附录　翻译原文及译文

Weld robot application present condition

According to incompletely statistics, the whole world about has in the industrial robot of service nearly half of industrial robots is used for multiform weld to process realm, weld robot of application in mainly have two kinds of methods most widespreadly, then order Han and electricity Hu Han.What we say's welding robot is in fact welding to produce realm to replace a welder to be engaged in the industrial robot of welding the task.These weld to have plenty of to design for being a certain to weld a way exclusively in the robot of, but majority ofly weld robot in fact is an in general use industrial robot to pack up a certain weld tool but constitute.In many task environments, a set robot even can complete include weld at inside of grasp a thing, porterage, install, weld, unload to anticipate etc. various tasks, robot can request according to the procedure with task property and automatically replace the tool on the robot wrist, the completion corresponds of task.Therefore, come up to say from a certain meaning, the development history of industrial robot is the development history that welds robot.

Know to all, weld to process to request that welder have to have well-trained operation technical ability, abundant fulfillment experience, stability of weld level;It is still a kind of labor condition bad, many smoke and dust, hot the radiation is big, risk Gao of work.The emergence of the industrial robot makes people naturally thought of first the handicraft that replace a person with it welds and eases the welder's labor strength, can also promise to weld quality and exaltation to weld an efficiency at the same time.

However, weld again with other industry process process different, for example, electricity Hu Han process in, drive welder piece because of part heat melt with cool off creation transform, the Han sews of the track will therefore take place to change.Handicraft Han the experienced welder can sew position according to the actual Han observed by eyes adjustment Han in good time the position, carriage of the gun and run about of speed to adapt to the variety that the Han sews a track.However the robot want to adapt to this kind of variety, have to the position and status of gun that want to"see" this kind of to change,

then adopt homologous measure to adjust Han like person first, follow while carrying out to sew actually to the Han.Because the electricity Hu welds to have in process strong arc light, give or get an electric shock Hu noise, smoke and dust and Rong drop transition unsteady and causable Han silk short circuit, big electric current strong magnetic field etc. complicated environment factor of existence, the robot wants to examine and identifies a withdrawing of the signal characteristic needed for sewing Han and don't seem to be industrial the other in the manufacturing to process the examination of process so easily, therefore, welding the application of robot is to used for to give or get an electric shock the process of Hu Han in the beginning.

Actually, industrial robot at welded the application of realm to produce on-line electric resistance to order a Han beginning from the car assemble at the earliest stage.The reason lies in the process that the electric resistance orders Han opposite more simple, control convenient, and not need Han to sew a track follow, to the accuracy of the robot and repeat the control of accuracy have lower request.Order the Han robot assembles to produce a great deal of on-line application to consumedly raise the rate of production that the car assemble welds and weld quality in the car, at the same time again have a gentle characteristics for welding, then want ～only change procedure, can produce in the same on-line carry on assemble to weld to different cars type.

BE born till the beginning of this 80's in century from the robot, the robot technique experienced a development process of long term slowness.90's, along with the rapid development of calculator technique, micro-electronics technique, and network technique...etc., the robot technique is also flown soon a development.The manufacturing level, control speed and control accuracy and dependable sex etc. of industrial robot continuously raises, but manufacturing cost and price of robot continuously descend.Is social in the west, with contrary robot price BE, the person's labor force cost contains the trend to continuously increase.United Nations European Economic Committee(UNECE) statisticses from the variety curve of 1990-2000 years of the robot price index number and labor force cost index number.Among them the robot price of 1990 index number and labor force cost the index number is all reference to be worth 100, go to 2000, labor force cost index number is 140, increased 40%;But robot under the sistuation that consider a quality factor the price index number is lower than 20, lowered 80%,

under the sistuation that take no account of a quality factor, the price index number of robot is about 40, lowered 60%.Here, the robot price that takes no account of a quality factor means actual price of the robot of now with compared in the past;And consider that the quality factor means because the robot make the exaltation of craft technique level, manufacturing quality and function of robot even if want also under the condition of equal price compare high before, therefore, if pressed the past robot equaled quality and function to consider, the price index number of robot should be much lower.

