第 4 章CHAPTER 4數位孿生 — 系統實體元件的數位表示Digital Twin—Digital Representation of the Physical Components of Your System

數位孿生是現實世界的模型，能夠分析對實體系統最重要的指標和結果。它是人工智慧驅動產品使用者體驗設計的優秀模型。數位孿生建模正處於人工智慧設計使用者體驗可以有效展示其不可思議的潛力的交匯點。

A digital twin is a model of the real world that enables the analysis of metrics and outcomes that matter most to a physical system. It is an excellent model for the UX design of AI-driven products. Digital twin modeling is at the exact intersection where UX for AI design can effectively demonstrate its incredible potential.

數位孿生是方便的工具，因為它們允許設計人員以足夠完整且易於管理的方式思考現實世界的系統。這是建立系統心智模型的絕佳方式，是各種基於人工智慧的建模和預測的重要練習。最後，數位孿生對於識別和建模系統追蹤的內容以及選擇忽略的內容非常重要。

Digital twins are handy tools because they allow designers to think about real-world systems in a way that is sufficiently complete yet manageable. It is an excellent way to build a mental model of your system, an essential exercise for all sorts of AI-based modeling and predictions. Finally, a digital twin is important for identifying and modeling what the system tracks and what it chooses to ignore.

讓我們用幾個例子來演示。

Let us demonstrate with a few examples.

風力渦輪機馬達的數位孿生

Digital Twin of a Wind Turbine Motor

我最喜歡的例子之一是 GE Haliade 150 上的數位孿生，這是一台巨大的離岸風力渦輪機，我在通用電氣工作時有機會參與其中。不幸的是，整個風力渦輪機的數字孿生有點太複雜了，無法在本章中使用。然而，我們可以看看一個更簡單的模型，即偏航電機。（對於那些不熟悉三維導航軸的人來說，偏航是風力渦輪機指向的方向 [例如東或南]。您可以在此處閱讀有關偏航的更多信息：www.machinedesign.com/learning-resources/engineering-essentials/article/21834526/whats-the-difference-between-pitch-roll-and-yaw。

One of my favorite examples is the digital twin on GE Haliade 150, a gigantic offshore wind turbine, which I had a chance to work on while at General Electric. Unfortunately, the digital twin of the entire wind turbine is a bit too complicated for use in this chapter. We can, however, look at a much simpler model, that of a yaw motor. (For those unfamiliar with the three-dimensional navigational axis, yaw is the direction [such as east or south] where the wind turbine is pointing. You can read more about yaw here: www.machinedesign.com/learning-resources/engineering-essentials/article/21834526/whats-the-difference-between-pitch-roll-and-yaw.)

因此，在本章中，我們將重點關注偏航系統的七個電機之一的數字孿生，該電機控制風力渦輪機指向的方向（見圖 4.1）。

Thus, in this chapter, we will focus on the digital twin of one of the seven motors of the yaw system that controls the direction in which the wind turbine is pointing (see Figure 4.1).

