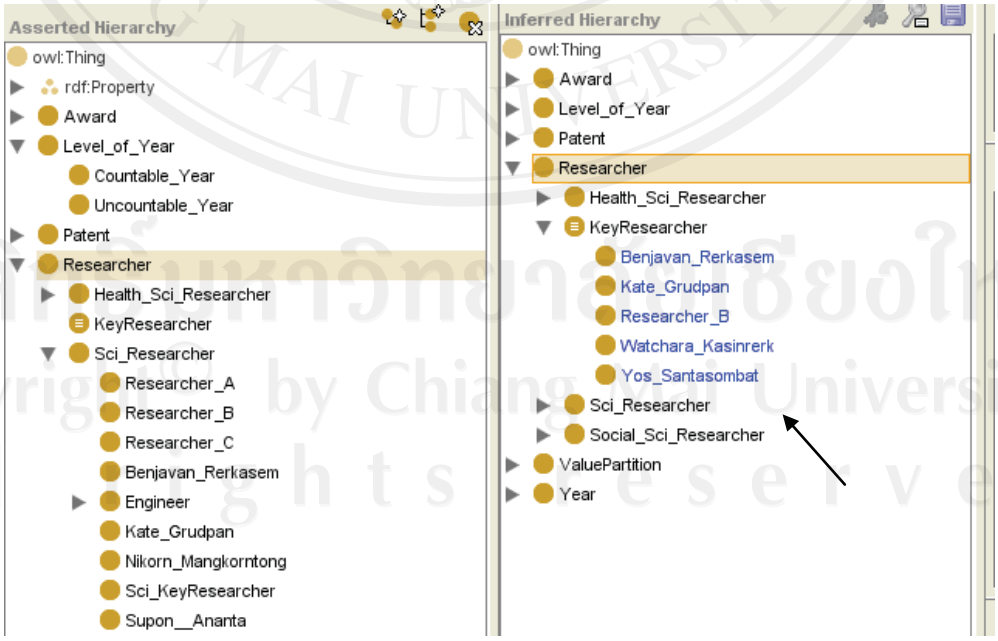

Figure 4.36 The member of Key researcher from inference step using award, patent, and publication condition.

Notice that in Figure 4.36, Researcher_B was classified to *Key researcher* class because he/she published ten or more papers per five years.

4.2.2.4 The example of identifying key researcher in dynamic of criteria.

The example of dynamic criteria is the fourth criterion. It claimed *key researchers have had their papers published in international journals with high impact factor (3 or more by Web of Science)*. From brain storming with candidate key researchers found that the specific minimum number of impact factor here was not suitable for all disciplines. This means that every discipline should have its own specific numbers of impact factor. In this topic this problem would be solved.

At first inference step was developed as shown in Figure 4.37. In the figure new class was added, *Impact Factor* class, and *Researcher* class had a relationship with *Impact Factor* class named *hasGot*. Meanwhile, *Impact Factor* class had a relationship with *Level of IF* class called *isUnder*. Every member of Impact Factor had to be classified into two levels, high impact factor level and low impact factor level. Thus *High IF* and *Low IF* were added to be subclasses of *Level of IF*. The *High IF* class contained impact factor numbers that were more than and equal to 3 as members in regards to the mentioned criteria. In the meantime, *Low IF* class contained impact factor numbers that were less than 3 as members.

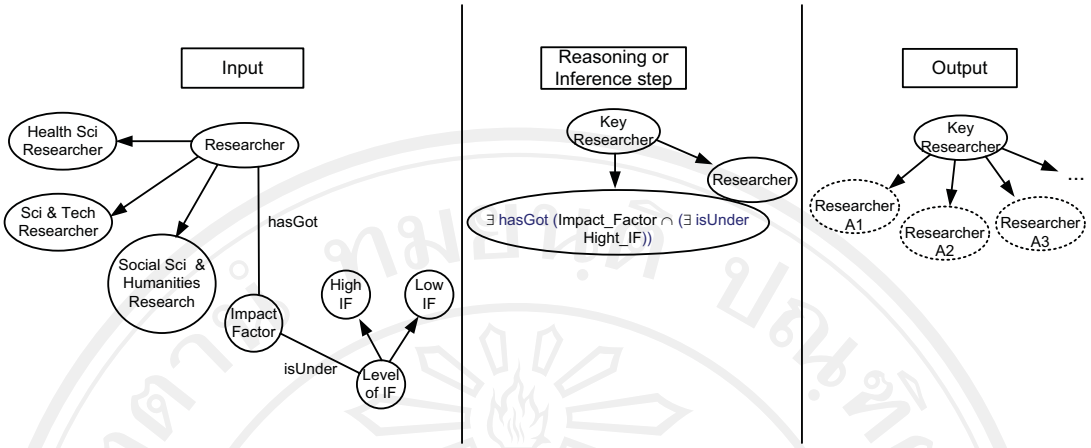

Figure 4.37 Diagram of inference step for identifying key researcher by using impact factor criterion.

The written predicate logic for identifying key researchers was

$$\exists\, hasGot\ (Impact\_Factor \cap (\exists\, isUnder\ Hight\_IF))$$

When written in the restrict box of Protégé, it will be changed to

hasGot some (Impact_Factor and (isUnder some High_IF))

With this predicate logic, inference step generated only key researchers for the universities administrators' point of view not for faculty administrators' requirement.

For the sake of identifying key researcher for three disciplines more precise to faculties' need, each discipline should have its own maximum number of impact factor. Consequently, Level of IF had to have more three subclasses i.e. *Level of IF HS, Level of IF ST*, and *Level of IF SS. Level of IF HS* subclass contained high level of impact factor of Health Sciences discipline. *Level of IF ST* subclass contained high

level of impact factor of Science & Technology discipline. *Level of IF SS* subclass contained high level of impact factor in requirement of Social Sciences & Humanities discipline. Those three of them had two subclasses. One was used for containing number of impact factors qualified for each discipline. The other was used for containing number of impact factor not qualified for each discipline. The output is shown in Figure 4.38