Can see from here, national in the west, because the exaltation of labor force cost brings not small pressure for business enterprise, but the lowering of robot price index number coincidentally expands application to bring a chance further for it again.Reduce the equipments investment of employee and increment robot, when their expenses attains some one balance point, the benefit of adoption robot obviously wants to compare to adopt the benefit that the artificial brings big, it on the other hand can consumedly raise the automation level of producing the equipments and raise to labor rate of production thus, at the same time again can promote the product quality of business enterprise, raise the whole competition ability of business enterprise.Although robot 1 time invests a little bit greatly, its daily maintenance and consume is more opposite than its to producing far is smaller than completing the artificial expenses that the same task consumes.Therefore, from farsighted see, the production cost of product also consumedly lowers.But the robot price lower to make some small and medium enterprises invest to purchase robot to become easy to accomplish.Therefore, the application of industrial robot is soon flown a development in every trade.According to the UNECE statistics, the whole world has 750,000 in 2001 set the industrial robot is used for industry manufacturing realm, among them 389,000 in Japan, 198,000 in EU, 90,000 in North America, 73,000 at rest nation.Go to at the end of 2004 the whole world to have at least in the industrial robot of service about 1,000,000.

Because the robot controls the exaltation of speed and accuracy and particularly give or get an electric shock the development that the Hu spreads a feeling machine to combine to weld in the robot in get an application, make the robot give or get an electric shock the Han of Hu Han to sew a track to follow and control a problem to some extent and get very solution, the robot

welds in the car to make the medium application orders Han to soon develop into the car zero from originally more single car assemble partses and electricity Hu within assemble process Han.Robot's giving or getting an electric shock the biggest characteristics of Hu Han is gentle, can immediately pass to weave a distance at any time a change to weld a track and weld sequence, therefore most be applicable to quilt welder piece the species variety is big, the Han sew short but many, product with complicated shape.This at the right moment again characteristics according to car manufacturing.Being the renewal speed of the particularly modern social car style is very quick, adopting the car production line of robot material can nicely adapt to this kind of variety.

Moreover, robot's giving or getting an electric shock Hu Han not only used for a car manufacturing industry, but also can used for other manufacturing industries that involve to give or get an electric shock Hu Han, like shipbuilding, motorcycle vehicle, boiler, heavy type machine etc..Therefore, the robot gives or gets an electric shock the application of Hu Han gradually extensive, on the amount greatly have exceed the robot order the power of Han.

Along with car reducing in weight manufacturing the technical expansion, some high strong metal alloy materials and light metal alloy material(is like aluminum metal alloy, and magnesium metal alloy...etc.) get an application in the material in the car structure.These materials' welding usually can not solve with the welding of tradition method, have to adopt to lately weld a method and weld a craft.Among them, Gao power laser Han and agitation rub Han etc. to have to develop a potential most .Therefore, robot and Gao power laser Han and agitation rub combining of Han to become inevitable trend.Be like the public in Shanghai to wait domestic to most have the car manufacturer of real strenght in fact at their new car type manufacturing process in have already in great quantities used robot laser to weld.

Give or get an electric shock Hu Han to compare with robot, robot laser the Han of the Han sews to follow accuracy to have higher request.According to the general request, the robot gives or gets an electric shock the Han of Hu Han(include GTAW and GMAW) to sew to follow accuracy to control in 1| of the electrode or the Han silk diameter 2 in, at have the condition that fill the silk under the Han sew to follow accuracy to loosen appropriately.But to laser Han, the laser projects light upon the light spot in the work piece surface while

welding diameter usually at 0.6 in, is farer small than Han silk diameter(be usually bigger than 1.0), but the laser weld usually and not add to fill Han silk, therefore, the laser is welding if only the spot position has a little bit deviation, then will result in to be partial to Han and leak Han.Therefore, the robot laser of the public in Shanghai's car car crest Han in addition to pack in the work tongs up adopt measure to prevent from welding to transform, still just the robot laser Han gun front installed the high accuracy laser of SCOUT company in Germany to spread a feeling machine to used for Han to sew a following of track.