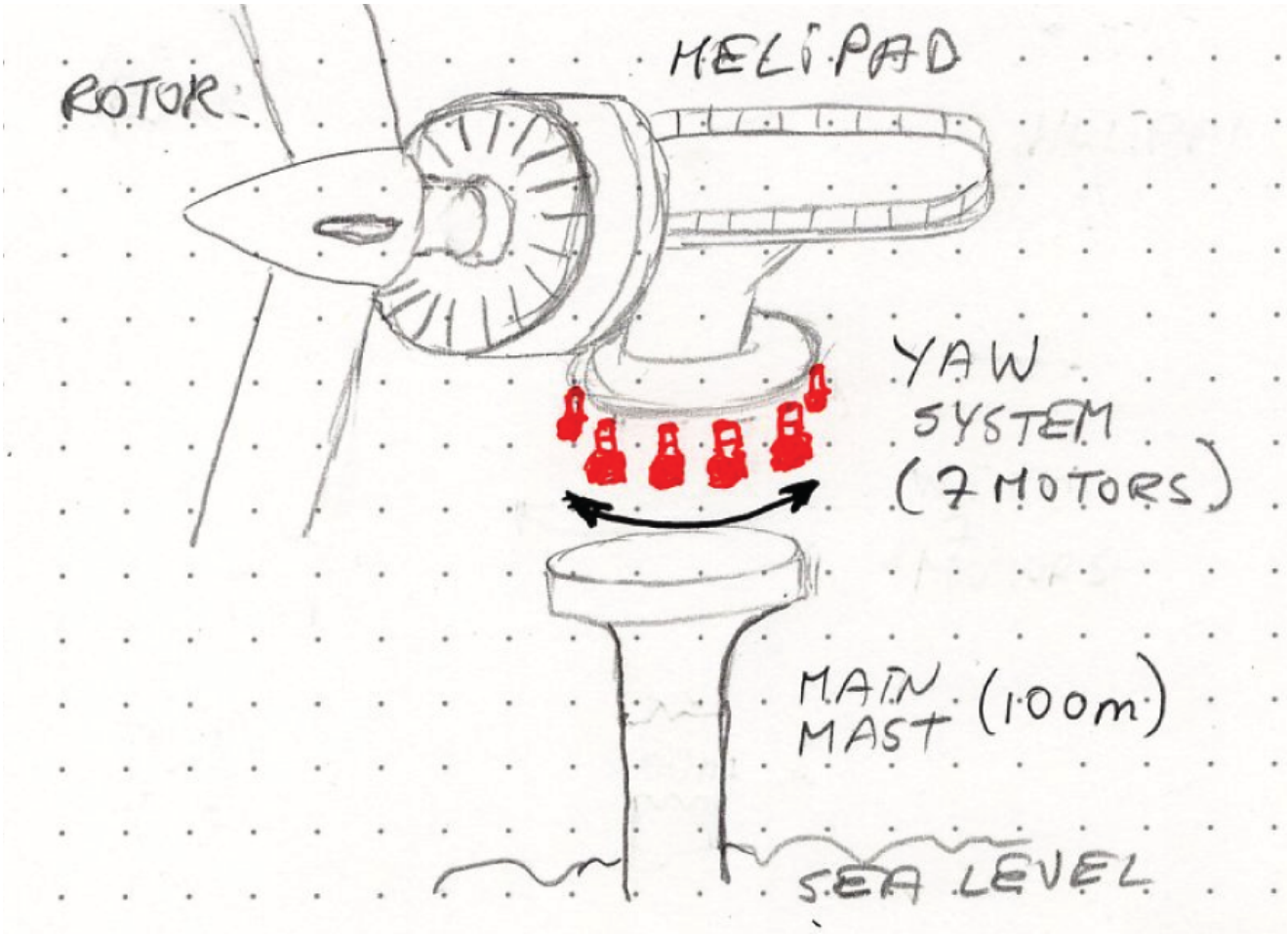

圖 4.1 GE Haliade 150 風力渦輪機示意圖，顯示七個偏航系統電機

Figure 4.1 Schematic of GE Haliade 150 wind turbine showing seven yaw system motors

每個單獨的偏航馬達都可以用一個相對簡單的數位孿生來描述，該數位孿生僅收集兩個測量值：

Each individual yaw motor can be described with a relatively simple digital twin collecting only two measurements:

- 輸入電流（發送到電機的“電力”）Input current (“electricity” sent to the motor)

- 電機溫度Temperature of the motor

使用這兩個輸入，這個數位孿生只預測一件事：剩餘的運動壽命。

Using these two inputs, this digital twin predicts just one thing: the remaining motor life.

這個簡單模型背後的基本思想是，電機運行時電機溫度跳躍得越多，其剩餘壽命就越短。直觀上，這個模型是有道理的。這有點像我們期望一輛舊車在上坡時容易過熱——車輛越舊，它就越會過熱，直到無法上山。您可以看到模型中的電機線圈過熱，因此電機可能很快就需要更換。

The basic idea behind this simple model is that the more motor temperature jumps when the motor is running, the less life it has remaining. Intuitively, this model makes sense. This is a bit like we would expect an old car to be prone to overheating when being driven uphill—the older the vehicle, the more it will overheat until it can’t make it up the hill. You can see that the motor coils in the model are overheating, so the motor will probably need to be replaced soon.

圖 4.2 顯示了手繪的數位孿生模型，總結了本章後面顯示的詳細 UI。

Figure 4.2 shows the hand-drawn digital twin model, summarizing the detailed UI shown later in the chapter.