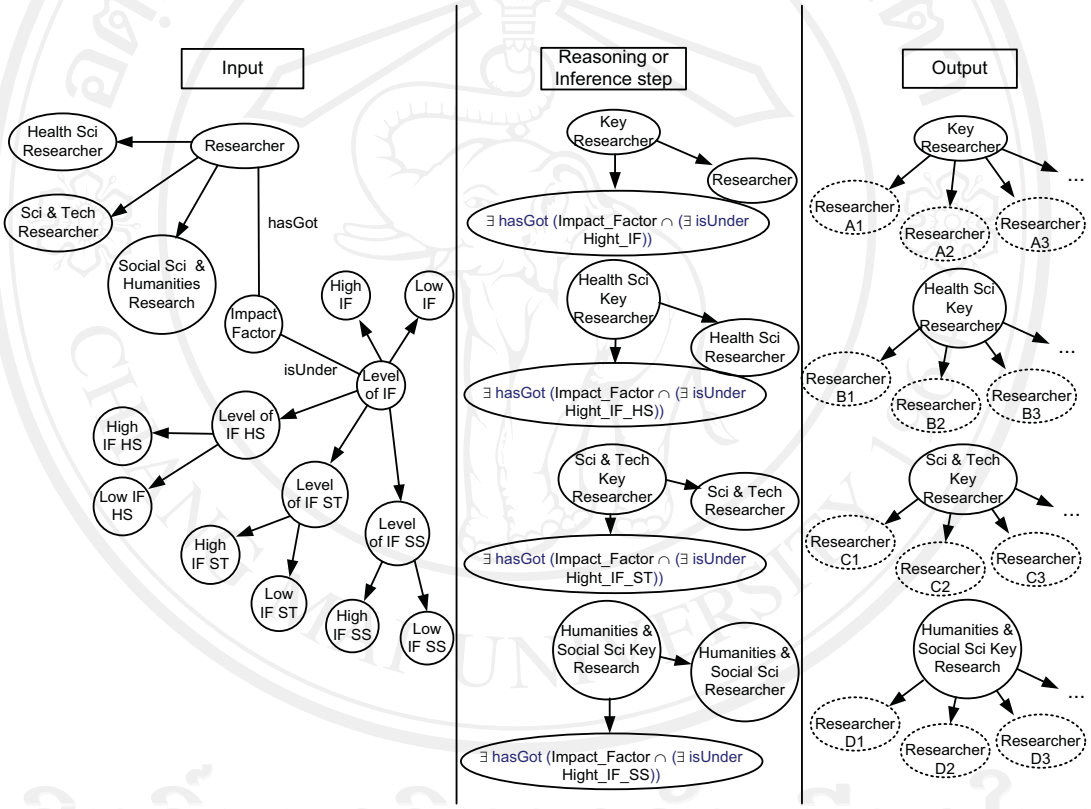

Figure 4.38 Diagram of inference step for identifying key researcher by using dynamic impact factor criterion.

Finally, Predicate Logic of three disciplines can be written in the same way as follow:

1. Health Science Key Researcher

$\exists$ *hasGot (Impact_Factor* $\cap$ *(*$\exists$ *isUnder Hight_IF_HS))*

2. Science Key Researcher

$\exists$ *hasGot (Impact_Factor* $\cap$ *(*$\exists$ *isUnder Hight_IF_ST))*

3. Social Science Key Researcher

$\exists$ *hasGot (Impact_Factor* $\cap$ *(*$\exists$ *isUnder Hight_IF_SS))*

The output of this inference step was the four lists of key researchers in four points of view three disciplines and the university. Similarly, in case of one faculty had the different requirement in maximum number of Impact Factor, inference step can be changed in the same way. For example, if administrator from the Faculty of Engineering desired to set an Impact Factor for his/her faculty different from Impact Factor of university. Since Impact Factor in this subject is very low. Its average is around 0.85. Thus CMU ontology commitment could be added *Level of IF Eng* class to be one subclass of *Level of IF ST* subclass. After that, *High IF Eng* and *Low IF Eng* subclass would be added to *Level of IF Eng* as well. Predicate Logic used for this was written as

$\exists$ *hasGot (Impact_Factor* $\cap$ *(*$\exists$ *isUnder Hight_IF_Eng))*

From this analysis, the inference step was changed as shown in Figure 4.39

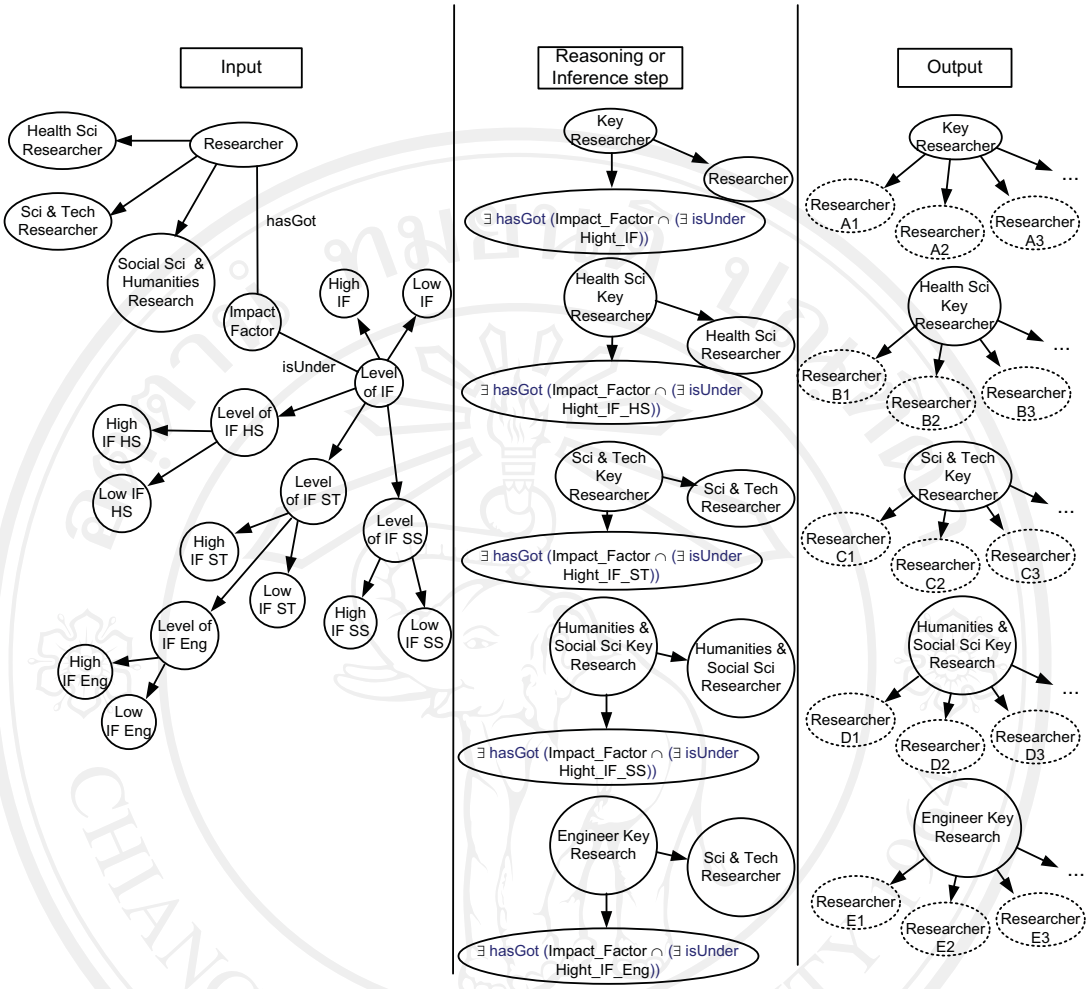

Figure 4.39 Diagram of inference step for identifying key researcher by using dynamic impact factor criterion.