The structure form of industrial robot is a lot of, in common usely have right angle to sit mark type, flexible type, and crawl along type...etc. by mark type, many joints by mark type, surface of sphere by mark type, pillar noodles, according to different use still at continuously development in.It is many robots of joint types of the mimicry person's arm function to weld what robot can adopt a different structure form according to the applied situation of dissimilarity, but use at most currently, this because the arm vivid of many joint type robots is the biggest, it can make space position and carriage of Han gun adjust into arbitrarily the status weld by satisfying a demand.Theoretically speak, the joint of robot is many more, the freedom degree is also many more, the joint redundancy degree is big more, and the vivid is good more;But also go against the sitting of kinetics control of marking the transformation and each joint position for robot to bring complexity at the same time.Because weld to usually need in the process with the space right angle sit to mark the Han on the representative work piece to sew position conversion for the Han gun carry the space position and carriage of department and pass robot again go against the kinetics compute a conversion for to the control of robot each joint angle position, but the solution of this transformation process usually isn't unique, the redundancy degree is big, solve more many more.How select by examinations the steady that the quite the cheese solution welds to exercise in the process to the robot very important.Different treatment of system to this problem of the robot control doesn't exert a homology.

Is general to come to speak, have 6 controls request of positions and space carriages that the robots of joints basically can satisfy a Han gun, 3 among those freedoms degree(XYZ) space position used for controling a Han gun to carry

a department, another 3 freedom degrees(ABC) are used for the space carriage that controls a Han gun.Therefore, currently weld robot majority as 6 joint types.

For some weld situation, work piece because of leading big or the space is several what the shape is too complicated, make the Han gun of welding the robot can not arrive appointed Han to sew position or Han gun carriage, have to pass the freedom degree of the way increment robot of increasing 1~3 exterior stalks at this time.Usually have two kinds of way of doings:One is the orbit that the robot Be packed to to move small car or Dragon gate up, the homework space of extension robot;Two is to let the work piece move or turn, make work piece up of weld the homework space that the part gets into robot.Also have of adopt two kinds of above-mentioned ways at the same time, let the welding of work piece part and robots all be placed in the best weld position.

Weld the plait distance of robot method currently still with on-line show and teach a way(Teach-in) is lord, but wove the interface ratio of distance machine to have many improvements in the past, particularly is the adoption of LCD sketch monitor and make and weld the plait distance of the robot interface lately gradually friendly, operation more easy.However robot plait distance Han's sewing the key point on the track to sit to mark position still have to pass to show to teach the way how to obtain, then deposit the sport instruction of procedure.This sews track to some Hans of complicated shapes to say, have to cost a great deal of time to show to teach and lowered the use efficiency of robot thus and also increased the labor strength of weaving the distance personnel.The method that solves currently includes 2 kinds:

One is show to teach a plait distance just rough obtain a few Hans to sew a few keys on the track to order, then spread a feeling machine(usually is give or get an electric shock Hu to spread feeling machine or laser sense of vision to spread a feeling machine) through the sense of vision of welding the robot of auto follow the actual Han sew a track.Although this way still cans not get away from to show to teach a plait distance,this way cans ease to show the strength of teaching the plait distance to some extent and raises to weave a distance efficiency.But because of the characteristics of electricity Hu Han, the sense of vision of robot spreads a feeling machine be not sew forms to all apply to all Hans.

Two is the way that adopts a completely off-line plait distance, make the

robot weld drawing up of procedure and Han to sew a track to sit to mark adjusting of obtaining of position, and procedure to try all to compute in a set to independently complete on board, don't need participation of robot.Robot off-line plait distance as early as several years ago have, just in order to being subjected to restriction of the calculator function at that time, off-line plait distance software with text originally way is lord, wove a distance member to need to acquaint with the all instruction systems and phrasing of robot, also needed to know how made sure that the space position that the Han sews a track sits a mark, therefore, wove a distance work to not and easily save time.Along with exaltation and calculator of the calculator function 3D sketch technical development, present robot off-line plait distance system majority can under the 3D sketch environment movement, the plait distance interface amity, convenience, and, obtaining Han to sew a sitting of track to mark position usually can adopt the way of "conjecture show to teach"(virtual Teach-in), using a mouse to easily click the welding of work piece in the 3D virtual environment the part can immediately the space acquiring the sit a mark;In some systems, can sew directly born Han of position to sew a track through the Han that define in advance in the CAD sketch document, then the automatically born robot procedure combines to download robot to control system.Thus and consumedly raised the plait distance of the robot efficiency, also eased the labor strength of weaving the distance member.Currently, it is international to there have been using an off-line plait distance of robot according to the company of common PC machine on the market software.It is like Workspace5, and RobotStudio...etc..Figure 9 show develop by oneself for the writer of according to PC of 3D can see to turn an off-line plait distance of robot system.The system can IRB140 robots aiming at ABB company carry on an off-line plait distance, the Han in the procedure sews a track to pass conjecture to show to teach to acquire, and can let the robot press the track in the procedure to imitate sport in the 3D sketch environment, examine its accuracy and rationality with this.The procedure woven can pass a network directly the download to the robot controller.

