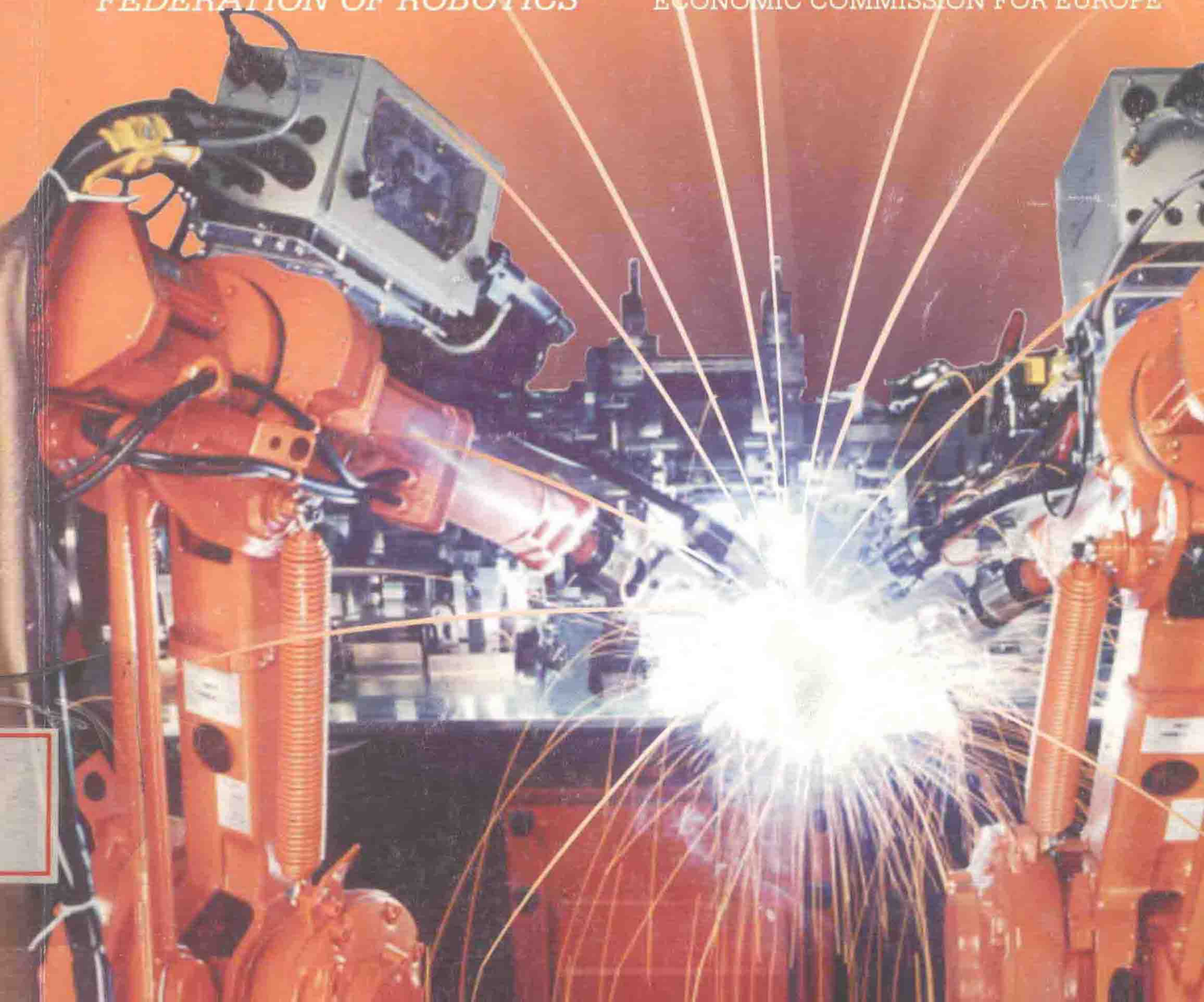
World 2003 ROBOTICS

Statistics, Market Analysis, Forecasts, Case Studies and Profitability of Robot Investment

Co-authored by:
THE INTERNATIONAL FEDERATION OF ROBOTICS

UNITED NATIONS
ECONOMIC COMMISSION FOR EUROPE



UNITED NATIONS
Economic Commission for Europe (UNECE)

