# APPLYING PATENT INFORMATION TO TRACKING A SPECIFIC TECHNOLOGY

***Chen-Yuan Liu [1]*, Shenq-Yih Luo[2]***

**[1]Huafan University, No.1, Huafan Rd. Shihtin Hsiang,Taipei Hsien.Taipei Taiwan.*
*Department of Mechatronic Engineering, Huafan University,*
*Department of Information Technology and Communication, TNIT*
*Email:*dori6803@ms37.hinet.net
*[2]Department of Mechatronic Engineering, Huafan University,*
*Email:syluo@huafan.hfu.edu.tw*

## *ABSTRACT*

*Patents in general contain much novel technological information. This paper demonstrates that the usage of patent analysis can facilitate a unique scheme for tracking technology development. In this paper, the walking technique of the Japanese biped robot is tracked as an example. The searching method of the FI (file index) and F-term classification system developed by JPO (Japan Patent Office) was employed in this study, where all the related patent data were searched from the IPDL (Intellectual Property Digital Library). This study investigated an important technique applied to the humanoid biped robot that imitates the walking behavior of the human beings on two legs. By analyzing the patent information obtained, the relative research capabilities, technical strengths, and patent citation conditions among patent competitors were compared. Furthermore, a formulated technical matrix of patent map is established in this paper to indicate that the ZMP (Zero Moment Point) control means is the main technology to achieve stabilized walking control of the humanoid biped robot. This study also incorporates relevant academic journal findings and industrial information. Results presented herein demonstrate that patents can function not only as a map for tracking a technology trajectory, but also as a guide to the main development of a new technology in years to come.*

**Keywords:** Japanese patent information, Humanoid biped robot, Walking technique, Laid-open publication, Technical matrix, Technology growth

## 1 INTRODUCTION

In recent years robots with the rapid advance of information technology, electrical and mechanical control system and artificial intellect have been widely used in many applications such as industry, living matter, security, hobbies, humanoids, etc. JARA (Japan Robot Association, http://www.jara.jp) predicted that the world market value of smart robots for home applications will reach US$15 billion in 2010. Besides, based on a technical report publicized by JPO (Japanese Patent Office, http://www.jpo.go.jp/indexj.htm) in 2002, the patent applications of 15,038 cases for industrial and non-industrial robots in Japan far exceed the patent applications of 3,217 cases in Europe and 2,471 cases in USA.

The robot patents in Japan can be classified, in the descending order of patent amounts, into eight techniques: walking, moving distance and direction measurement, barrier ducking, learning computation, multiple robot control, image identification, sound identification, and remote control. The walking technique, which has the most patent applications compared to other techniques, is in fact the major feature of the humanoid robot. Hence, in order to further investigate the control means and the control purposes of the walking technique for the humanoid robot, the FI (file index) and F-term classification system (Schellner, 2002) of JPO was used to analyze the related patent information and construct the related technical matrix.

## 2 DATA AND METHODOLOGY

In investigating Japanese patent events, it is certainly most effective to use the Japanese patent database. First of all, the movement features of the robots can be analyzed using the cause-effect diagram as shown in Fig. 1 in which the “humanoids” and “biped” are two technical elements to be considered.

