TED演讲者：Giada Gerboni | 吉阿达·格尔博尼

演讲标题：The incredible potential of flexible, soft robots | 灵活的柔性机器人潜力无限

内容概要：Robots are designed for speed and precision -- but their rigidity has often limited how they're used. In this illuminating talk, biomedical engineer Giada Gerboni shares the latest developments in "soft robotics," an emerging field that aims to create nimble machines that imitate nature, like a robotic octopus. Learn more about how these flexible structures could play a critical role in surgery, medicine and our daily lives.

机器人为速度和精度而设计——但刚性常常限制了它们的使用方式。在这个启发性的演讲中，生物医学工程师吉阿达·格尔博尼分享了"柔性机器人"的最新发展，这是一个新兴领域，旨在创造能模仿大自然的灵活机器，例如机器章鱼。进一步了解这些柔性结构是如何在手术、医疗和日常生活中发挥关键作用的吧。

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So, robots.	機器人,[00:13]
Robots can be programmed to do the same task millions of times with **minimal** error, something very difficult for us, right?	能夠編寫程式以最少出錯的次數 讓機器人完成數百萬次相同的任務, 但對我們人類來說相當困難,對吧？ [00:15]
And it can be very **impressive** to watch them at work.	看它們工作,可能令人印象很深刻。[00:22]
Look at them.	看它們。[00:26]
I could watch them for hours.	我可以連看幾個小時。[00:27]
What is less impressive is that if you take these robots out of the **factories**, where the environments are not perfectly known and measured like here, to do even a simple task which doesn't require much **precision**, this is what can happen.	不太令人印象深刻的是 如果這些機器人到了工廠外, 和這裡全然已知和測量過的 環境不一樣, 即使做個簡單、無須太精密的任務, 可能會這樣。[00:31]
I mean, opening a door, you don't require much precision.	我是說,開一扇門無須太精密。[00:46]
(Laughter) Or a small error in the **measurements**, he misses the **valve**, and that's it --	（笑聲） 或者測量中的一個小錯誤, 使它錯過了閥門,就這樣,完了。[00:49]
(Laughter) with no way of **recovering**, most of the time.	（笑聲） 大多數時候沒有辦法恢復。[00:54]
So why is that?	為什麼呢？[00:59]

Well, for many years, robots have been designed to emphasize speed and precision, and this translates into a very specific architecture.	多年來, 機器人的設計強調速度和精密度, 轉化成為非常具體的架構。[01:01]
If you take a robot arm, it's a very **well-defined** set of **rigid** links and **motors**, what we call **actuators**, they move the links about the joints.	如果拿一隻機器手臂, 用的是一套很明確的剛性鏈接 和被稱為執行器的機電, 移動關節周圍的鏈接。[01:09]
In this **robotic** structure, you have to perfectly measure your environment, so what is around, and you have to perfectly program every movement of the robot joints,	在這機器人結構裡 周圍的環境必須被完美地測量, 周圍有什麼, 也必須完美地編寫 每個機器人關節動作的指令,[01:17]
because a small error can generate a very large fault, so you can damage something or you can get your robot damaged if something is harder.	因為一個小錯誤可能會 導致非常大的錯誤, 可能損毀東西; 或者,如果那東西比較硬, 就會損毀機器人。[01:27]
So let's talk about them a moment.	讓我們來談一會兒,[01:35]
And don't think about the brains of these robots or how carefully we program them, but rather look at their bodies.	不要考慮這些機器人的腦 或它的程式寫得多仔細, 而是看它們的身體。[01:38]
There is obviously something wrong with it, because what makes a robot precise and strong also makes them **ridiculously** dangerous and **ineffective** in the real world, because their body cannot **deform** or better **adjust to** the interaction with the real world.	身體顯然有點不對勁, 因為使機器人精確和強大的因素 也使它們在現實世界中 危險和沒效率, 因為它們的身體不能變形, 也無法更適應 與真實世界的相互作用。[01:46]

So think about the opposite approach, being softer than anything else around you.	因此反向思考, 比周圍的其他事物更柔軟。[02:03]
Well, maybe you think that you're not really able to do anything if you're soft, probably.	也許你認為柔軟就辦不了事。 或許吧。[02:09]
Well, nature teaches us the opposite.	然而,大自然告訴我們的恰恰相反。[02:15]