On implementation in Protégé, there were two classes, *Level_of_IF* class and *Impact_Factor* class, were created. *Level_of_IF* class was composed of High_IF and Low_IF using for classifying numbers of IF which are qualified and not qualified. Further the level of IF for each discipline was built i.e. LevelOfIF_HS, LevelOfIF_S, and LevelOfIFSS. Inside all three subclasses, there were two subclasses for each of them i.e. High_IF_HS, Low_IF_HS, High_IF_S, Low_IF_S, High_IF_SS, Low_IF_SS. In the case of some subjects need their maximum number of Impact

Factor, which was different from any subject in the same discipline, such as engineering, new subclass could be built in LevelOfIF_S subclass named LevelOfIF_Eng. It had High_IF_Eng and Low_IF_Eng as subclass. The output of this is shown in Figure 4.40

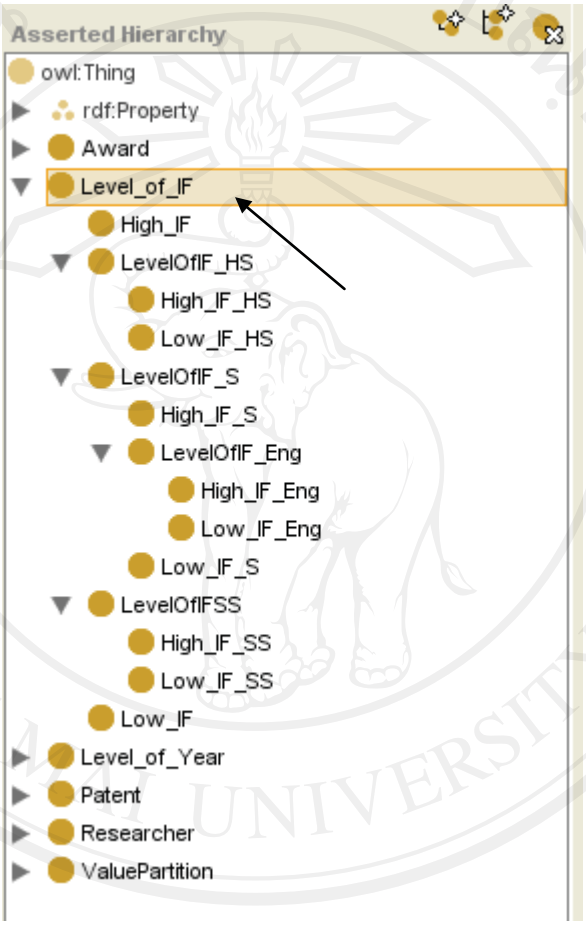

Figure 4.40 Class and subclass of Level of Impact Factor in Protégé

Other class had been built was *Impact_Factor* class. Its members were shown in Figure 4.41

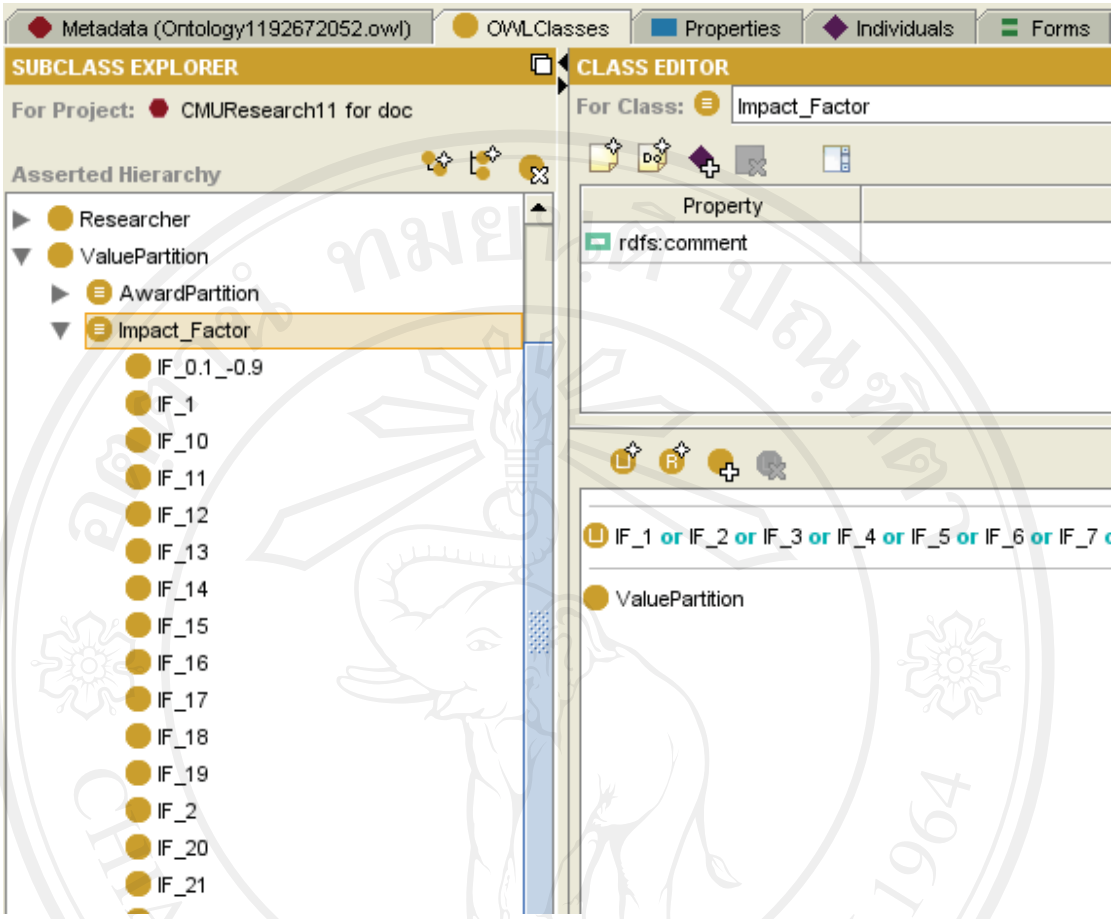

Figure 4.41 Impact_Factor class in Protégé

After that relationships between *Impact_Factor* class and *Level_of_IF* class and relationship between *Researcher* class and *Impact_Factor* class were built. Relationship from *Impact_Factor* class to *Level_of_IF* class was *isUnder* as shown in Figure 4.42. Relationship from *Researcher* class to *Impact_Factor* class was *hasGot* as shown in Figure 4.43.