IFR International Federation of Robotics

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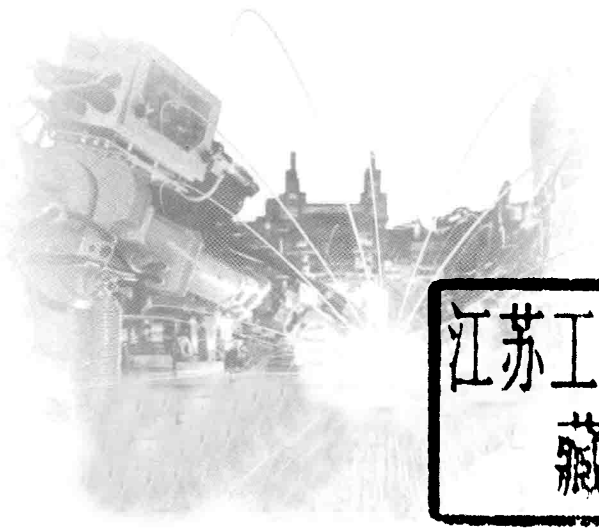

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FOREWORD

Since their introduction at the end of the 1960s, industrial robots have undergone an impressive technological evolution. With declining real prices and continuously improved performance, robots are now widespread in industry in many countries while in others the technology is on the verge of being introduced.

Robots have become a symbol and a test of industrial automation in its most advanced form. Together with computerized numerically controlled machine tools, automated guided vehicles and host computers of various kinds, robots form the centrepiece of computer-integrated manufacturing systems.

The introduction of industrial robots is not only motivated by a wish to improve productivity but also to obtain higher and more consistent product quality. Robotics is also an important technology for eliminating workplace hazards, e.g. those related to exposure to heat, gases and chemicals or those where heavy lifting or monotonous work movements are involved.

Total accumulated yearly sales of robots since the beginning of the 1970s amounted at the end of 2002 to some 1.33 million units, of which some 770,000 are estimated still to be in operational use. Driven by advances in semiconductor and computer technologies and the vast potential for new applications, not only in industry but also in construction and in services (hotels, health care, laboratories, surgery etc), there is every reason to believe that robotics will continue to expand rapidly and play an increasingly important role in production rationalization.

This yearly publication, in addition to summarizing the development of industrial robots to date, presents time-series data for the period up to 2002 and inclusive, forecasts for the period 2003-2006 and, for the fourth year in a row, an analysis of the diffusion of service robots. It is a joint effort of the United Nations Economic Commission for Europe (UNECE) and the International Federation of Robotics (IFR). The two organizations have enjoyed close and fruitful co-operation in the area of robotics for many years.

Monitoring economic and social trends, developing indicators with a focus on performance and outcomes, supporting business and policy decisions with an infrastructure of good quality information and analysis, are core preoccupations and strategic objectives of the UNECE Statistical Division. This Report therefore provides an outstanding illustration of what can be achieved in monitoring industrial development.

For the fifth time World Robotics includes an editorial, where a well-known person with a worldwide reputation is invited to give his/her view of the future of robotics. The first editorial appeared in ***World Robotics 1999***. It was written by Mr. Marvin Runyon, Postmaster General and Chief Executive Officer of the United States Postal Service. In ***World Robotics 2000*** there were three editorials. The first was prepared by Mr. Björn Weichbrodt, International Federation of Robotics (IFR) and the second by Mr. Rolf Dieter Schraft and Mr. Matin Hägele, Fraunhofer Institute for Manufacturing Engineering and Automation (IPA). The third editorial was written by Mr. Hadi A. Akeel and Mr. Gary J. Rutledge, both from FANUC Robotics North America. In the 2001 issue, an editorial was presented by Mr. Lars-Erk Ringström, Business Manager of ABB Flexible Automation. Mr. Steffan Müller, Executive Vice President of KUKA Roboter GmbH, Germany was the author of the editorial in ***World Robotics 2002***.

The editorial in the present issue was prepared by Mr. Massimo Mattuci, Corporate Senior Vice President and Mr. Arturo Baroncelli, Product Planning and OEM Sales, Comau S.p.A.

The present publication and all previous yearbooks on robotics were written by Mr. Jan Karlsson, teamleader ECE Statistical Division with the assistance of the IFR secretariat. Mr. Yves Clopt, ECE, designed the cover page and made the photo set-ups. Ms. Linette Blanchandin, ECE Statistical Division, assisted in the text processing and the proof reading of the publication.

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EDITORIAL
Production system evolution in the automotive industry

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1 Introduction

The automatic body production systems used today in the automotive industry are required to address and solve various technological issues: productivity, flexibility, the complex shapes involved, precision, efficiency and assembly methods.