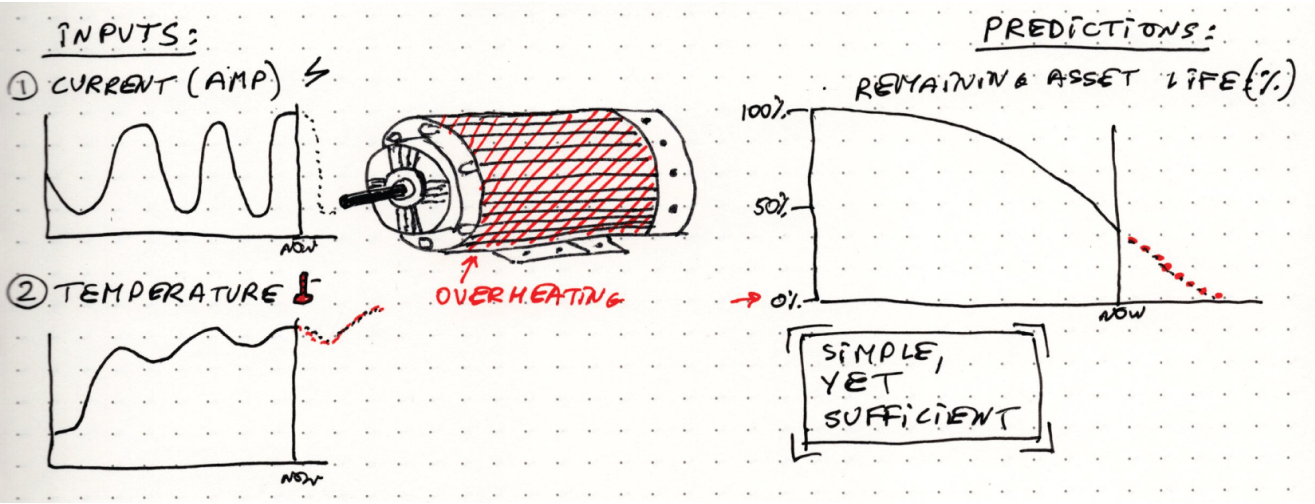

圖4.2 風力渦輪機偏航馬達數位孿生模型圖

Figure 4.2 Digital twin model diagram of the wind turbine yaw motor

GE 風力渦輪機管理軟體 （GE-WTMS） 利用這個簡單的數位孿生來建立四個詳細的螢幕，向使用者展示偏航馬達的健康狀況。這是數位孿生如何在 UI 中顯示的絕佳範例（如果有點字面意思）。

The GE Wind Turbine Management Software (GE-WTMS) leverages this simple digital twin to create four detailed screens that represent the health of the yaw motor to the user. This is an excellent (if somewhat literal) example of how a digital twin might appear in the UI.

第一個畫面如圖 4.3 所示，顯示渦輪機的零件視圖。UI 遵循簡單的主細節模式：左側的主列表顯示偏航系統的所有七個電機，當前選擇了發動機 EN4 細節。您可以直觀地確定這個特定的電機有問題，因為中間的部分發動機原理圖是紅色的（相信我，儘管這本書不是彩色的）。

The first screen, shown in Figure 4.3, displays the turbine’s Parts View. The UI follows a simple master-detail pattern: The master list on the left shows all seven motors of the yaw system, with Engine EN4 detail currently selected. You can visually ascertain that something is wrong with this particular motor because part of the engine schematic in the middle is red (trust me, although this book isn’t in color).