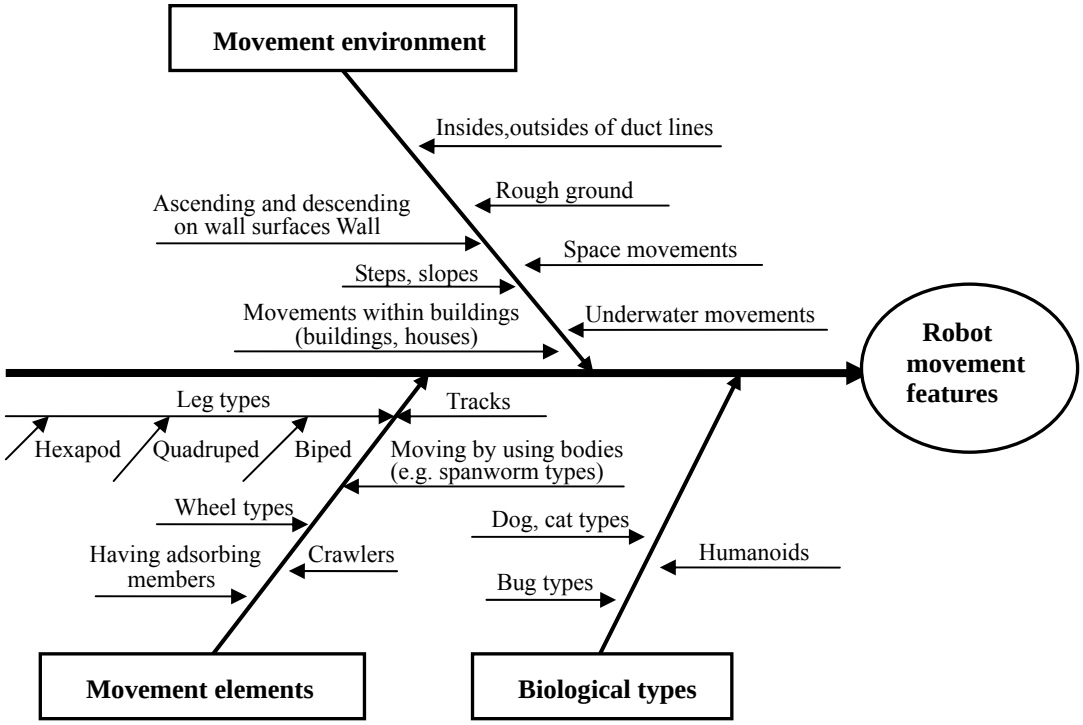


**Figure 1.** Cause-effect diagram for the movement features of the robots

Next, by using the file index (FI) and F-term classification system developed by JPO to search the open publication documents from the IPDL (Industrial Property Digital Library, http://www.ipdl.ncipi.go.jp/homepg_e.ipd) of JPO, the theme code "3C007" which has "humanoid" and "biped" technical elements is derived. The number of the found open publications, *T*, was based on a logical intersection operation of the term codes "WA03" (humanoids), "WA13" (biped), and "WB01" (control means of the walking technique) in the "3C007" theme code, as given by expression by formula (1).

$$T = \mathrm{WA03} \cap \mathrm{WA13} \cap \mathrm{WB01} \quad (1)$$

where WA03, WA13, WB01 $\subset$ S are term codes, and the theme code S= 3C007 is a universal set.

As a result, a total of 257 open publications were collected up to 31 December, 2005. This study was based on these open publications undertaking the analysis of patent technology and patent map pertaining to the walking technique of the biped walking robot.

## 3 PATENT GROWTH CONDITION

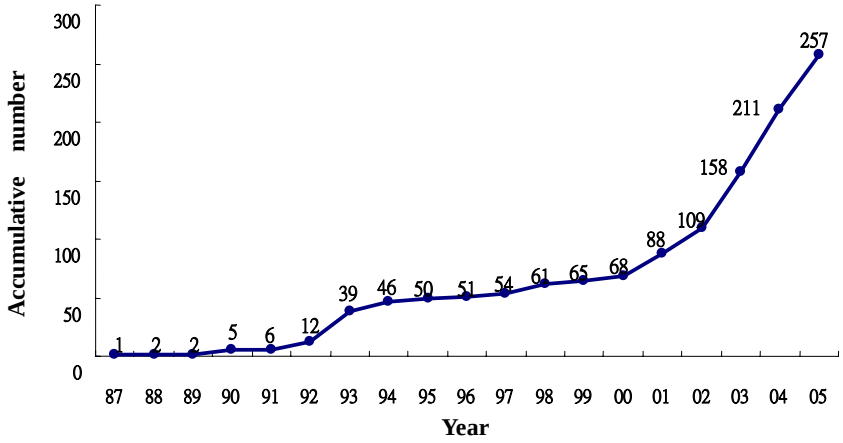


**Figure 2.** Patent growth tend of the walking technique for the biped robot in Japan (numbers versus year)

According to the chronicle of open publications in Japan, the development trend of the walking control technique for the biped robot is given in Figure 2, which shows a total of 257 walking technique patents from 1987 to 2005.