As far as productivity is concerned, cycles times of around 30 seconds per vehicle may be requested. Very often, the degree of flexibility required entails concurrent production of 3 models. A complete body may consist of more than a hundred different parts, of complex three-dimensional shape. Once these parts have been assembled, body precision must be around the mm. System components must guarantee more than 99.99% reliability (for example, robots) and, last but not least, the parts and subassemblies are assembled using a wide range of different technologies, stretching from spot, arc and laser welding to riveting, gluing, etc. which are, for the most part, carried out by robots.

This document analyzes a part of the problem tied in particular to two of the above-mentioned issues: productivity and flexibility. The reference framework reflects Comau's long-term experience in the development and commissioning of production systems for all leading auto-makers.

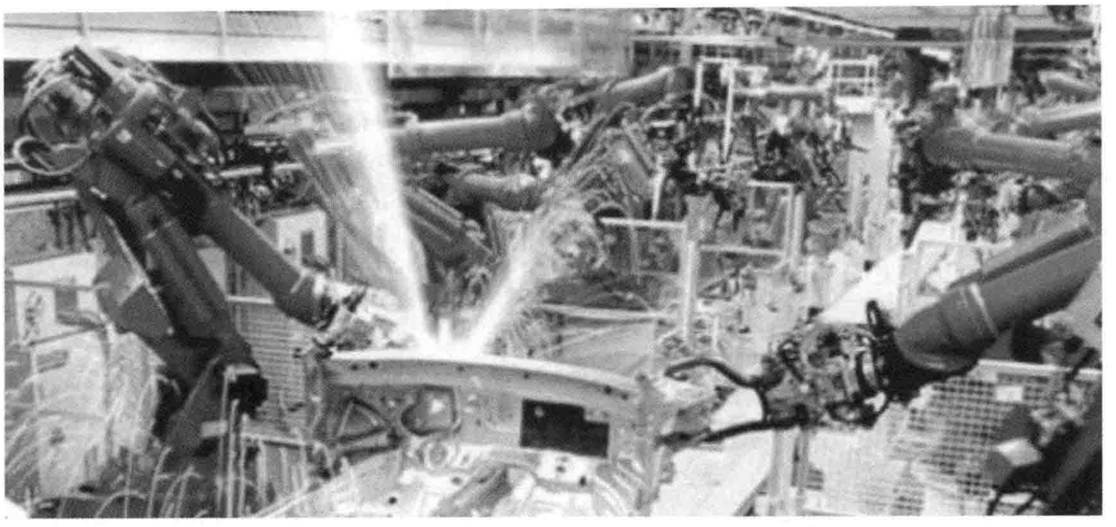


Fig. 1: Detail of robotized system

2 Productivity and flexibility: basic concepts and quantity data

A number of limit values of the main basic parameters of the plants concerned were outlined in point 1. The typical values and concepts of cycle time and flexibility are defined in more detail below.

As regards cycle time, medium/high productivity plants (with maximum use of robotized automation) have CT values of between 30 and 60 sec.

With regard to flexibility, in terms of use of the plants, the number of models that can be produced at the same time and the minimum size of the production lot are usually considered. In this case, reference is made to a mix of from 1 to 3 models with a minimum lot of one unit (random).

Flexibility is also assessed according to the possibility of changing the models produced on the same plant during its life time, and therefore the possibility of re-tool and re-program it in order to produce a new model mix with minimum down time on production. Basically, the higher the flexibility of a plant, the lower the cost, in terms of investment and down-time, to start production of a new type of body when necessary.

Taking into account these market/customer demands, system solutions have been developed that are able to address all productivity-flexibility mix requirements in a single competitive framework as regards technological solutions and investment costs.

3 Best Practices

Body production systems are usually grouped in 6 subsystems:

- body framing systems, i.e. the line on which the underbody, body side and roof are joined in order to form the complete body;
- underbody systems
- body side systems
- subassembly systems: cells where basic parts are joined together to produce more complex components which are then fed to other lines
- closure assembly systems (doors, hood and tailgate)
- Closure Hang systems, where mobile doors, hood and tailgates are joined to the body.

Flexible production solutions should be developed for each subsystem; in other words; "best practices" in terms of optimal solutions able to cover to all cases of productivity/flexibility mix.