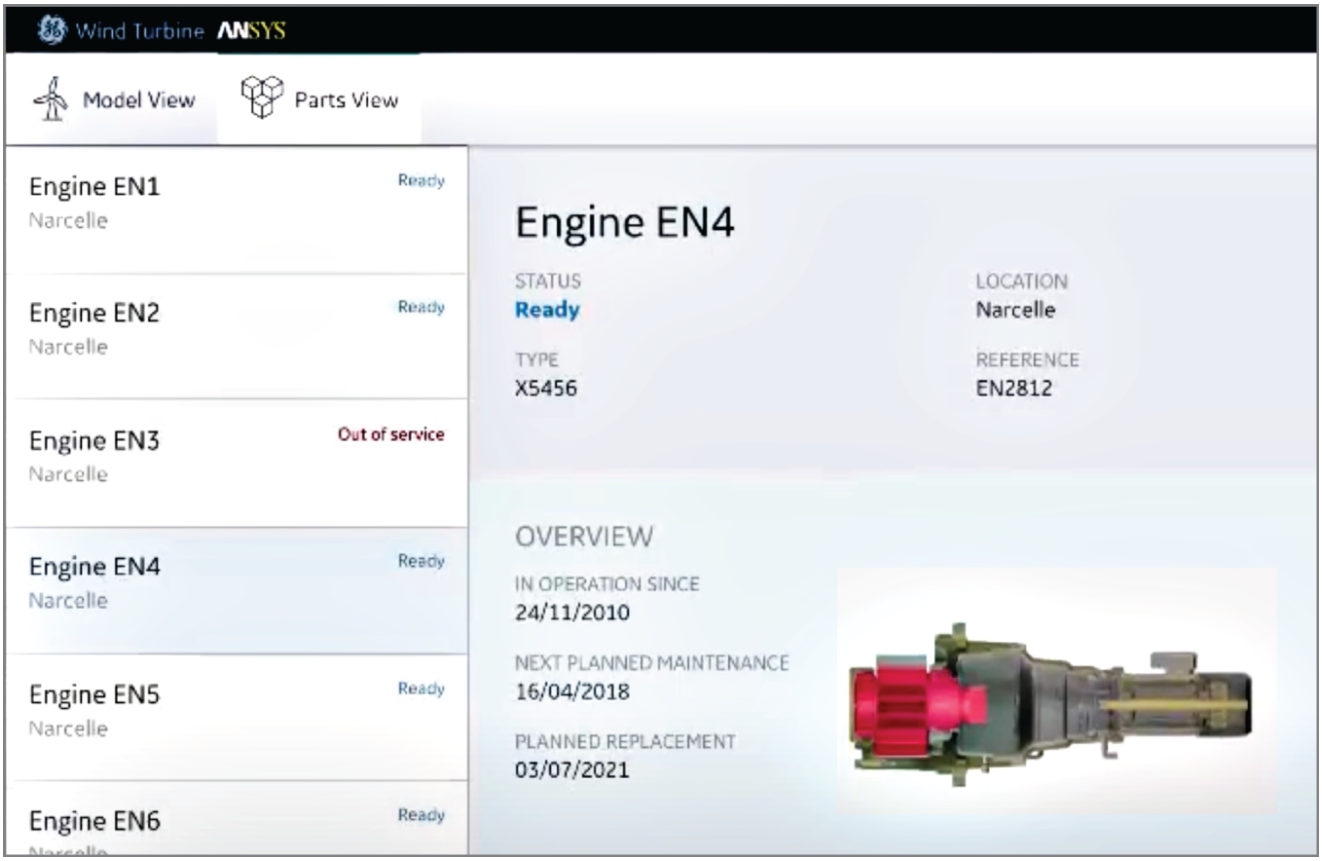

圖 4.3 顯示 EN4 偏航馬達原理圖和元資料的 GE-WTMS 零件視圖

Figure 4.3 GE-WTMS Parts View showing the EN4 yaw motor schematic and metadata

資料來源：YouTube 上的 GE：https://youtu.be/P36yJkE1zlM?si=vqXiH5uHfrputhsE

Source: GE on YouTube: https://youtu.be/P36yJkE1zlM?si=vqXiH5uHfrputhsE

第二個屏幕如圖 4.4 所示，顯示輸入電流。請注意，電流僅在某些時候打開，因為渦輪機只需要在風向改變時接合偏航系統。輸入電流的圖表顯示出週期性模式，因此也許早上風從北風吹來，下午風向南。因此，偏航系統會定期接合，將渦輪機旋轉到風中。請注意，儘管圖表具有循環性質，但預測（超過垂直“現在”線的線）預測了連續的最大輸入電流，這將不斷地圍繞羅盤點旋轉渦輪機——顯然不是一個理想的預測！我們現在可以忽略這個預測，因為我們將在第 13 章「使用折線圖進行預測」中重新討論這個主題。

The second screen, shown in Figure 4.4, displays the input current. Note that the current is only on some of the time because the turbine only needs to engage the yaw system when the wind changes direction. The graph of the input current shows a cyclical pattern, so perhaps the wind blows from the north in the morning and changes direction to the south in the afternoon. Hence, the yaw system periodically engages to pivot the turbine into the wind. Note that despite the cyclic nature of the graph,

the forecast (line past the vertical “ now ” line) predicts a continuous max input current, which would constantly spin the turbine all the way around the points of the compass—clearly not an ideal prediction! We can ignore this forecast for now, as we will revisit this topic in Chapter 13, “ Forecasting with Line Graphs. ”

第三個屏幕如圖 4.5 所示，顯示電機的溫度。請注意此圖的循環性質——它與輸入電流完全對應，這是有道理的——流過電機的電流越多，溫度就會相應升高。然而，與電流不同的是，“ 導通 ” 狀態的溫度不斷逐漸升高——也許這個電機正在老化並且效率越來越低。

The third screen, shown in Figure 4.5, displays the motor ’ s temperature. Note the cyclical nature of this graph—it corresponds perfectly with the input current, which makes sense—more current flowing through the motor will cause the corresponding increase in temperature. However, unlike the current, the temperature of the “ on ” state keeps gradually increasing—perhaps this motor is getting older and becoming less efficient.