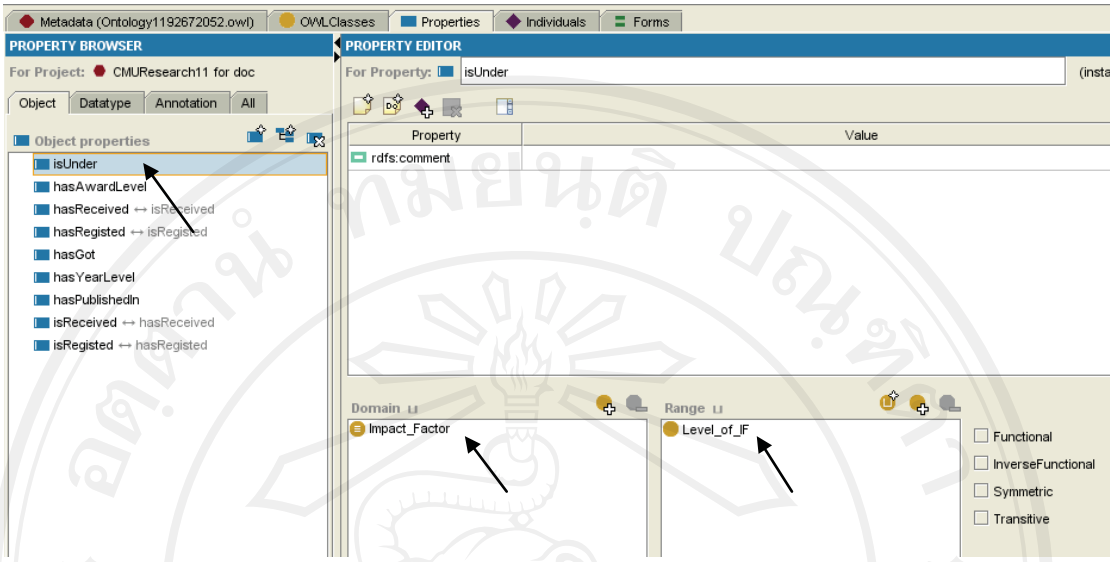

Figure 4.42 Relationship between Impact_Factor class and Level_of_IF class

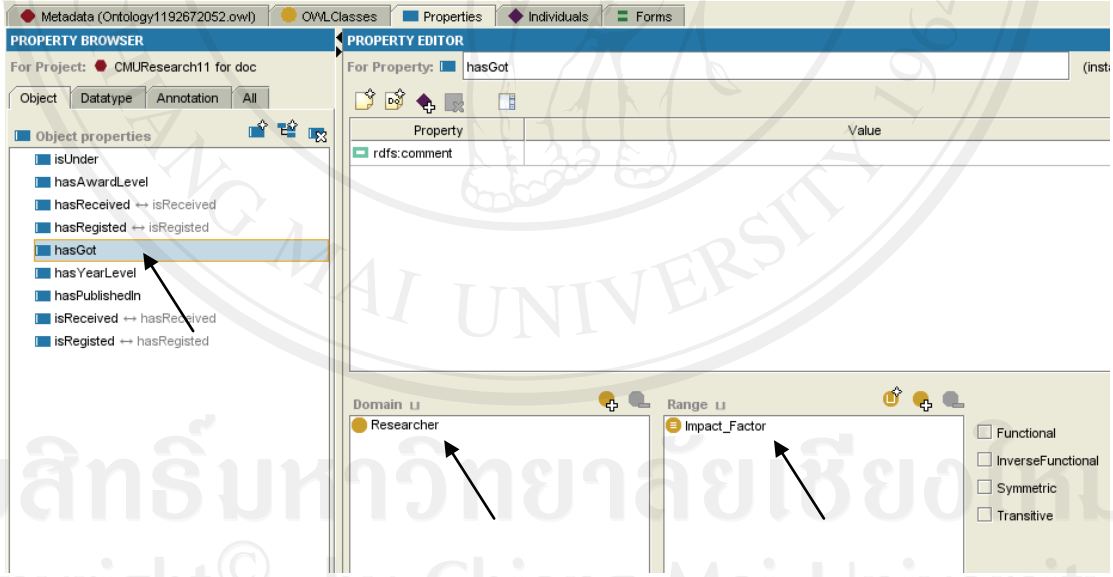

Figure 4.43 Relationship between Researcher class and Impact_Factor class

After that each Impact Factor had to classify in the level for each discipline. For example Impact factor equal two was classified in the low level of university level,

Health Science discipline, and Science and Technology discipline. But it was classified in the high level for Social Science discipline and Engineering subject. The output for this is shown in Figure 4.44.

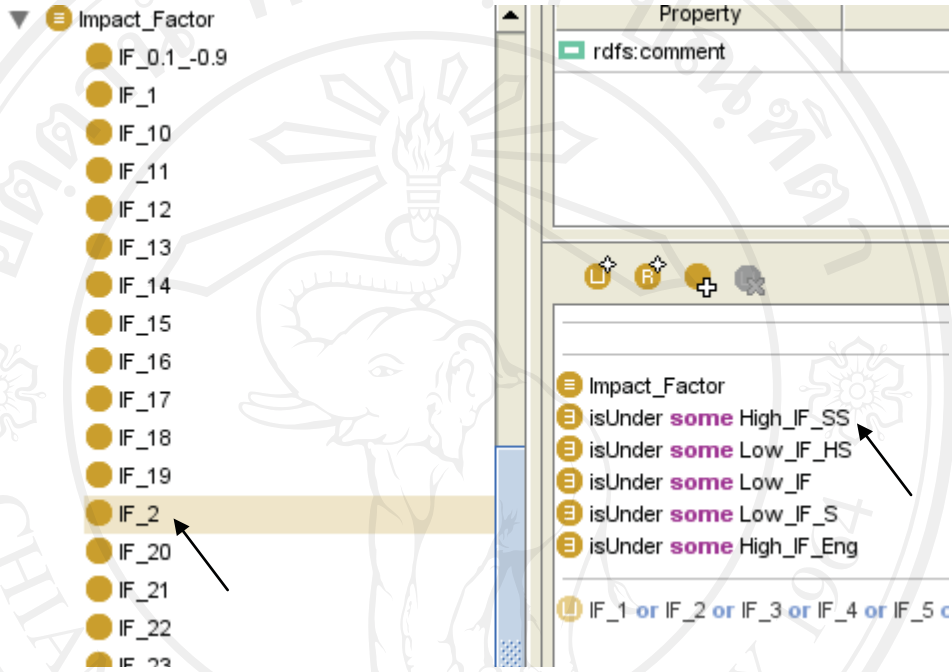

Figure 4.44 Level of Impact factor equal 2 in each disciplines and subject

For example, Researcher_A was one researcher in Science & Technology Discipline who published his/her papers in journal with Impact Factor equal 2 and 10. The restriction of this researcher was

Sci_Researcher

hasGot some IF_10

hasGot some IF_2

The result on implementing is shown in Figure 4.45

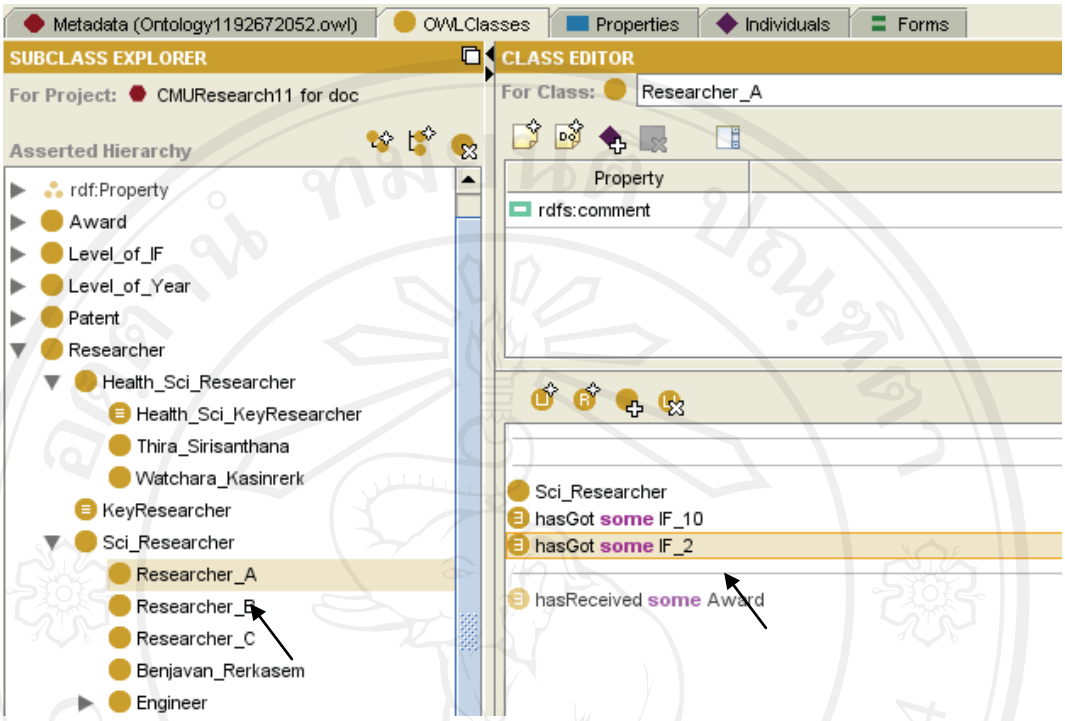

Figure 4.45 The example of impact factor condition in Protégé

After modified the restriction, predicate logic in Protégé was changed as shown in Figure 4.46