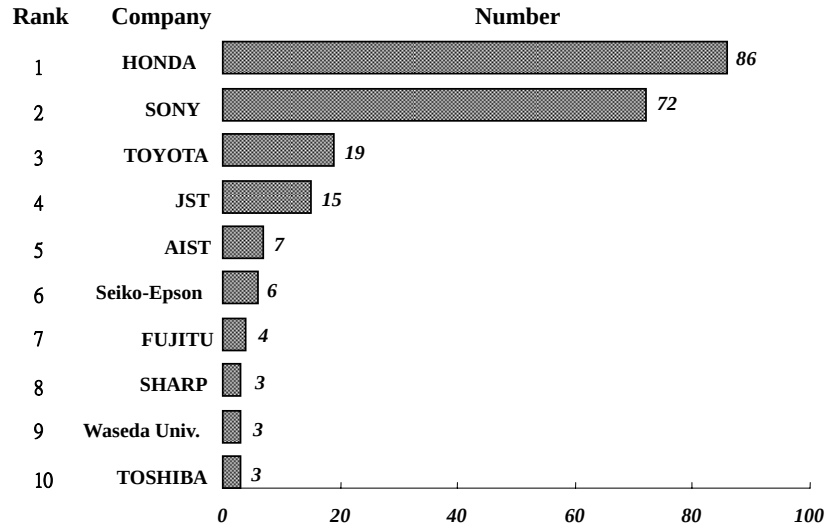


**Figure 3**. Ranking for the 10 top owners of the walking technique for the biped robot in Japan

Furthermore, the top ten companies or organizations owning the patents are presented in Figure 3. In 1987, the Waseda University invented the biped walking robot and gained the first patent of the walking control technique for the biped robot in Japan. Since 1991, Honda has contributed to open publication of the technique every year and is ranked as the number one company owning a total of 86 open publications up to 2005. Sony began with the first patent case in 1999 and has owned a total of 72 open publications, next to Honda. Toyota, the number three patent owner, has accumulated 19 open publications. These three giants share 69% of the open publications for the biped walking robot. It is obvious that in Japan, the patented technology of the biped robot is developed and dominated by the leading big companies. As for the contribution of other organizations, 10% (25 cases) of the patents are shared by Japan Science and Technology Agency (JST), the Association for Iron and Steel Technology (AIST), and Waseda University. In addition, 15% (39 cases) of the patents are owned by "others," including Korean Samsung (3 cases).

From the analysis of the patent document contents, Honda's research places emphasis on walking balance control, walking speed increase, and fast response mode, and its representative robot is the biped walking robot ASIMO (HONDA, http://www.honda.co.jp/ASIMO) introduced in November 2000. Most Honda patents, i.e. 72% or 62 cases of all Honda open publications are dedicated to enhancing the processing system related to the above technical interests. Honda has no patents involved in the recreational robot; this is a distinguishing feature

of Honda. In contrast, Sony's major effort is placed on the development of the recreation robot. Starting from 1999, the number of inventors and patents by Sony rose tremendously.