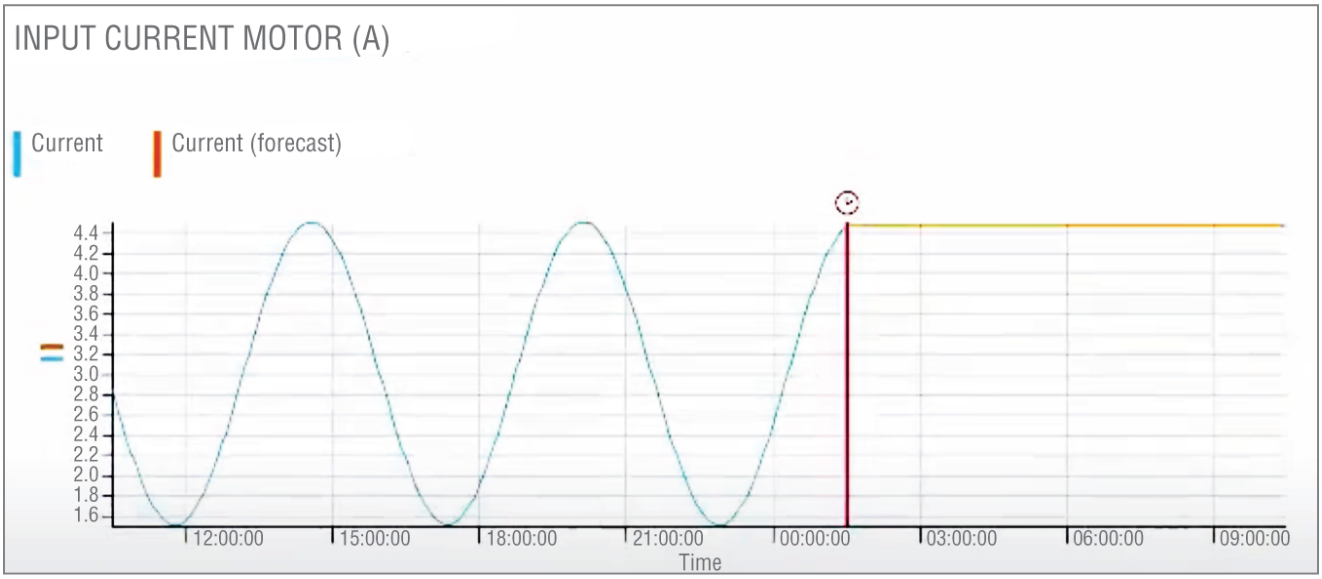

圖 4.4 顯示 EN4 輸入電流的 GE-WTMS 零件視圖

Figure 4.4 GE-WTMS Parts View showing EN4 ’ s input current

資料來源：YouTube 上的 GE：https://youtu.be/P36yJkE1zlM?si=vqXiH5uHfrputhsE

Source: GE on YouTube: https://youtu.be/P36yJkE1zlM?si=vqXiH5uHfrputhsE

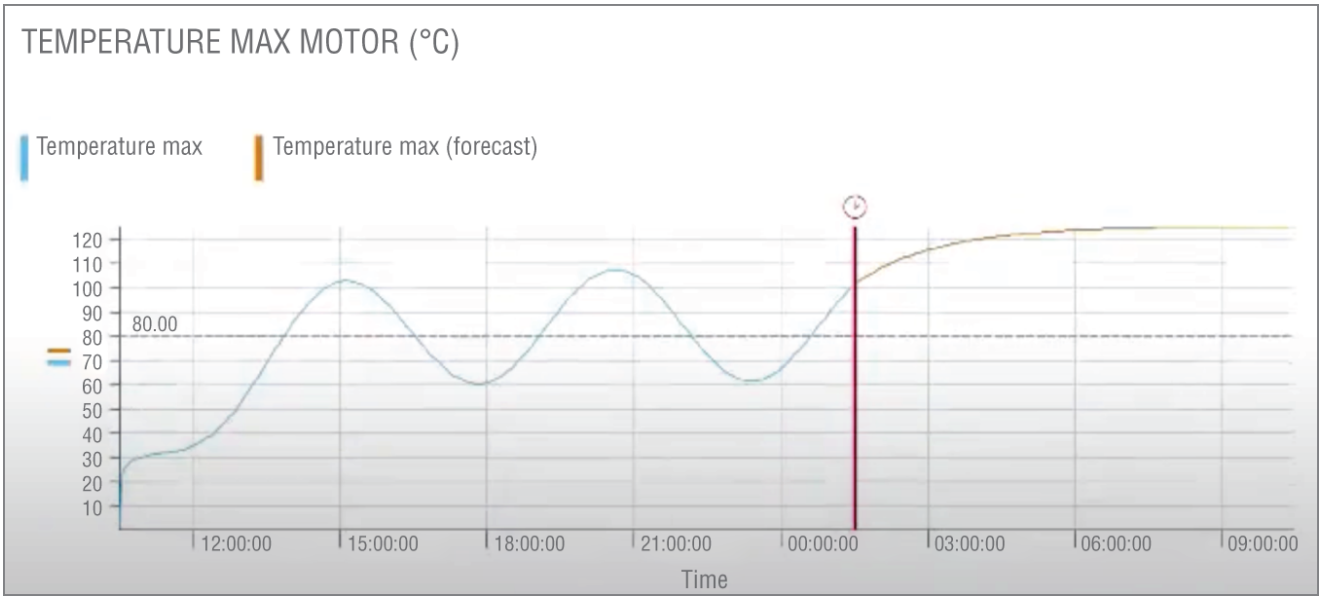

圖 4.5 顯示 EN4 溫度的 GE-WTMS 零件視圖

Figure 4.5 GE-WTMS Parts View showing EN4 ’ s temperature

資料來源：YouTube 上的 GE：https://youtu.be/P36yJkE1zlM?si=vqXiH5uHfrputhsE

Source: GE on YouTube: https://youtu.be/P36yJkE1zlM?si=vqXiH5uHfrputhsE

現在我們有了輸入電流和溫度輸入，我們可以使用 GE Predix AI 使用“ AI 魔法 ”來預測最重要的變量：剩餘資產壽命。此「剩餘壽命」圖如圖 4.6 所示。如果您可以看到插圖的顏色，您可能會注意到預測現在顯示為綠色（為一致性萬歲！無論如何，我們現在有了數位孿生模型的輸出：預測偏航馬達 EN4 將保持運作多長時間。

Now that we have both input current and temperature inputs, we can use the GE Predix AI to use the “ AI magic ” to predict the all-important variable: remaining asset life. This “ remaining lifetime ” graph is shown in Figure 4.6. If you could see the color of the illustrations, you might notice that the prediction is now shown in green (hurray for consistency!). Regardless, we now have the output of our digital twin model: the forecast of how much longer the yaw motor EN4 will remain operational.