3.1 Open Robogate

The framing station patented by Comau at the end of the 1970s, the most recent version of which has been named "Open Robogate " (see fig. 2), is an example of a modular solution characterized by high level automation.

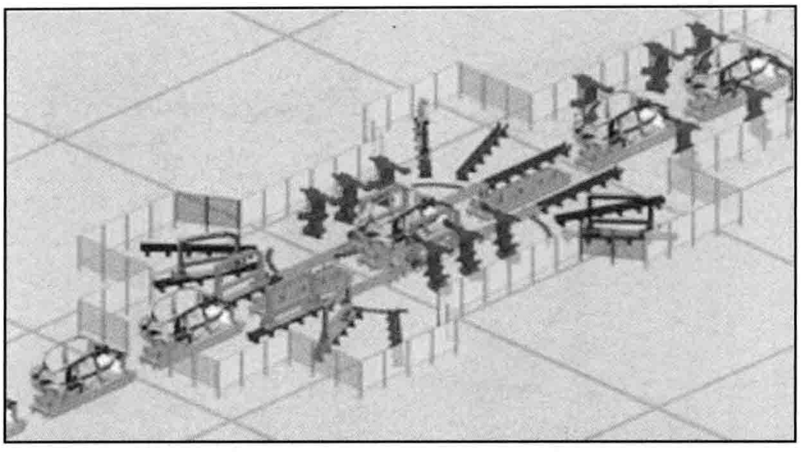


Fig. 2: example of Open Robogate (2-4 models)

At this station, precise and stiff fixtures, one for each body model, are moved to the work area in order to hold in position the parts that, once welded, determine the final shape of the body.

Figure 2 shows the Open Robogate with 4 fixtures (for 4 models); figure 3 with 2 fixtures (2 models).

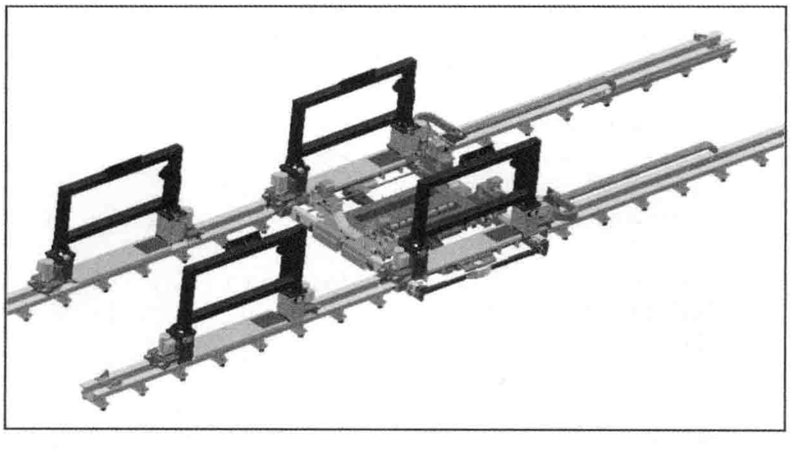


Fig. 3: Open Robogate for 2 models

4 Standards

Production systems (and therefore "best practices") consist of modular, standardized sets of components such as: robots, elevators, transport systems, welding guns, clamping systems, control and programming systems etc..

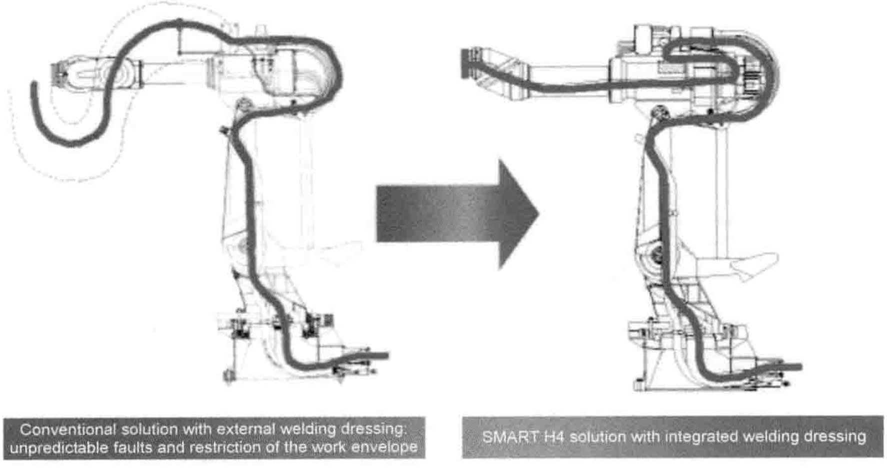
When defining and establishing the performance of these components, the aim is to achieve maximum standardization and optimization of the performance of the individual elements in relation to the targets that the entire system is required to achieve.