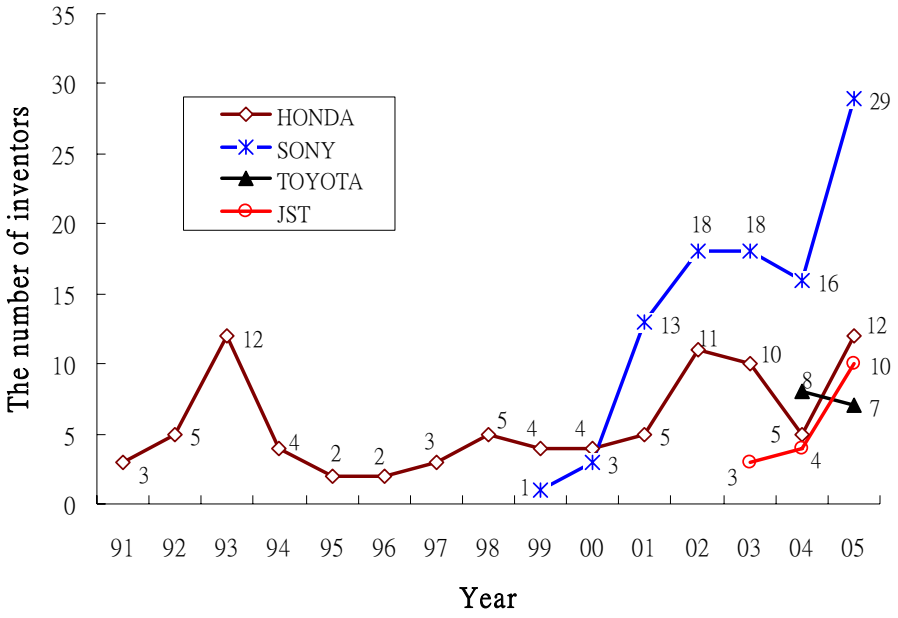


**Figure 4**. The number of inventors for the top four companies from 1991 to 2005

As shown in Figure 4, the number of inventors by Sony increased rapidly from 1999 and reached the amount of 29, far beyond Honda, in 2005. On March 19, 2002, Sony introduced the robot SDR-4X (SONY,http://www.watch.impress.co.jp/pC/docs/2002 /0319/sony3.htm ), with a weight of 6.5 kg and a movement of 38 degrees of freedom. Differing from the Honda robot entirely, the Sony robot is equipped with sound identification system, and characterized by weight lightness, pattern loveliness, and function multiplicity.

## 4 TECHNICAL MATRIX IN WALKING TECHNIQUE

This paper further investigates the 257 walking technique open publication cases of the humanoid biped robot by using a technical matrix as discussed from the viewpoint of multiple techniques deliberately in the following (Hanel, 1994; Cheng, et al., 2003). In this study, the walking technique of the robot, according to the F-term list of theme code "3C007", is analyzed from the viewpoint of control means and from the viewpoint of control purpose, respectively. The control means of the walking technique adopted include 8 modes of walking control:

- WB02: static walk
- WB03: characterized by switching walking conditions (e.g. changes in directions),
- WB04: walking patterns determined in advance,
- WB05: characterized by generation of walking figures or walking patterns,
- WB06: upper body inclination and attitude control,
- WB07: considering ZMP (Zero Moment Point),
- WB08: control by paying attention to joint angles or joint torques,
- WB09: control by paying attention to specific positions (center of gravity or the like).

The control purposes of the walking technique for the biped robot are divided into 9 modes:

- MT02: speed increase of control and operations,
- MT03: simplification of structures,
- MT04: improvement of accuracy and correctness,
- MT05: vibration prevention and stabilization,
- MT07: expansion of operation and working ranges,
- MT08: responses to plural patterns and changes,
- MT11: applications to specific usages,
- MT13: energy saving,
- MT14: improvement of entertainment.

Let the term code "WB01" denote "control means of the walking technique" and the term code "MT00" denote "control purposes of the walking technique". Then, "WB01" and "MT00" can be expressed as

WB01 = {WB02, WB03, WB04, WB05, WB06, WB07, WB08, WB09} and
MT00 = {MT02, MT03, MT04, MT05, MT07, MT08, MT11, MT13, MT14} respectively.