The industrial robot of our country"75" science and technologies offend a pass to start starting from the 80's, currently already basic control a robot operation of the design manufacturing of the machine technique, control system hardware and software to design technique, kinetics and track to program a

technique, gave birth to parts of robot key dollar spare part, develop to spray a paint, Hu Han and order robots, such as Han, assemble and porterage...etc.;The robot of Hu Han has already applied in the Han of car manufactory to pack on-line.But total of come to see, our country of industrial robot technique and it engineering application of level and abroad than still have certain distance, such as:Credibility low outside the country product;The robot application engineering starts a little bit late and apply realm narrow, production line system technique and abroad than have a margin;The applied scale is small, didn't form robot industry.

The robot of the current our country the production is all request that applies a door, list door the single time re- design, the species specification is many, small batch quantity, zero partses are in general use to turn degree low, provide a goods period long, the cost is not low either, and the quality, credibility is unsteady.Consequently and urgently need to solve industry to turn an ex- key technique for expecting, Be to the product carry on programing completely, make good series to turn, in general use turn, the mold piece turn a design and actively push forward industry to turn progress.

3, weld robot development trend

The international robot boundaries are enlarging a research, carry on robot currently total technical research.The development trend sees from the robot technique, weld robot similar to the other industrial robot, continuously turn to the intelligence and diversify a direction to develop.Is concrete but talk, performance in as follows a few aspects:

1).The robot operates machine structure:

Pass a limited dollar the analysis and mold Tai analyze and imitate the usage of true design etc. modern design method and carry out robot operation organization of excellent turn a design.

Quest high strength light quality material, raise a load further|hold with dignity a ratio.For example, take Germany's KUKA company as the representative's robot company, have already merged robot the parallelogram structure change to opening chain structure and expand the work scope of robot, the application of light quality aluminum metal alloy material add, consumedly raise the function of robot.The RV that in addition adopts a forerunner decelerates a machine and communicates servo electrical engineering, make robot operation machine almost

become don't need support system.

The organization facing mold piece turns and can weigh to reach a direction development.For example, the servo electrical engineering in the joint mold piece, decelerate machine and examine system Christian Trinity to turn;From joint mold piece, connect a pole mold piece is constructed robot the whole machine with the reorganization method;The abroad has already had the mold piece the disguise to go together with a robot product to ask city.

The structure of the robot is getting clever, control system smaller and smaller, twos just turn a direction development toward the integral whole.

The adoption merges organization and makes use of a robot technique, realization Gao accuracy measure and process, this is the robot technique to number control technique of expand, carried out robot and number to control technique integral whole to turn to lay foundation for future.Italian COMAU company, companies like Japan FANUC,etc developed this kind of product.

附录Ⅱ

焊接机器人应用现状

据不完全统计，全世界在役的工业机器人中大约有将近一半的工业机器人用于各种形

式的焊接加工领域，焊接机器人应用中最普遍的主要有两种方式，即点焊和电弧焊。我们所说的焊接机器人其实就是在焊接生产领域代替焊工从事焊接任务的工业机器人。这些焊接机器人中有的是为某种焊接方式专门设计的，而大多数的焊接机器人其实就是通用的工业机器人装上某种焊接工具而构成的。在多任务环境中，一台机器人甚至可以完成包括焊接在内的抓物、搬运、安装、焊接、卸料等多种任务，机器人可以根据程序要求和任务性质，自动更换机器人手腕上的工具，完成相应的任务。因此，从某种意义上来说，工业机器人的发展历史就是焊接机器人的发展历史。

众所周知，焊接加工要求焊工要有熟练的操作技能、丰富的实践经验、稳定的焊接水平；它还是一种劳动条件差、烟尘多、热辐射大、危险性高的工作。工业机器人的出现使人们自然而然首先想到用它代替人的手工焊接，减轻焊工的劳动强度，同时也可以保证焊接质量和提高焊接效率。