Two examples relating to robot applications are analyzed below as "best practices".

4.1 The SMART H4 robot

In addition to more conventional models, a robot model has been developed which is dedicated to body welding applications, with unique characteristics in the field of industrial robotics: the SMART H4.

One of the distinguishing features of the "hollow wrist" type SMART H4 is that the entire welding dressing is housed in the forearm rather than externally, as in the case of conventional robots.



In addition to improved efficiency and maintainability, this particular feature also assures maximum re-use on systems designed for concurrent production of several models. The movements of a robot with external dressing are conditioned by the not absolutely predictable position of the cables while, in the case of the model with hollow wrist, movements can be simulated as all the positions gradually assumed by the wrist of the robot are known with maximum precision and predictability.

Figure 4 show how the presence of cables restricts the theoretically achievable work envelope for conventional robots.

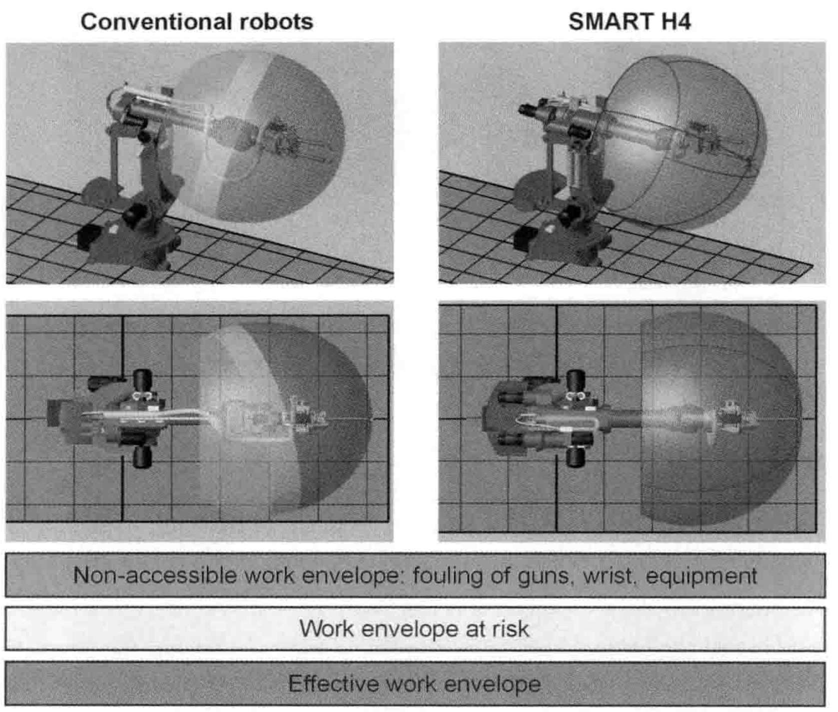


Fig. 4

The SMART H4 robot has been developed to optimize also the second concept of flexibility, i.e. the ease with which a new model can be introduced on the line as quickly as possible. With this type of robot, all programming can be carried out “off-line “, i.e. on computer rather than directly in field according to the conventional method. In other words, the procedure is similar to that used on chip removal machines with CAD/CAM: the programs are prepared on a simulator according to the shape of the parts to be produced and then transferred automatically to the real robots; the presence of external cables prevents 100% simulation as they cannot be modeled as rigid elements. Using off-line programming tools, start-up in production of a new type of body can be reduced to a few hours, rather than taking several weeks.

Practical Advantages

The use of the H4 in more than 2,000 installations worldwide has granted sound practical advantages to the end users.

In terms of life-cycle cost, for example, the fact that cables are not subjected to wear and therefore do not break for a long time (a warranty 3 years/3 shifts on internal dressing can be granted) generates savings of order of magnitude of thousands of Euro /robot in few years.

A second advantage is that welding lines using the Smart H4 have a significant higher availability in comparison with solutions with conventional robots; the reason is that there are no sudden and unexpected stops, with consequent production losses, caused by random failures of dressing.

Finally, the absence external cables allows to run different models without constraints and therefore there is no limit to design automatic systems with levels of flexibility which cannot be reached with standard robots.