English	Chinese
For example, at the bottom of the ocean, under thousands of pounds of **hydrostatic** pressure, a completely soft animal can move and interact with a much **stiffer** object than him.	例如,在海底, 在數千磅的靜水壓力下, 完全柔軟的動物能移動, 也能與比牠硬的物體相互作用。 [02:18]
He works by carrying around this **coconut** shell thanks to the **flexibility** of his **tentacles**, which **serve as** both his feet and hands.	牠帶著這個椰子殼走來走去, 牠的觸手靈活, 既是腳,也是手。 [02:29]
And apparently, an **octopus** can also open a jar.	很顯然,章魚能開罐。 [02:38]
It's pretty impressive, right?	令人印象深刻,對吧? [02:43]
But clearly, this is not enabled just by the brain of this animal, but also by his body, and it's a clear example, maybe the clearest example, of **embodied** intelligence, which is a kind of intelligence that all living **organisms** have.	但顯然,牠辦得到不僅由於腦, 也由於身體。 這是個明顯,也許最明顯 展現智能的例子, 一種生物具有的智能。 [02:47]

hydrostatic: adj.流体静力学的;静水力学的 **stiffer:** adj.更硬的(stiff的比较级) **coconut:** n.椰子;椰子肉 **flexibility:** n.灵活性;弹性;适应性 **tentacles:** n.[动]触手;[动]触须(tentacle的复数) **serve as:** 担任...,充当...;起...的作用 **octopus:** n.章鱼;章鱼肉 **embodied:** v.呈现(embody的过去式及过去分词形式);具体表达 **organisms:** n.[生物]生物体(organism的复数);[生物]有机体

English	Chinese
We all have that.	我們都有。 [03:03]
Our body, its shape, material and structure, plays a fundamental role during a physical task, because we can **conform to** our environment so we can **succeed in** a large variety of situations without much planning or calculations ahead.	我們的身體、形狀、材質和結構, 在做動作時起至關重要的作用; 因為我們符合環境, 因此能在各種情況下成功, 無需提前計劃或計算。 [03:05]
So why don't we put some of this embodied intelligence into our robotic machines, to release them from **relying** on excessive work on computation and **sensing**?	那為什麼不把這些展現的身體智能 放入機器人, 讓它們擺脫 過度依賴計算和感知的工作呢? [03:23]
Well, to do that, we can follow the strategy of nature, because with evolution, she's done a pretty **good job** in designing machines for environment interaction.	為了做到這一點, 我們可以遵循自然的戰略; 因為演化過程中的機器 與環境的交互作用設計得非常好。 [03:32]
And it's easy to notice that nature uses soft material **frequently** and stiff material **sparingly**.	容易注意到大自然常用軟質的材料, 很少用堅硬的材料。 [03:42]
And this is what is done in this new field or **robotics**, which is called "soft **robotics**,"	這就是在「軟式機器人」 這個新的機器人技術領域裡做的。 [03:49]

conform to: 符合;遵照 **succeed in:** 成功;在...方面成功;顺利完成 **relying:** v.依赖;信任;指望(rely的ing形式) **sensing:** n.传感;感觉;测知/adj.敏感的/v.感觉,了解(sense的现在分词) **good job:** 好运;幸运的事情;干的不错 **frequently:** adv.频繁地,经常地;时常,屡次 **sparingly:** adv.节俭地;保守地;爱惜地 **robotics:** n.机器人学

English	Chinese
in which the main objective is not to make super-precise machines, because we've already got them, but to make robots able to face unexpected situations in the real world, so able to go out there.	主要的目標不是製造超精密的機器, 因為我們已經有了; 而是要讓機器人能夠面對 現實世界中的意外情況, 能夠走出去。 [03:55]
And what makes a robot soft is **first of all** its **compliant** body, which is made of materials or structures that can undergo very large **deformations**, so no more rigid links,	要讓機器人柔軟 先要讓的它的身體柔順, 用可承受大變形的材料或結構構成, 不用剛性的連接。 [04:07]
and secondly, to move them, we use what we call distributed **actuation**, so we have to control **continuously** the shape of this very deformable body, which has the effect of having a lot of links and joints, but we don't have any stiff structure at all.	其次,用分佈式驅動來移動它們, 必須不斷地控制這種變形身體的形狀, 這種變形身體 有很多連接和關節的效果, 但沒有任何僵硬的結構。 [04:18]
So you can imagine that building a soft robot is a very different process than stiff robotics, where you have links, **gears**, **screws** that you must combine in a very defined way.	可以想像建造軟式機器人 是個非常不一樣的過程, 不是用鏈接、齒輪、 螺絲的僵硬機器人, 必須以一種非常明確的方式結合。 [04:33]
In soft robots, you just build your actuator **from scratch** most of the time, but you shape your **flexible** material to the form that **responds** to a certain input.	做軟式機器人大多時候只需從頭開始建造執行器, 但是將柔性的材料 塑造成會回應特定輸入的形式。 [04:42]

first of all: adv.首先 **compliant:** adj.顺从的;服从的;应允的 **deformations:** [力]变形 **actuation:** n.冲动,驱使;刺激;行动 **continuously:** adv.连续不断地 **gears:** n.[机]齿轮,[机]传动装置(gear的复数形式)/v.以齿轮连起,安排(gear的三单形式) **screws:** n.[机]螺丝;潜水员病;螺旋体(screw的复数)/v.用螺钉固定;用螺杆操纵(screw的三单形式) **from scratch:** 白手起家;从头做起 **flexible:** adj.灵活的; 柔韧的; 易弯曲的 **responds:** 响应