然而，焊接又与其它工业加工过程不一样，比如，电弧焊过程中，被焊工件由于局部加热熔化和冷却产生变形，焊缝的轨迹会因此而发生变化。手工焊时有经验的焊工可以根据眼睛所观察到的实际焊缝位置适时地调整焊枪的位置、姿态和行走的速度，以适应焊缝轨迹的变化。然而机器人要适应这种变化，必须首先像人一样要“看”到这种变化，然后采取相应的措施调整焊枪的位置和状态，实现对焊缝的实时跟踪。由于电弧焊接过程中有强烈弧光、电弧噪音、烟尘、熔滴过渡不稳定引起的焊丝短路、大电流强磁场等复杂的环境因素的存在，机器人要检测和识别焊缝所需要的信号特征的提取并不像工业制造中其它加工过程的检测那么容易，因此，焊接机器人的应用并不是一开始就用于电弧焊过程的。

实际上，工业机器人在焊接领域的应用最早是从汽车装配生产线上的电阻点焊开始的。原因在于电阻点焊的过程相对比较简单，控制方便，且不需要焊缝轨迹跟踪，对机器人的精度和重复精度的控制要求比较低。点焊机器人在汽车装配生产线上的大量应用大大提高了汽车装配焊接的生产率和焊接质量，同时又具有柔性焊接的特点，即只要改变程序，就可在同一条生产线上对不同的车型进行装配焊接。

从机器人诞生到本世纪 80 年代初，机器人技术经历了一个长期缓慢的发展过程。到了 90 年代，随着计算机技术、微电子技术、网络技术等的快速发展，机器人技术也得到了飞速发展。工业机器人的制造水平、控制速度和控制精度、可靠性等不断提高，而机器人的制造成本和价格却不断下降。在西方社会，和机器人价格相反的是，人的劳动力成本有不断增长的趋势。联合国欧洲经济委员会(UNECE)统计从 1990 年至 2000 年的机器人价格指数和劳动力成本指数的变化曲线。其中把 1990 年的机器人价格指数和劳动力成本指数都作为参考值 100，至 2000 年，劳动力成本指数为 140，增长了 40%；而机器人在考虑质量因素的情况下价格指数低于 20，降低了 80%，在不考虑质量因素的情况下，机器人的价格指数约为 40，降低了 60%。这里，不考虑质量因素的机器人价格是指现在的机器人实际价格与过去相比较；而考虑质量因素是指由于机器人制造工艺技术水平的提高，机器人的制造质量和性能

即使在同等价格的条件下也要比以前高，因此，如果按过去的机器人同等质量和性能考虑，机器人的价格指数应该更低。

由此可以看出，在西方国家，由于劳动力成本的提高为企业带来了不小的压力，而机器人价格指数的降低又恰巧为其进一步推广应用带来了契机。减少员工与增加机器人的设备投资，在两者费用达到某一平衡点的时候，采用机器人的利显然要比采用人工所带来的利大，它一方面可大大提高生产设备的自动化水平，从而提高劳动生产率，同时又可提升企业的产品质量，提高企业的整体竞争力。虽然机器人一次性投资比较大，但它的日常维护和消耗相对于它的产出远比完成同样任务所消耗的人工费用小。因此，从长远看，产品的生产成本还会大大降低。而机器人价格的降低使一些中小企业投资购买机器人变得轻而易举。因此，工业机器人的应用在各行各业得到飞速发展。根据 UNECE 的统计，2001 年全世界有 75 万台工业机器人用于工业制造领域，其中 38.9 万在日本、19.8 万在欧盟、9 万在北美，7.3 万在其余国家。至 2004 年底全世界在役的工业机器人至少有约 100 万。

由于机器人控制速度和精度的提高，尤其是电弧传感器的开发并在机器人焊接中得到应用，使机器人电弧焊的焊缝轨迹跟踪和控制问题在一定程度上得到很好解决，机器人焊接在汽车制造中的应用从原来比较单一的汽车装配点焊很快发展为汽车零部件和装配过程中的电弧焊。机器人电弧焊的最大的特点是柔性，即可通过编程随时改变焊接轨迹和焊接顺序，因此最适用于被焊工件品种变化大、焊缝短而多、形状复杂的产品。这正好又符合汽车制造的特点。尤其是现代社会汽车款式的更新速度非常快，采用机器人装备的汽车生产线能够很好地适应这种变化。