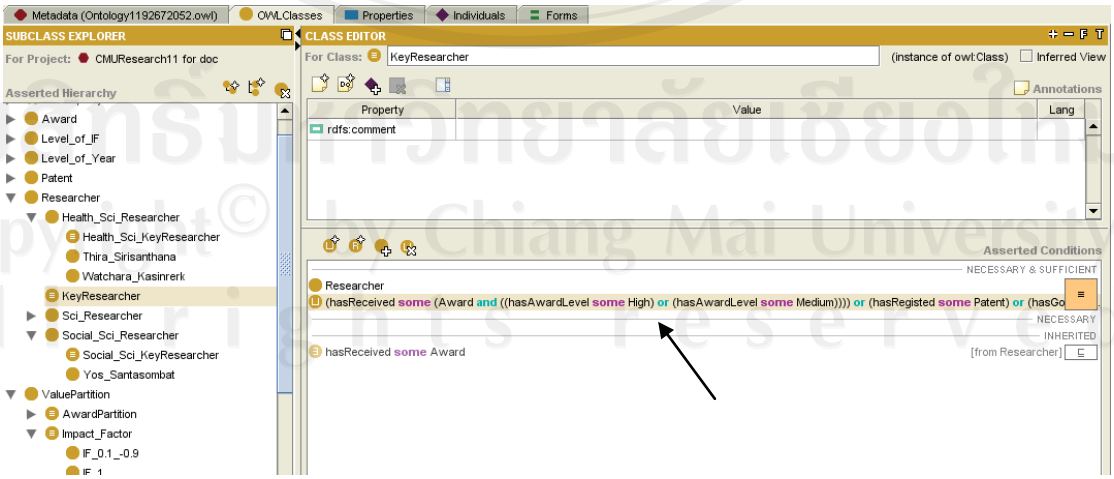

Figure 4.46 Key researcher condition with patent, award, publication, and Impact Factor

Further in each discipline and subject had to set their own predicate logic for identifying their key researchers. Thus three new equivalence classes were built -- Health_Sci_KeyResearcher, Sci_KeyResearcher, Social_Sci_KeyResearcher, Engineer_KeyResearcher as shown in Figure 4.47

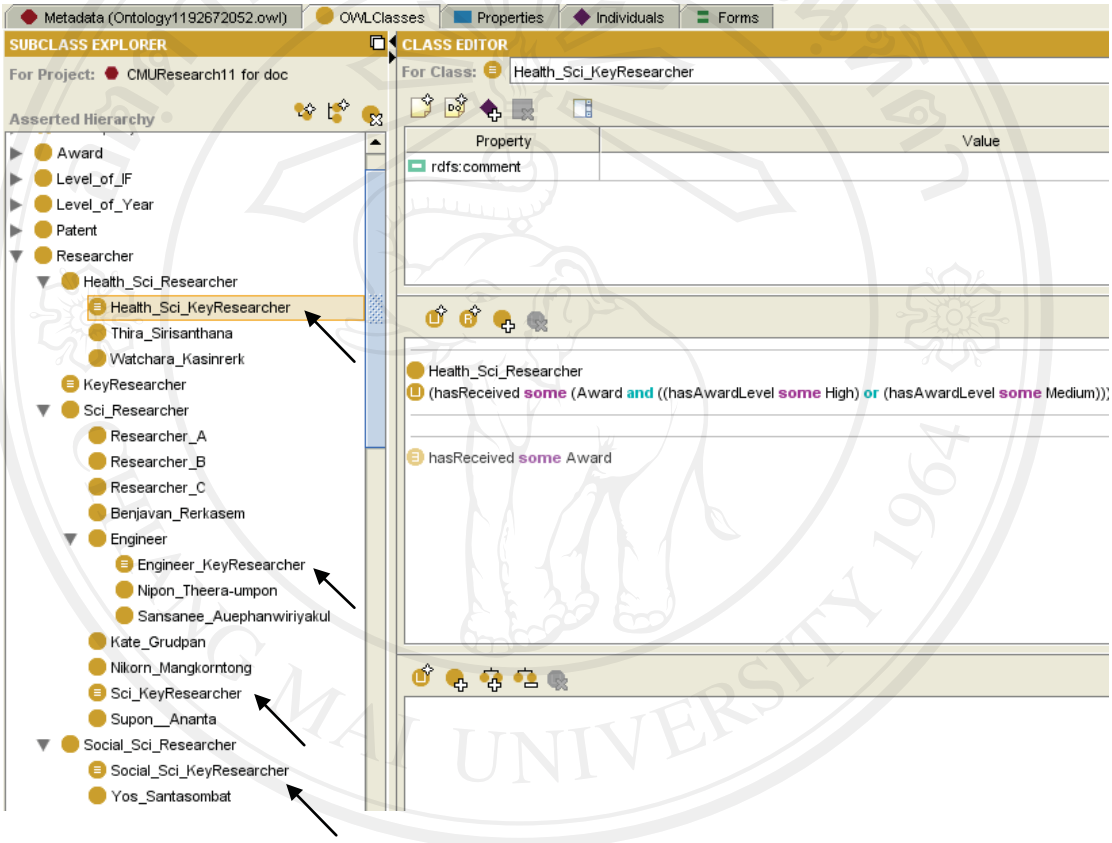

Figure 4.47 Key researcher class for each discipline and subject

When running inference step, the members of each key researcher were generated as show in Figure 4.48