雖然這個模型顯然非常簡單，但它對於其預期目的來說效果很好：避免讓機械師在波濤洶湧的大海中將船帶到離岸 50 英里的地方，並在每小時 50 英里的嚴酷風中爬上 100 米（30 層）陡峭的渦輪桅杆來檢查偏航電機——同時渦輪葉片以每小時 150 英里的速度旋轉！

While this model is obviously quite simplistic, it works pretty well for its intended purpose: to avoid having a crew of mechanics take a boat 50 miles offshore in rough seas and climb 100m (30 stories) up the sheer turbine mast in punishing 50-mile-per-hour winds to inspect the yaw motors—all while the

turbine blades are spinning at 150 miles per hour!

現在，考慮到派機械人員進行偏航馬達檢查的痛苦和費用，您可能會認為我們的數位孿生過於簡單：畢竟，您可以追蹤其他內容，例如馬達速度（RPM）、扭矩和馬達上各個點的溫度（例如前後滾珠軸承組的溫度， 線圈、安裝座等）、電機軸的振動、功率曲線（電流增加如何對應電機功率輸出）以及更多測量。

Now, given the pain and expense of sending the mechanics crew over for the yaw motor inspection, you might think that our digital twin is too simplistic: you could, after all, track other things, like the speed of the motor (RPM), torque, and temperatures at various spots on the motor (like that of front and rear sets of ball bearings, electrical coils, mount, etc.), vibration of the motor shaft, power curve (how increase in current corresponds to motor power output), and many more measurements.