另外，机器人电弧焊不仅用于汽车制造业，更可以用于涉及电弧焊的其它制造业，如造船、机车车辆、锅炉、重型机械等等。因此，机器人电弧焊的应用范围日趋广泛，在数量上大有超过机器人点焊之势。

随着汽车轻量化制造技术的推广，一些高强合金材料和轻合金材料(如铝合金、镁合金等)在汽车结构材料中得到应用。这些材料的焊接往往无法用传统的焊接方法来解决，必须采用新的焊接方法和焊接工艺。其中高功率激光焊和搅拌摩擦焊等最具发展潜力。因此，机器人与高功率激光焊和搅拌摩擦焊的结合将成为必然趋势。事实上，像上海大众等国内最具实力的汽车制造商在他们的新车型制造过程中已经大量使用机器人激光焊接。

和机器人电弧焊相比，机器人激光焊的焊缝跟踪精度要求更高。根据一般的要求，机器人电弧焊(包括 GTAW 和 GMAW)的焊缝跟踪精度必须控制在电极或焊丝直径的 1/2 以内，在具有填充丝的条件下焊缝跟踪精度可适当放宽。但对激光焊而言，焊接时激光照射在工件表面的光斑直径通常在 0.6 以内，远小于焊丝直径(通常大于 1.0)，而激光焊接时通常又不加填充焊丝，因此，激光焊接中若光斑位置稍有偏差，便会造成偏焊、漏焊。因此，上海大众的汽车车顶机器人激光焊除了在工装夹具上采取措施防止焊接变形外，还在机器人激光焊枪前方安装了德国 SCOUT 公司的高精度激光传感器用于焊缝轨迹的跟踪。

工业机器人的结构形式很多，常用的有直角坐标式、柱面坐标式、球面坐标式、多关节坐标式、伸缩式、爬行式等等，根据不同的用途还在不断发展之中。焊接机器人根据不同的应用场合可采取不同的结构形式,但目前用得最多的是模仿人的手臂功能的多关节式的机器人，这是因为多关节式机器人的手臂灵活性最大，可以使焊枪的空间位置和姿态调至任意状态，以满足焊接需要。理论上讲，机器人的关节愈多，自由度也愈多，关节冗余度愈大，灵活性愈好；但同时也给机器人逆运动学的坐标变换和各关节位置的控制带来复杂性。因为焊接过程中往往需要把以空间直角坐标表示的工件上的焊缝位置转换为焊枪端部的空间位置和姿态，再通过机器人逆运动学计算转换为对机器人每个关节角度位置的控制，而这一变换过程的解往往不是唯一的，冗余度愈大，解愈多。如何选取最合适的解对机器人焊接过程中运动的平稳性很重要。不同的机器人控制系统对这一问题的处理方式不尽相同。

一般来讲，具有 6 个关节的机器人基本上能满足焊枪的位置和空间姿态的控制要求，其中 3 个自由度(XYZ)用于控制焊枪端部的空间位置，另外 3 个自由度(ABC)用于控制焊枪的空间姿态。因此，目前的焊接机器人多数为 6 关节式的。

对于有些焊接场合，工件由于过大或空间几何形状过于复杂，使焊接机器人的焊枪无法到达指定的焊缝位置或焊枪姿态，这时必须通过增加 1～3 个外部轴的办法增加机器人的自由度。通常有两种做法：一是把机器人装于可以移动的轨道小车或龙门架上，扩大机器人本身的作业空间；二是让工件移动或转动，使工件上的焊接部位进入机器人的作业空间。也有的同时采用上述两种办法，让工件的焊接部位和机器人都处于最佳焊接位置。

焊接机器人的编程方法目前还是以在线示教方式(Teach-in)为主,但编程器的界面比过去有了不少改进，尤其是液晶图形显示屏的采用使新的焊接机器人的编程界面更趋友好、操作更加易。然而机器人编程时焊缝轨迹上的关键点坐标位置仍必须通过示教方式获取，然后存入程序的运动指令中。这对于一些复杂形状的焊缝轨迹来说，必须花费大量的时间示教，从而降低了机器人的使用效率，也增加了编程人员的劳动强度。目前解决的方法有 2 种：