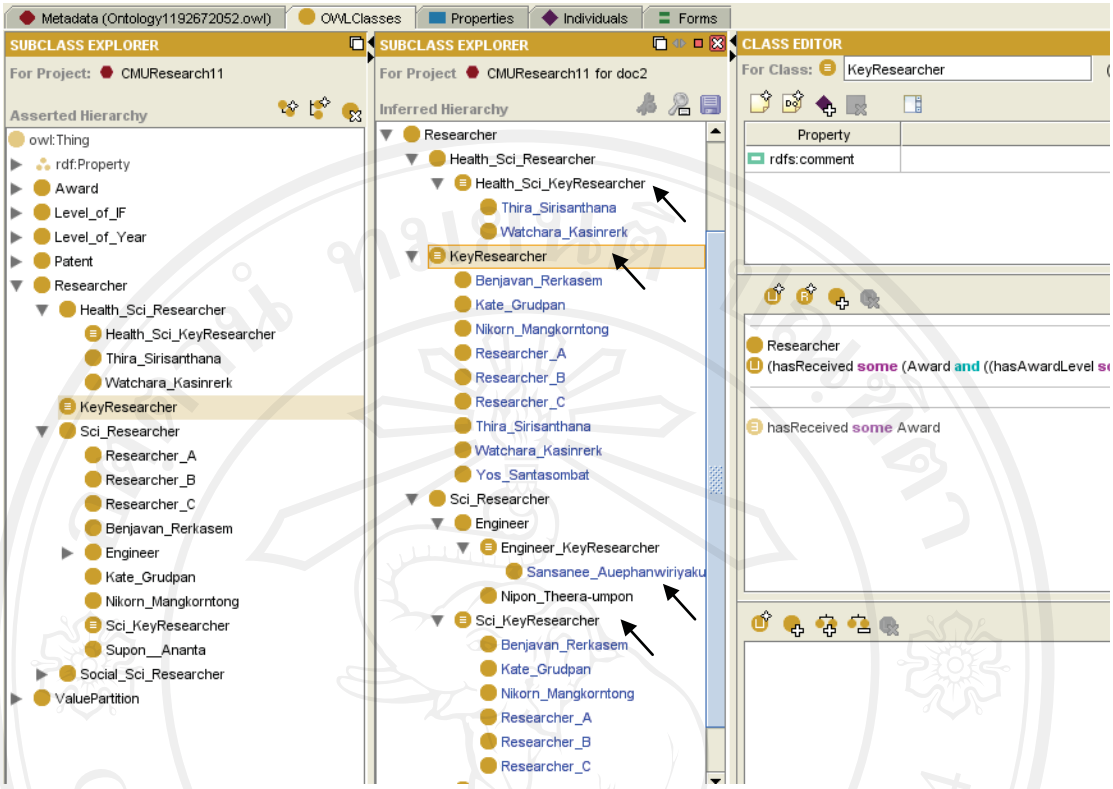

Figure 4.48 The member of Key researcher of all disciplines and subject (Engineering)

4.2.3 Set up research clusters

In CMU ontology normalization, it was found that the relevant classes for representing expertise and research direction of candidate key researcher consisted of: *Application, Subject*, and *Methodology* classes. The CMU Ontology was added with these three classes as shown in Figure 4.49

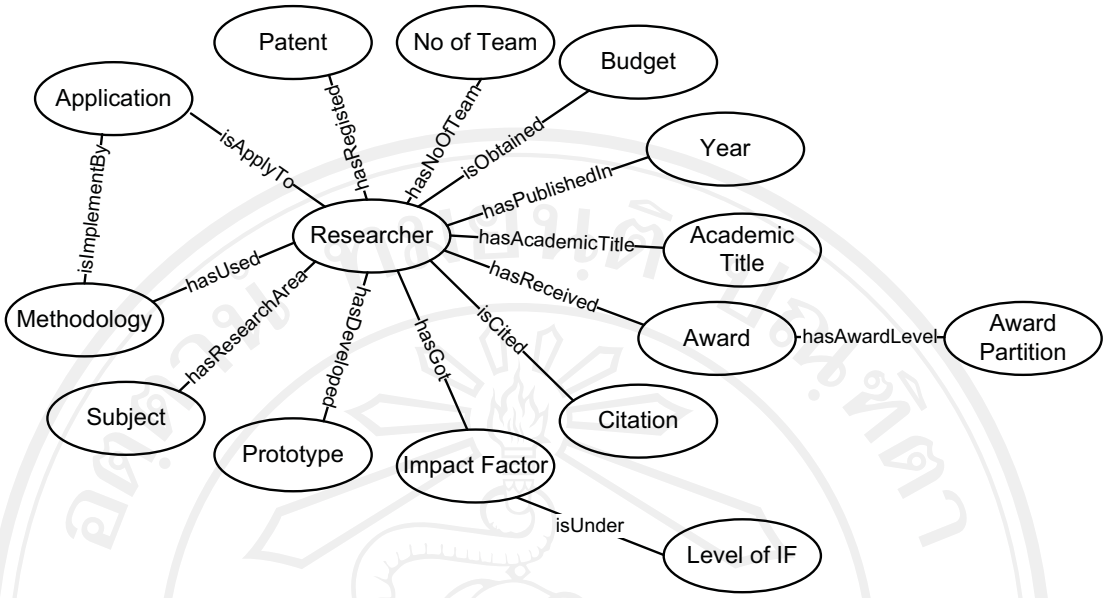

Figure 4.49 CMU Ontology commitment after added three classes: Application, Methodology, and Subject

The Application class describes the applications implemented by researchers' research. The Methodology describes technology, techniques, or tools that researchers used in their research. The Subject class describes subjects or research areas of researchers.

There are three new relationships added to CMU research ontology commitment. The relationship between *Researcher* class and *Application* class is *isApplyTo.* This implies that the researcher was applying his/her research to certain applications. The relationship between *Researcher* class and *Subject* class is *hasResearchArea* implies that there were certain subjects corresponding to the researcher's research area. The relationship between *Researcher* class and *Methodology* class is *hasUsed* implies that the researchers used some tools, techniques, and technology by the researcher for conducting his/her research. The relationship between *Application* class and

Methodology class is *isImplementedBy* implies that tools, techniques, and technology used in the certain applications.

In addition, the three new subclasses -- Application, Methodology, and Subject -- also have subclasses. These subclasses would help to identify expertise of key researchers specifically. For example, *Application* class has *Service, Industrial* and *Agricultural* as subclasses. *Subject* class had *Multidiscipline* and *Discipline* subclasses as. *Methodology* Class has *Technology, Technique* and *Tools* as subclasses. These subclasses could be further added depending on the characteristics of research in each university. The result is shown in Figure 4.50

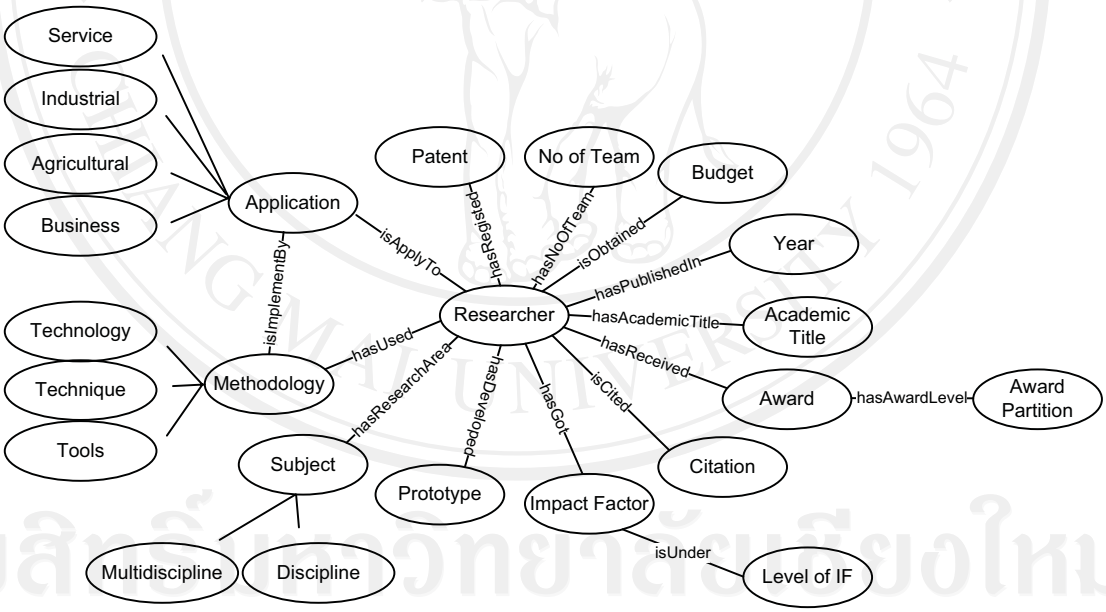

Figure 4.50 Subclass of Application, Subject, and Methodology

The results of card sorting technique in the first part were used to populate in the CMU ontology as instance of subclasses.