4.2 The SMART X1 robot

To replace hard automation with flexible systems, another type of robot has also been developed intended specifically for bodywork plants: the SMART X1. It has extremely high payload (500 - 700 kg) and reach (more than 3,8 meters).

The SMART X1 can manipulate special equipment that may be difficult to reconfigure in the case of flexible production.

For example, the SMART X1 can replace lifters (fig. 5), warehouse stacker cranes (fig. 6), etc..

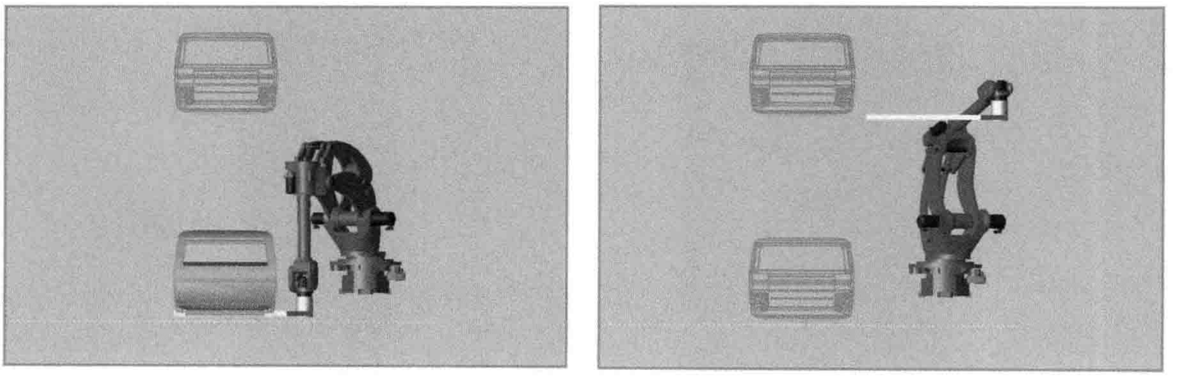


Fig. 5: Smart X1 used a lifter

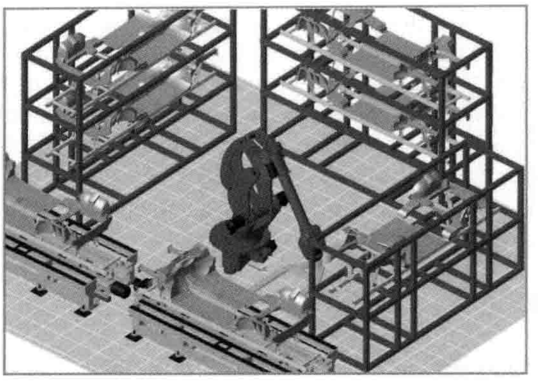


Fig. 6: SMART X1 used in a warehouse.

5 Conclusions

Body production systems require effective solutions with the most effective combination of productivity and flexibility. With this kind of modular approach described here, it possible to set up highly complex systems based on a set of simple, individually certified (standard) solutions.

This approach is based on high level standardization of the basic components of the systems. Many of these elements have been developed from a technical point of view so as to permit optimal integration of the systems; the most significant example in this context is the development of special robots able to promote maximum simplification of flexibility-related problems.

The optimal set of these components lays the bases for subsequent " best practices", i.e. system solutions able to produce bodies and the most important parts of these in accordance with the productivity/flexibility mix required.

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CONTENTS

EXECUTIVE SUMMARY

WORLDWIDE DIFFUSION OF INDUSTRIAL ROBOTS

2002 World Robot Market

Total world sales: 68,600 units, -12% over 2001

World stock of operational industrial robots: 770,000 units, +2% over 2001

World market fell by 12% in 2002...

Worldwide sales of multipurpose industrial robots peaked in 1990 when they reached over 80,000 units. Following the recession in 1991-1993, worldwide sales fell to about 53,000 units in 1993. The world robot market then started a period of strong recovery, which peaked in 1997 when it reached a level of 82,000 units. In 1998, however, sales plunged by 15% to just under 69,000 units. The market recovered sharply in 1999 with sales of nearly 80,000 units, an increase of almost 15% over 1998. In 2000, growth accelerated to 24%, attaining a record of almost 99,000 units. In **2001 and 2002, however, the world market fell by 21% and 12%, respectively, reaching 68,600 units** (see table 1 and figure 1).