Further, let "WA03" denote the term code "humanoids", "WA13" denote the term code "biped". The number of the open publications, *R*, for the humanoid biped robots constructed with specific control means and control purposes can be expressed in a logical intersection operation as follows:

$$R = \text{WA03} \cap \text{WA13} \cap \text{WB01} \cap \text{MT00} \quad (2)$$

where WA03, WA13, WB01, MT00 $\subset$ S are term codes, the theme code S= 3C007 is a universal set, and *R* is the intersection of WA03, WA13, WB01, and MT00.

The technical matrix for analysis of the humanoid biped robot is shown by Table 1, and the number of open publication cases, $R_{ij}$, which apply "control means" to "control purpose" in **t**able can be expressed as:

$$R_{ij} = \text{WA03} \cap \text{WA13} \cap Ai \cap Bj \quad (3)$$

where $i$=1~8 , $j$=1~9; *Ai* ($i$=1, 2, 3, 4, 5, 6, 7, 8) corresponds to "control means" WB02, WB03, WB04, WB05, WB06, WB07, WB08, WB09, respectively; *Bj* ($j$=1, 2, 3, 4, 5, 6, 7, 8, 9) corresponds to "control purpose" MT02, MT03, MT04, MT05, MT07, MT08, MT11, MT13, MT14, respectively. As an example of $i$=6 and $j$=4, we have $R_{64}$ =15 as shown by Table 1. Furthermore, the summations *SUMX* and *SUMY* are derived using.

$$SUMX = \{\text{SUMX}_i\}, \text{ where } SUMX_i = \sum_{j=1}^{9} Rij \quad (4)$$

$$\text{and } SUMY = \{\text{SUMY}_j\}, \text{ where } SUMY_j = \sum_{i=1}^{8} Rij \quad (5)$$

respectively. Therefore, according to (4) and (5), we have

*SUMX* = {2, 13, 9, 9, 19, 35, 24, 15}
and *SUMY* = {9, 2, 4, 58, 2, 6, 1, 27, 17}.

**Table 1**. Technical matrix of control means and control purposes for walking control of the humanoid biped robot

| Means / Purpose | static walk (WB02) | characterized by switching walking conditions (e.g. changes in directions)(WB03) | walking patterns determined in advance (WB04) | characterized by generation of walking figures or walking patterns (WB05) | upper body inclination and attitude control(WB06) | considering ZMP (Zero Moment Point)(WB07) | control by paying attention to joint angles or joint torques (WB08) | control by paying attention to specific positions (center of gravity or the like)(WB09) | *SUMY* |
|---|---|---|---|---|---|---|---|---|---|
| **speed increase of control and operations（MT02)** | 0 | 0 | 0 | 0 | 1 | 5 | 0 | 3 | 9 |
| **simplification of structures (MT03)** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 |
| **improvement of accuracy and** | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 4 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **correctness (MT04)** | | | | | | | | | |
| **vibration prevention and stabilization(MT05)** | 1 | 7 | 6 | 4 | 10 | 15 | 10 | 5 | 58 |
| **expansion of operation and working ranges (MT07)** | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 |
| **responses to plural patterns and changes (MT08)** | 0 | 1 | 1 | 1 | 1 | 2 | 0 | 0 | 6 |
| **applications to specific usages (MT11)** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| **energy saving (MT13)** | 0 | 4 | 1 | 1 | 4 | 3 | 10 | 4 | 27 |
| **improvement of entertainment (MT14)** | 1 | 1 | 1 | 2 | 1 | 7 | 2 | 2 | 17 |
| *SUMX* | 2 | 13 | 9 | 9 | 19 | 35 | 24 | 15 | *126* |

In short, Table 1 represents the technical matrix （8×9）of 72 technical keys woven by the horizontal axis (control means) and the vertical axis (control purpose). The numeral key in the intersection block expresses the number of Japan open publications that use the conditions of specific control means and the specific control purpose. The numeral "0" means no publication has been made open in this field, i.e. the specific control means for the specific control purpose does not exist up to now.