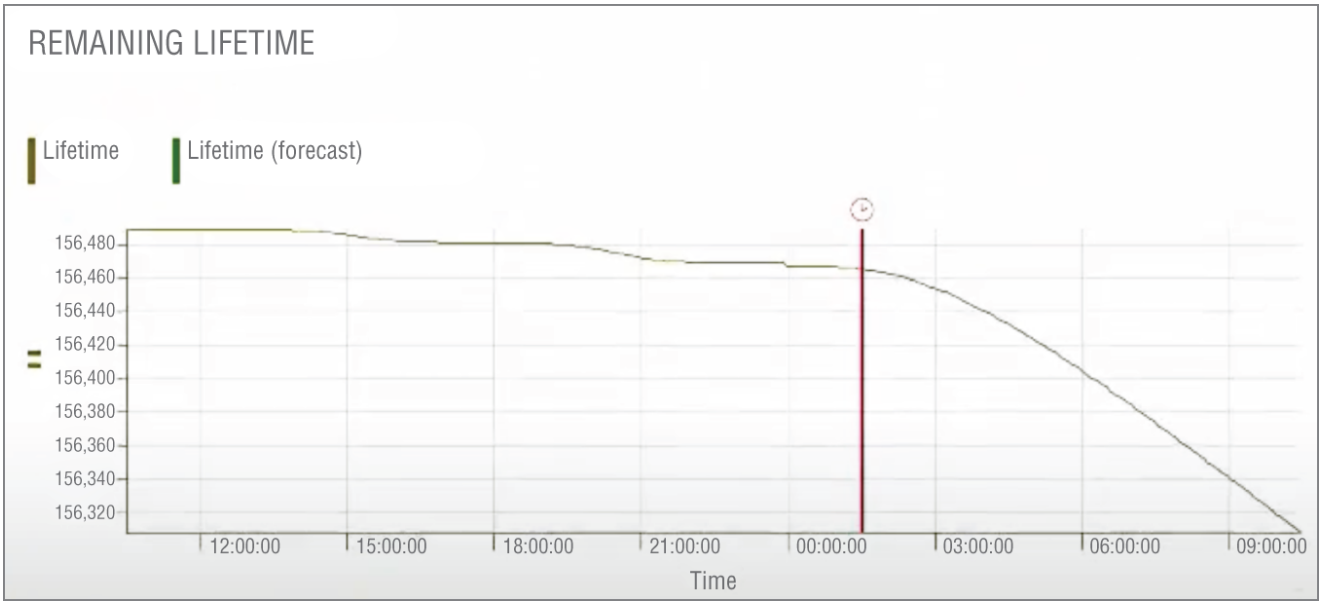

圖 4.6 顯示 EN4 剩餘壽命的 GE-WTMS 零件視圖

Figure 4.6 GE-WTMS Parts View showing EN4’s remaining lifetime

資料來源：YouTube 上的 GE：https://youtu.be/P36yJkE1zlM?si=vqXiH5uHfrputhsE

Source: GE on YouTube: https://youtu.be/P36yJkE1zlM?si=vqXiH5uHfrputhsE

GE 監控其他機器的所有這些東西——只是不監控這台電機。為什麼不呢？偏航電機是一種相對便宜且可靠的組件，安裝了三倍以上的冗餘（例如，在正常情況下，兩個電機可能足以旋轉渦輪機，而 GE 安裝了七個）。

GE monitors all of these things for other machines—just not for this motor. Why not? The yaw motor is a relatively cheap and reliable component, installed with more than triple redundancy (e.g., two motors are likely sufficient to rotate the turbine under normal circumstances, and GE installed seven).

因此，我們簡單的數字孿生對於監控該電機是必要且足夠的。在我們的特定用例中，其他測量對於機器的操作方面並不重要。套用愛因斯坦的話，數位孿生需要盡可能簡單，但不能更簡單。

Thus, our simple digital twin is necessary and sufficient to monitor this motor. In our specific use case, other measurements are not essential to the machine's operational aspects. To paraphrase Einstein, digital twins need to be as simple as possible but not simpler.

便條

NOTE

創建數字孿生的價值在於進行練習，弄清楚模型中必須包含哪些內容和哪些內容不重要，並確定模型將提供的用例。

The value of creating a digital twin is in conducting the exercise of figuring out what is essential and not essential to include in the model and nailing down the use cases your model will deliver.

數位孿生是設計人工智慧驅動產品的重要建模練習

The Digital Twin Is an Essential Modeling Exercise for Designing AI-Driven Products

數位孿生是理解和建模的重要練習。這樣一來，這有點像創建角色的練習：我的角色在乎或不在乎什麼？可用性？美學？效率？還是學習的便利性？以同樣的方式思考數位孿生的創建，但針對人工智慧系統。數位孿生應包括驅動系統操作控制的所有方面，並有助於了解要旋轉的「旋鈕」和按下的「按鈕」。

A digital twin is an essential exercise in understanding and modeling. In that way, it’s a bit like the exercise of creating a persona: what does my persona care about or not care about? Usability? Aesthetics? Efficiency? Or the ease of learning? Think of the digital twin creation in the same way, but for AI systems. The digital twin should include all of the aspects that drive operational control of the system and

contribute to knowing which “ knobs ” to rotate and “ buttons ” to push.