...as a result of falling demand in all major markets

After two years of falling or stagnant sales, there was a sharp recovery in **Japan** in 2000. Sales of all types of industrial robots surged by 32% over 1999, reaching almost 47,000 units. As from 2001, data for Japan excludes almost all dedicated robots (only dedicated robots for machining are included). Data for 2000 and 2001 are thus not comparable. **Between 2001 and 2002, however, sales in Japan fell by almost 11% to about 25,400 units.**

From 1995 to 2000, the robot market in the **United States** was booming every second year and, in the years between, it was flat or falling. In 1995, 1997 and 1999 it increased by 32%, 28% and 37%, respectively. By contrast, in 1996 and 1998, the market dropped by 5% and 13%, respectively, while in 2000 it was almost flat (+1%). However, the highest sale of industrial robots ever recorded was in 2000 when it reached nearly 13,000 units. **In 2001, the market fell by nearly 17% to 10,800 units followed by another drop of 8% in 2002 to just under 10,000 units.**

... but robots did much better than many other types of investment goods

While the market for industrial robots fell by 8% in the United States, the market for machine tools fell by as much as 36%. In Japan and Germany the same pattern was prevailing. Machine tools fell by 32% and 20%, respectively, while robots "only" fell by 11% and 7%.

After years of booming sales the robot market in the European Union fell by 16% ...

In the **European Union**, sales of multipurpose industrial robots rose by 19% in 2000 to 29,800 units. In 2001, sales continued to grow but by a modest 3%, reaching 30,700 units. With the exception of 1997, when the market fell by 1%, the European Union has had market growth since 1994 and, except for 2001, double digit growth. This came to a halt in **2002, when the market fell by 16% to just under 26,000 units**. Almost all EU countries showed a falling demand. In the United Kingdom, the market plummeted by as much as 61%.

Is recovery around the corner? The first half of 2003 was the best first half ever recorded for robotics

Looking at the first half of 2003, the UNECE/IFR quarterly survey on order intake of industrial robots, which includes most of the world's largest companies, showed that worldwide order intake increased by 22%, compared with the same period in 2002. It was the highest order intake of industrial robots ever recorded, worldwide and in all regions, except for North America where it was the third best half year recorded. The order intake, by regions, of industrial robots during the first half of 2003, compared with the same period in 2002, were as follows:

North America	**+18%**	**Europe**	**+25%**
Asia	**+18%**	**Other regions**	**+19%**

These figures indicate that **a strong recovery is in sight** in the investment propensity in industry. They also give solid support to the forecasts described above. In fact these results for the first half of 2003 point to total sales of over 80,000 robots in 2003, compared with 68,600 in 2002 (it should be noted that the forecast of merely 73,400 units for 2003, which is indicated in table 1, is part of a trend forecast for the whole period 2003-2006 and not a short term forecast which is presented here).

Europe and the United States are rapidly catching up with Japan...

In the early 1990s, **installations of multipurpose industrial robots** in the European Union and the United States only amounted to about 20% and 7%, respectively, of Japan's installations of (all types of) industrial robots. Following the more restrictive reporting by Japan, data show that as from 2001 **more multipurpose industrial robots were installed in the European Union than in Japan**.

Looking at the **operational stock** of industrial robots, again relating Japan's stock (to which all types of robots were added up to and including 2000) to those of multipurpose robots in the European Union and the United States, the same pattern prevails. **The EU stock rose from 23% of that of Japan in 1990 to 67% in 2002. The corresponding figures for the United States were 12% and 30%, respectively**. Again, if separate data had been available for multipurpose industrial robots in Japan, they might very well have shown a stock of a magnitude between that of the United States and that of the European Union.

Estimate of the worldwide operational stock of industrial robots

Total accumulated yearly sales, measured since industrial robots started to be introduced in industry at the end of the 1960s, amounted at the **end of 2002** to some **1,328,000 units, including, as mentioned before, the dedicated industrial robots installed in Japan up to and including 2000**. Many of the early robots, however, have by now been taken out of service. The stock of industrial robots in actual operation is therefore lower. UNECE and IFR estimate the

total worldwide stock of operational industrial robots at the end of 2002 between a minimum of 770,000 units and a possible maximum of 1,050,000 units

The minimum figure above is derived on the assumption that the average **service life is 12 years**. A UNECE/IFR pilot study has indicated that the average service life might in fact be as long as **15 years**, which would result in a **worldwide stock of 1,050,000 units**.