English	Chinese
For example, here, you can just deform a structure doing a fairly complex shape if you think about doing the same with rigid links and joints, and here, what you use is just one input, such as air pressure.	例如在這裡, 如果用剛性的鏈接和關節, 結構將會相當複雜; 而 (軟式結構) 這裡只需一個輸入, 例如氣壓。 [04:52]
OK, but let's see some cool examples of soft robots.	讓我們看一些軟式機器人的酷例子。 [05:05]
Here is a little cute guy developed at **Harvard** University, and he works thanks to waves of pressure applied along its body,	這裡有個哈佛大學開發的 可愛的小伙子, 由身體上施加的壓力波而行走; 並且靈活到可以在低矮的橋

and thanks to the flexibility, he can also sneak under a low bridge, keep walking, and then keep walking a little bit different afterwards.	下潛行, 一直走, 一直走,然後有些不同。[05:09]
And it's a very **preliminary** prototype, but they also built a more **robust** version with power on board that can actually be sent out in the world and face **real-world interactions** like a car passing it over it …	這是個極為初步的原型, 還有個配有電源板的進階版, 能實際在現實世界面對面交流, 例如汽車開過它的身旁,[05:27]
and keep working.	它繼續向前走。[05:41]
It's cute.	它真可愛。[05:43]
(Laughter) Or a robotic fish, which **swims** like a real fish does in water simply because it has a soft tail with distributed actuation using still air pressure.	（笑聲） 還有機器魚,像真魚一樣游在水中, 只因它有柔軟的尾巴, 用靜止空氣壓來分佈式驅動它。[05:45]

Harvard: n.哈佛大学；哈佛大学学生 **preliminary:** n.准备；预赛；初步措施/adj.初步的；开始的；预备的 **robust:** adj.强健的;健康的;粗野的;粗鲁的 **real-world:** adj.现实生活的;工作的 **interactions:** n.[计]交互,相互作用;相互交流(interaction复数) **swims:** n.游泳(swim的复数);熏鱼上附著的鳔/v.游泳(swim的第三人称单数)

That was from MIT, and of course, we have a robotic octopus.	是麻省理工學院做的。 當然,我們還有機器章魚。[05:55]
This was actually one of the first projects developed in this new field of soft robots.	實際上是軟式機器人 這新領域開發的第一批專案之一。[05:59]
Here, you see the artificial tentacle, but they actually built an entire machine with several tentacles they could just throw in the water, and you see that it can kind of go around and do **submarine** exploration in a different way than rigid robots would do.	這裡看到人造的觸手, 實際上他們造了 帶有幾隻觸手的整個機器, 可以把它扔進水中, 它可以四處走動, 以不同於硬式機器人的 方式在水裡探索,[06:04]
But this is very important for delicate environments, such as **coral reefs**.	這對珊瑚礁等微妙環境非常重要。[06:21]
Let's go back to the ground.	讓我們回到地面。[06:24]
Here, you see the view from a growing robot developed by my colleagues in Stanford.	這裡看得到史丹佛大學的同事 正開發的機器人的圖。[06:26]

You see the camera fixed on top.	相機固定在頂部。[06:31]
And this robot is particular, because using air pressure, it grows from the tip, while the rest of the body stays in firm contact with the environment.	這機器人很特別, 因為用氣壓,它向上長, 而身體的其餘部分 維持與環境的緊密接觸。[06:33]
And this is inspired by plants, not animals, which grows via the material in a similar manner so it can face a pretty large variety of situations.	它的靈感來自於植物,不是動物, 植物以類似的方式生長, 因此能面對各式各樣的狀況。[06:41]

submarine: n.潜水艇;海底生物/adj.海底的;水下的/vt.用潜水艇攻击/vi.在下疾行;在下滑动 **coral:** n.珊瑚；珊瑚虫/adj.珊瑚的；珊瑚色的/ **reefs:** n.礁石(reef的复数形式);礁体;群礁/v.收帆;降低桅杆;把(伞)收拢(reef的第三人称单数形式)