In design new subclasses might be added because keywords were variety. Sometimes keywords could not be inserted into any existing subclasses. For example, if at the beginning, *Application* class has only three subclasses: *Service*, *Industrial*, and *Agricultural*. In implementing, some applications such as *e-commerce* and *multilevel direct sale* cannot be inserted in any existing subclasses. In this case, *Business* subclass should be added for covering the real fact. The result is shown in Figure 4.51

Furthermore, some related applications such as eco-tourism, culture-tourism, health tourism, and nature tourism should be grouped into the same subclass called *Tourism* under *Business* subclass. This new subclass could be facilitated administrators to search for key researchers in tourism and specific kind of tourism.

After populating those keywords in Protégé, CMU research ontology represented an expertise road map of CMU researchers. The road map was presented in hierarchical structure.

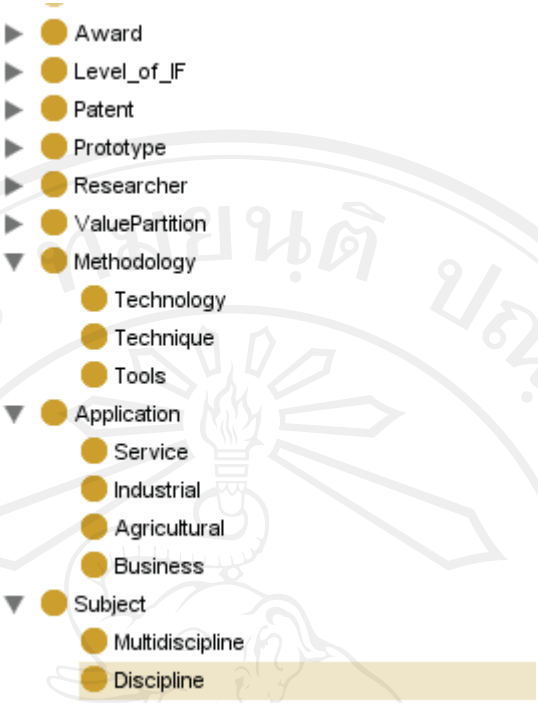

Figure 4.51 The new three classes and their subclasses in Protégé

Next step, Resource Description Framework Query Language (SPARQL), query language of OWL ("Web and XML Glossary", 2006), was used to query the research ontology. Query statements written with SPARQL were used to retrieve researchers who were interested in the same domain or the same application. These researchers were grouped to form a research cluster. For example, when searching for *Lanna* (Thai northern culture) application in Protégé, the list of key researchers who run research on Lanna culture is obtained. Using this technique, CMU administrators either identified research clusters or managed research funding for specific areas more efficiently.

An example of searching the CMU research ontology commitment with SPARQL is shown in Figure 4.52. This query was designed to identify all key researchers who were interested in *tourism*. The query language was written as

SELECT DISTINT ?Researcher ? Application ? Group

WHERE{ ?Research :isApplyTo ? Application.

?Application :nameApplicationGroup ?Group.

Filter (REGEX(?Group, "Tourism"))

}

Order by ?Researcher

These researchers used various disciplines and methodologies in the same application, *tourism*. Administrators might consider forming a cluster of *tourism* comprising these individuals.

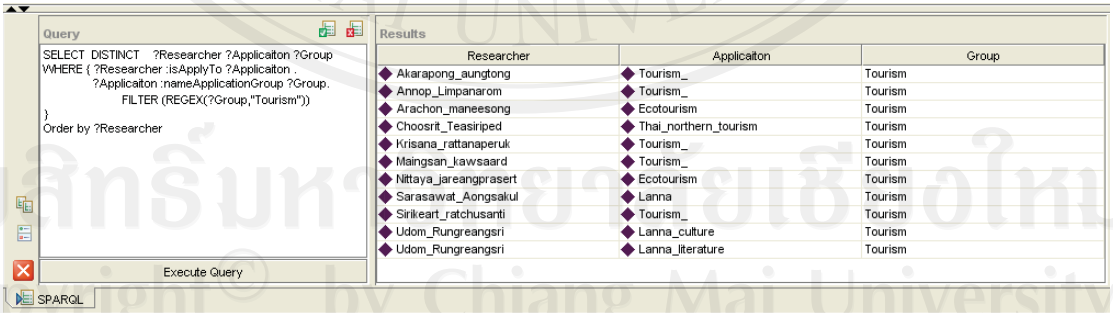

Figure 4.52 The example of using SPARQL for query a research cluster of Tourism

4.2.4 Analyze interesting of each research cluster

CMU research ontology commitment was embellished to incorporate the TCM (Thai Competitive Matrix) by adding a new class, *TCM,* as shown in Figure 4.53

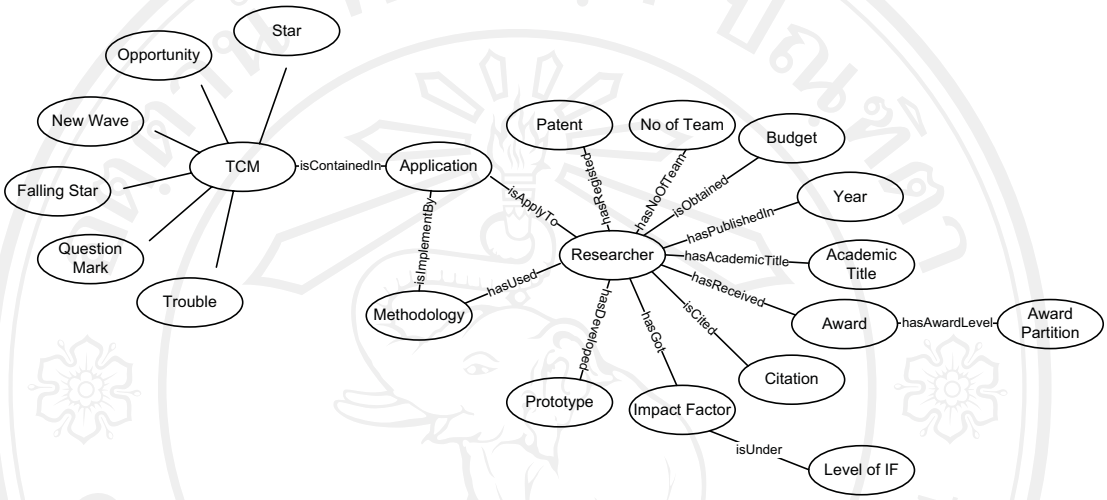

Figure 4.53 The structure of the research ontology commitment, now including the TCM

TCM comprises six subclasses: Star, Opportunity, New Wave, Falling Star, Question Mark, and Trouble. The TCM class is related to the Application class by the relations *contains* and *isContainedIn*. For example, *travel & tourism*, which is an instance of the Star subclass, *contains ecotourism*, which is an instance of the Application class. On the other hand, ecotourism *isContainedIn* Travel & Tourism.