The minimum 2002 stock of 770,000 units can be compared with 756,000 units at the end of 2001, representing an increase of just under 2%. As can be seen from table 1 and figure 2, **Japan accounts for just under half the world robot stock - largely because the Japanese figures (up to and including 2000) include all types of robots**. Its share is, however, rapidly diminishing.

As from **1998, the robot stock in Japan started to decline at an accelerated rate**. By 2002, its robot stock had fallen to only 85% of that of 1997.

Excluding Japan and the Republic of Korea, the world stock of multipurpose industrial robots amounted at the end of 2002 to 375,000 units, or 6% more than in 2001. In the **European Union** and **North America**, the stock of industrial robots rose by 6% in both regions, reaching 233,000 units and 104,000 units, respectively.

Table 1

Installations and operational stock of multipurpose industrial robots in 2001 and 2002 and forecasts for 2003-2006.
Number of units

	Yearly installations				Operational stock at year-end			
Country	**2001**	**2002**	**2003**	**2006**	**2001**	**2002**	**2003**	**2006**
Japan	**28,369**	**25,373**	**27,300**	**33,900**	**361,232**	**350,169**	**344,000**	**333,400**
United States	**10,813**	**9,955**	**11,400**	**14,500**	**97,257**	**103,515**	**111,100**	**135,200**
European Union	**30,735**	**25,866**	**26,600**	**31,800**	**219,515**	**233,139**	**248,100**	**303,500**
Germany	12,706	11,867	12,000	13,900	99,195	105,217	111,300	136,400
Italy	6,373	5,470	5,700	6,600	43,911	46,881	50,500	62,000
France	3,484	3,012	2,900	3,300	22,753	24,277	25,900	31,700
United Kingdom	1,941	750	800	1,100	13,411	13,651	13,700	14,400
Austria a/	330	670			3,153	3,521		
Benelux a/	620	620			8,590	8,674		
Denmark	330	249			1,683	1,853		
Finland	408	248			2,927	3,023		
Portugal	100	100			800	844		
Spain	3,584	2,420			16,378	18,352		
Sweden	859	460			6,714	6,846		
Other Europe	**698**	**744**	**800**	**1,100**	**11,002**	**11,013**	**10,500**	**12,100**
Czech Rep. a/	70	90			985	1,025		
Hungary	27	64			120	176		
Norway	98	80			618	664		
Poland	20	150			520	644		
Russian Fed. a/	150	190			5,000	5,000		
Slovakia b/								
Slovenia b/								
Switzerland a/	333	170			3,759	3,504		
Asia/Australia	**5,310**	**5,108**	**5,600**	**7,500**	**56,997**	**60,412**	**64,300**	**73,300**
Australia	270	510			2,953	3,310		
Rep. of Korea (all types of industrial robots)	4,080	3,998			41,267	44,265		
Singapore a/	300	100			5,458	5,346		
Taiwan, Province of China	660	500			7,319	7,491		
Other countries a/	**2,250**	**1,520**	**1,700**	**2,300**	**10,374**	**11,640**	**12,900**	**17,800**
Subtotal, excl. Japan and Rep. of Korea	**45,726**	**39,195**	**41,800**	**51,900**	**353,878**	**375,454**	**446,900**	**541,900**
Total, including Japan and Rep. of Korea	**78,175**	**68,566**	**73,400**	**91,100**	**756,377**	**769,888**	**838,400**	**875,300**

Sources: UNECE, IFR and national robot associations.

a/ Estimated by UNECE and IFR for some or for all the years.

b/ As from 1999 included in the aggregate "Other countries".

Forecasts for 2003-2006

The world market for industrial robots is projected to increase from 68,600 units in 2002 to just over 91,000 in 2006 or by a yearly average of 7.4% (see table 1 and figure 1).

Growth in robot investment in Japan will be spurred by an increasing demand for replacement investment. Between **2002 and 2006**, sales are projected to increase **from 25,400 units to almost 34,000 units** , which, bearing in mind the slump in recent years, is a rather modest recovery.

Steady growth in Europe and in North America

The robot market in the **European Union** is expected to grow from **25,900 units in 2002 to just under 32,000 units in 2006**, representing an annual average growth of 5.3% (see table 1 and figure 1). In **North America**, the market is estimated to grow by an average annual rate of 9.9%, which implies that it will reach between 14,000 and 15,000 units in 2006. In view of a somewhat optimistic economic forecast by OECD of a recovery, these forecasts for robotics, mainly based on the opinions of robotics experts, might be somewhat too conservative.