It is noticed that there are 35 cases in total ($SUMX_6$) which apply the ZMP method, and they exhibit the main trend using this mode of control means for walking control. In fact, the ZMP theory had been discussed since the 1980 decade, but other related techniques such as the balance sensor and operation processing were not mature at that time. The main stream value of this means for walking control had not been verified until the appearance of ASIMO robot recently.

In this technical field of ZMP control means, Honda Motor Co. Ltd. possesses 12 Japan laid-open publications, that is, WO2003/090978, WO2003/057429, JP2002-326173A, JP1999-10567A, JP1998-86080A, JP1995-201782A, JP1994-170757A, JP1993-318339A, JP1993-305583A, JP1993-305582A, JP1993-277968A, and JP1993-245780A. Sony Corporation also possesses 12 Japan laid-open publications, that is, JP2005-199403A, JP2005-144624A, JP2005-96000A, JP2005-7491A, JP2004-142095A, JP2003-172388A, WO2003/068455, JP2003-266339A, JP2002-349658A, JP2002-307350A, JP2001-157973A, and JP2001-138273A. Toyota Motor Corporation possesses 5 Japan laid-open publications, that is, JP2005-118924A, JP2005-22039A, JP2004-174654A, JP2004-174653A, and JP2004-174648A. It is apparent that these top three corporations occupy an 83% share of the publications and dominate the development of this technique.

Furthermore, it is noted that there are 58 applications in total ($SUMY_4$) that concern the control purpose of vibration prevention and stabilization (MT05). They reveal that this mode of control purpose for the humanoid biped robot has attracted the attention of skilled professionals.

Finally, it is observed that, for solving problems to reach the advantageous effect of vibration prevention and stabilization (MT05), the technical means of ZMP (WB07) has gained most of the Japan laid-open publications and it counts up as many as 15 cases ($R_{ij}=R_{64}=15$). The 15 cases of using ZMP for vibration prevention and stabilization include 6 cases as WO2003/090978, WO2003/057429, JP1995-201782A, JP1993-305583A, JP1993-305582A, JP1993-245780A by Honda Motor Co. Ltd, 5 cases as JP2005-144624A, JP2004-142095A, WO2003/068455, JP2001-157973A, JP2001-138273A by Sony Corporation, 3 cases as JP2004-17180A, JP2003-145457A, JP2002-361574A by AIST, and one case as JP2004-174653A by Toyota Motor Corporation. This fact reveals the effectiveness of this technique. Among them, three have been submitted as WIPO (World Intellectual Property Organization, http://www.wipo.int/export/portal/index.html.en) applications via the PCT (Patent Cooperation Treaty, http://www.wipo.int/pct/en) route, i.e. WO2003/090978, WO2003/057429 and WO2003/068455, and they also stress the importance and value of using the ZMP technique in the biped walking robot technical field.

## 5 CONCLUSIONS

This study demonstrates searching patent data from the IPDL to learn about technology patterns. The FI and F-term classification system is employed to prepare a variety of patent maps, which offer valuable information regarding the development dynamics of the humanoid biped walking robot technology. The technical matrix presented in this paper shows how robot developers bring related robot technologies under control. This study not only helps robot researchers to access the technical trends but also provides the business managers with an example of using patent information to manage related technologies. All in all, this study presents an effective approach using patent information in the development of a specific technology.

## 6 REFERENCES

Cheng, H., Zhang, Z., & Huang, W. (2003) Study of CGE model of policy analysis in high-tech industry based on social accounting matrix. *Journal of Wuhan University of Technology 27(3)*: 333.

Hanel. P. (1994) Interindustry flows of technology. An analysis of the Canadian patent matrix and input-output matrix for 1978-1989. *Technovation 14(8):* 529.

Schellner. I. (2002) Japanese File Index and F-Terms classification. *World Patent Information 24*:197-201.