The TCM class can be used to guide the policy for managing research in each group of the model. Applications in Star, Opportunity, and New Wave groups are desirable applications for world markets. But the competitiveness in these groups are different—Star group has higher competitiveness—so research that falls into this group should be promoted. However, applications in the Opportunity and New Wave

groups, which have medium and low competitiveness respectively, should be well-supported, in order to raise competitiveness.

For applications in the Falling Star, Question Mark and Trouble groups, the demand in world markets is low. However Falling Star has high competitiveness, being a niche market in Thailand. Research in this area should look for new markets in order to increase its attractiveness. Researchers in this area should seek other partners and try to cooperate with researchers in other countries. For example, in rice-related research, CMU can cooperate with China. For the Question Mark group there are two options. If research in this group can find new market, research in this area can be continued; otherwise, research in these application areas should be reduced or stopped. For the Trouble group, research should be closed except for that research that is conducted for public or social purposes.

After implementation with Protégé, the TCM class has six subclasses as shown in Figure 4.54. Instances of TCM are industries corresponding to each group. For example, the Star subclass has *meat & poultry*, *transport*, and *travel & tourism* as instances.

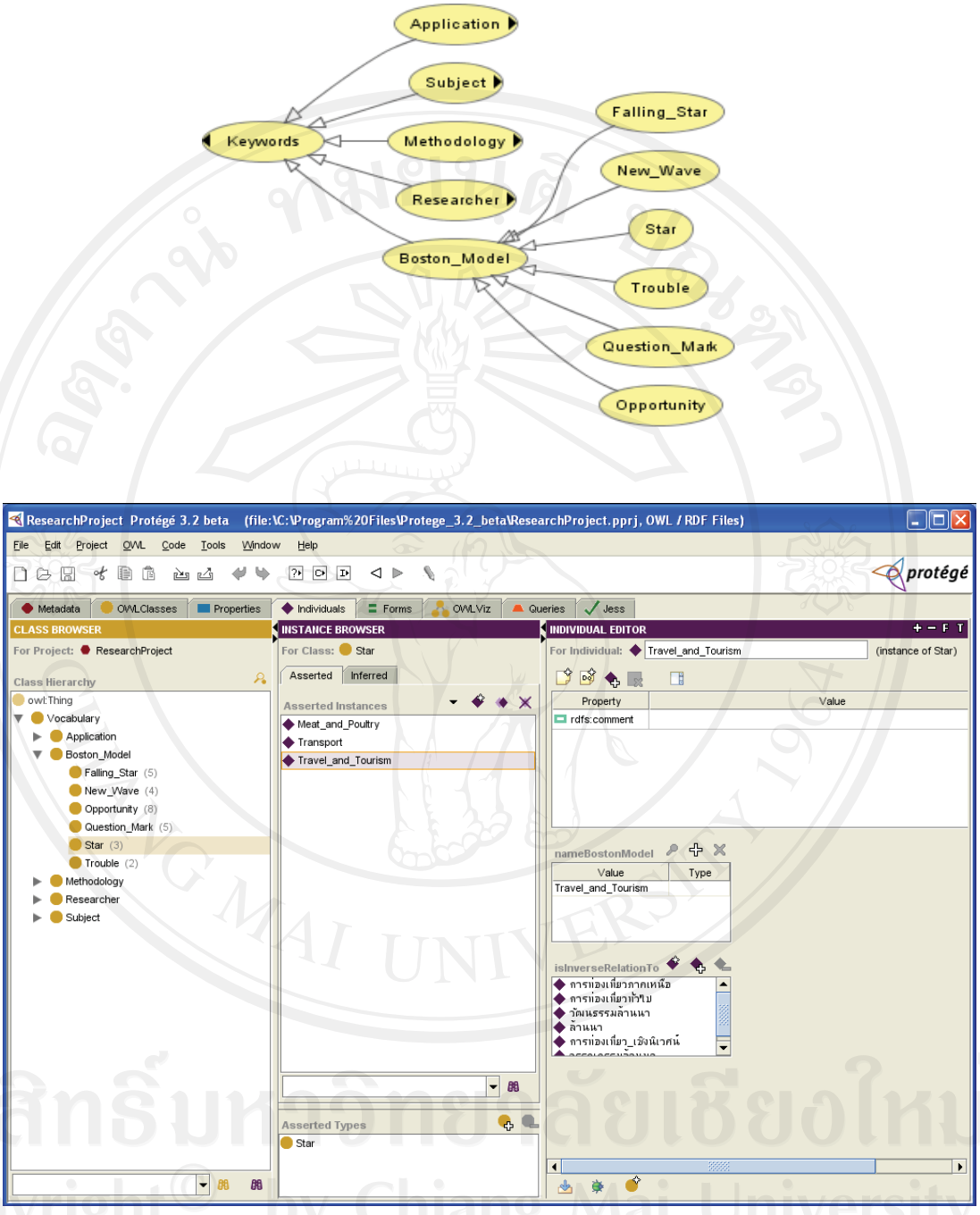

Figure 4.54 Six subclasses of TCM class

An example of a query using SPARQL to search for *travel & tourism* is shown in Figure 4.55. The result of this search represents researchers who do research in

travel and tourism, which is in the Star group of the TCM, so they should be promoted and supported by the executive.

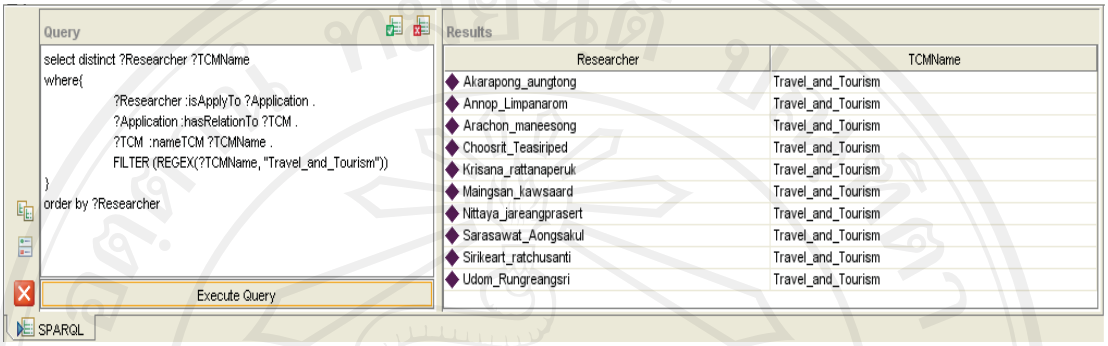

Figure 4.55 Search TCM by travel & tourism

For recommendation of setting up multidiscipline research clusters, using the TCM is just one option. In the future, one might use some alternative (yet to be developed) matrix— a "Thailand Research Direction" matrix, "CMU Research Direction" matrix, or "National Research Institute" matrix. However, all options may be used together at the same time, especially in the case of research in the Social Sciences & Humanities. These research areas are not suitable to be justified only by the TCM because research in these areas is most often motivated by niche capabilities or social welfare, not profit.