But I'm a **biomedical** engineer, and perhaps the application I like the most is in the medical field, and it's very difficult to imagine a closer interaction with the human body than actually going inside the body, for example, to perform a **minimally invasive** procedure.	我是生物醫學工程師, 我最喜歡醫學領域的應用, 難以想像還有更為緊密的 與人體的相互作用, 除非實際進入人體的內部, 例如,執行微創手術。[06:50]
And here, robots can be very helpful with the surgeon, because they must enter the body using small holes and straight instruments, and these instruments must interact with very delicate structures in a very **uncertain** environment, and this must be done safely.	在此機器人能對外科醫師很有幫助, 因為醫師們必須使用小孔 和直的器械進入人體, 這些器械必須在很不確定的環境中 與非常微妙的結構相互作用, 且必須安全地進行。[07:06]
Also bringing the camera inside the body, so bringing the eyes of the surgeon inside the surgical field can be very challenging if you use a rigid stick, like a classic **endoscope**.	將相機帶入身體內部, 將外科醫師的眼睛帶入手術區域 如果用剛性棒可能極具挑戰, 像傳統的內視鏡之類的。[07:21]
With my previous research group in Europe, we developed this self-camera robot for surgery, which is very different from a classic endoscope, which can move thanks to the flexibility of the **module** that can bend in every direction and also **elongate**.	我與以前在歐洲的研究小組一起 開發這款手術用的軟式照相機機器人, 與傳統的內視鏡很不同,它能移動, 這要歸功於模塊的靈活性, 可以向各個方向彎曲或伸長。[07:32]

biomedical: adj.生物医学的 **minimally:** adv.最低限度地;最低程度地 **invasive:** adj.侵略性的;攻击性的 **uncertain:** adj.无常的;含糊的;靠不住的;迟疑不决的 **endoscope:** n.[临床]内窥镜;内诊镜 **module:** n.[计]模块;组件;模数 **elongate:** vt.拉长;使延长;使伸长/vi.拉长;延长;伸长/adj.伸长的;延长的

And this was actually used by **surgeons** to see what they were doing with other instruments from different points of view, without caring that much about what was touched	實際上,外科醫師用這種方法 從不同的角度 觀察其他儀器進行的操作, 無須分心去在乎觸及了什麼。[07:49]

English	Chinese
around.	
And here you see the soft robot in action, and it just goes inside.	在這裡看得到軟式機器人在行動, 它進入體內,[07:59]
This is a body **simulator**, not a real human body.	這是一具模擬的人體, 不是真正的人體。[08:05]
It goes around.	它四處走動。[08:08]
You have a light, because usually, you don't have too many lights inside your body.	有個燈, 因為體內通常沒亮光。[08:10]
We hope.	最好沒有。[08:14]
(Laughter) But sometimes, a surgical procedure can even be done using a single needle, and in Stanford now, we are working on a very flexible needle, kind of a very tiny soft robot	（笑聲） 但有時候,甚至可以 用單針完成外科手術, 我們現今在史丹佛大學 研究一種非常靈活的針頭, 它是一種非常小巧的軟式機器人,[08:16]
which is **mechanically** designed to use the interaction with the **tissues** and steer around inside a solid organ.	被設計來與組織相互作用, 在堅實的器官內轉來轉去,[08:30]
This makes it possible to reach many different targets, such as tumors, deep inside a solid organ by using one single insertion point.	所以通過單個插入孔 就能到達實體器官深處的腫瘤 或許多不同目標。[08:36]

surgeons: 外科医生 **simulator:** n.模拟器;假装者,模拟者 **mechanically:** adv.机械地;呆板地;物理上地 **tissues:** n.[组织]组织,薄的纱织品;面巾纸(tissue的复数)

English	Chinese
And you can even steer around the structure that you want to avoid on the way to the target.	甚至還可以繞過[08:44]
So clearly, this is a pretty exciting time for robotics.	顯然對於機器人來說 這是個非常來勁的時刻。[08:51]
We have robots that have to deal with soft structures, so this **poses** new and very challenging questions for the robotics community, and indeed, we are just starting to learn how to control, how to put **sensors** on these very flexible structures.	有了軟式結構的機器人, 給機器人業界帶來新的、極具挑戰性的問題, 而我們實際上才剛剛 開始學習如何控制, 如何將傳感器放在這些 非常靈活的結構上。[08:54]
But of course, we are not even close to what nature figured out in millions of years of evolution.	但是當然我們還離自然界 數百萬年演變過程中的發現還遠得很。[09:07]
But one thing I know for sure: robots will be softer and safer, and they will be out there helping people.	但有一點我很肯定: 機器人會更柔軟、更安全, 它們能幫人的還多著呢。[09:12]
Thank you.	謝謝。[09:20]
(Applause)	（掌聲）[09:21]

poses: 姿势 **sensors:** n.[自]传感器,感应器;感测器(sensor的复数)