一是示教编程时只是粗略获取几个焊缝轨迹上的几个关键点,然后通过焊接机器人的视觉传感器(通常是电弧传感器或激光视觉传感器)自动跟踪实际的焊缝轨迹。这种方式虽然仍离不开示教编程，但在一定程度上可以减轻示教编程的强度，提高编程效率。但由于电弧焊本身的特点，机器人的视觉传感器并不是对所有焊缝形式都适用。

二是采取完全离线编程的办法，使机器人焊接程序的编制、焊缝轨迹坐标位置的获取、以及程序的调试均在一台计算机上独立完成，不需要机器人本身的参与。机器人离线编程早在多年以前就有，只是由于当时受计算机性能的限制，离线编程软件以文本方式为主，编程员需要熟悉机器人的所有指令系统和语法，还要知道如何确定焊缝轨迹的空间位置坐标，因此，编程工作并不轻松省时。随着计算机性能的提高和计算机三维图形技术的发展，如今的机器人离线编程系统多数可在三维图形环境下运行，编程界面友好、方便，而且，获

取焊缝轨迹的坐标位置通常可以采用“虚拟示教”(virtual Teach-in)的办法，用鼠标轻松点击三维虚拟环境中工件的焊接部位即可获得该点的空间坐标；在有些系统中，可通过CAD图形文件中事先定义的焊缝位置直接生成焊缝轨迹，然后自动生成机器人程序并下载到机器人控制系统。从而大大提高了机器人的编程效率，也减轻了编程员的劳动强度。目前，国际市场上已有基于普通PC机的商用机器人离线编程软件。如Workspace5、RobotStudio等。图9所示为笔者自行开发的基于PC的三维可视化机器人离线编程系统。该系统可针对ABB公司的IRB140机器人进行离线编程，程序中的焊缝轨迹通过虚拟示教获得，并在三维图形环境中可让机器人按程序中的轨迹作模拟运动，以此检验其准确性和合理性。所编程序可通过网络直接下载给机器人控制器。

我国的工业机器人从80年代“七五”科技攻关开始起步，目前已基本掌握了机器人操作机的设计制造技术、控制系统硬件和软件设计技术、运动学和轨迹规划技术，生产了部分机器人关键元器件，开发出喷漆、弧焊、点焊、装配、搬运等机器人；弧焊机器人已应用在汽车制造厂的焊装线上。但总的来看，我国的工业机器人技术及其工程应用的水平和国外比还有一定的距离，如：可靠性低于国外产品；机器人应用工程起步较晚，应用领域窄，生产线系统技术与国外比有差距；应用规模小，没有形成机器人产业。

当前我国的机器人生产都是应用户的要求，单户单次重新设计，品种规格多、批量小、零部件通用化程度低、供货周期长、成本也不低，而且质量、可靠性不稳定。因此迫切需要解决产业化前期的关键技术，对产品进行全面规划，搞好系列化、通用化、模块化设计，积极推进产业化进程。

3、 焊接机器人发展趋势

目前国际机器人界都在加大科研力度，进行机器人共性技术的研究。从机器人技术发展趋势看，焊接机器人和其它工业机器人一样，不断向智能化和多样化方向发展。具体而言，表现在如下几个方面：

1). 机器人操作机结构：

通过有限元分析、模态分析及仿真设计等现代设计方法的运用，实现机器人操作机构的优化设计。

探索新的高强度轻质材料，进一步提高负载/自重比。例如，以德国KUKA公司为代表的机器人公司，已将机器人并联平行四边形结构改为开链结构，拓展了机器人的工作范围，加之轻质铝合金材料的应用，大大提高了机器人的性能。此外采用先进的RV减速器及交流伺服电机，使机器人操作机几乎成为免维护系统。

机构向着模块化、可重构方向发展。例如，关节模块中的伺服电机、减速机、检测系统三位一体化；由关节模块、连杆模块用重组方式构造机器人整机；国外已有模块化装配机器人产品问市。

机器人的结构更加灵巧，控制系统愈来愈小，二者正朝着一体化方向发展。

采用并联机构，利用机器人技术，实现高精度测量及加工，这是机器人技术向数控技术的拓展，为将来实现机器人和数控技术一体化奠定了基础。意大利 COMAU 公司，日本 FANUC 等公司已开发出了此类产品。