回想一下四個盲人和一頭大象的古老故事（來自佛教經典《提多經》;https://en.wikipedia.org/wiki/Blind_men_and_an_elephant）：摸尾巴的人認為大象像繩子，摸耳朵的人認為大象像扇子，鼻子讓人想起蛇的三分之一，等等。

Recall the old story of the four blind men and an elephant (from the Buddhist text Tittha Sutta; https://en.wikipedia.org/wiki/Blind_men_and_an_elephant): The person touching the tail thinks an elephant is like a rope, the one touching the ear thinks an elephant is like a fan, the trunk reminds the third of a snake, and so on.

便條

NOTE

就像角色創建練習一樣，創建數字孿生的練習最好由一個由四個專業組成的團隊進行：產品經理、用戶體驗設計師、開發人員主管和數據科學家，他們都專注於現實世界的用例，並具有基於現實世界用戶研究的直接主題專業知識。就像四個盲人觸摸大象一樣，作為一個團隊，您更有可能發現對您的模型真正重要的所有方面，並發現 AI
可以提供的重要用例。這種討論，這個過程，提供了創建數字孿生模型的實際價值。

Just as a persona creation exercise, the exercise of creating a digital twin is best undertaken as a team of four-in-a-box specialties: Product Manager, UX Designer, Developer Lead, and Data Scientist, all focused on real-world use cases and with direct subject matter expertise grounded in real-world user research. Just like the four blind men touching an elephant, as a team, you are much more likely to discover all of the aspects that really matter to your model and uncover important use cases the AI can deliver. That discussion, this process, delivers the actual value of creating a digital twin model.

如何建立數位孿生：範例

How to Build a Digital Twin: An Example

那麼，我們如何建立數位孿生模型呢？該過程的核心非常簡單：

So, how do we go about building a digital twin model? The core of the process is pretty straightforward:

1. 了解 AI 模型感測器從現實世界中收集哪些資訊。Understand what information the AI model sensors collect from the real world.
2. 繪製一幅直觀地代表物理世界相關方面的圖片。Draw a picture visually representing relevant aspects of the physical world.
3. 用傳入資料標記圖片。Label the picture with the incoming data.
4. 找出模型可以預測的用例和最有價值的測量值。Figure out the use case and most valuable measurements that the model can predict.
5. 記下任何遺失的傳入資料，並與團隊討論系統如何取得資料。Note any missing incoming data and discuss with the team how the system can obtain it.
6. 考慮您需要打破哪些孤島才能取得額外的資料。Consider which siloes you need to break to get the additional data.
7. 留意「令人毛骨悚然」的數據結論，例如可能影響保險費率和貸款資格的數據結論。道德很重要！Watch out for“ creepy ”data conclusions, such as those that might affect insurance rates, and loan eligibility. Ethics matter!
8. 保持謙虛。保持好奇心。迭代，迭代，迭代！Remain humble. Remain curious. Iterate, iterate, iterate!

最後一點是最重要的一點——你一開始就猜出正確的模型的可能性與盲人一樣可能通過觸摸大象的腿來準確描述大象！讓我們以智慧手錶運動追蹤器為例。智能手錶收集的最重要的測量值是人的脈搏。通過一些巧妙的測量（而且因為手錶，咳咳，跟踪時間），我們還可以收集靜息心臟和運動心臟之間的脈搏率差異。如果我們還知道這個人的年齡，我們可以將運動後脈搏恢復正常的速度與年齡相近的人進行比較，並得出大致的健康水平。因此，僅使用智慧手錶的數位孿生的第一次迭代可能如圖 4.7 所示。

The last point is the most important one—you are about as likely to guess at the right model at the outset as one of the blind men to accurately describe an elephant by touching its leg! Let ’s take, for example, the case of a smartwatch exercise tracker. The most important measurement that the smartwatch is collecting is the person ’s pulse. With some clever measurements (and because the watch also, ahem, tracks time), we can also collect the difference in pulse rate between resting and exercising heart. If we also know the person ’s age, we can compare how quickly the pulse goes back to normal after exercise to those of similar age and come up with an approximate fitness level. Thus, the first

iteration of the digital twin, utilizing just the smartwatch, might look like Figure 4.7.

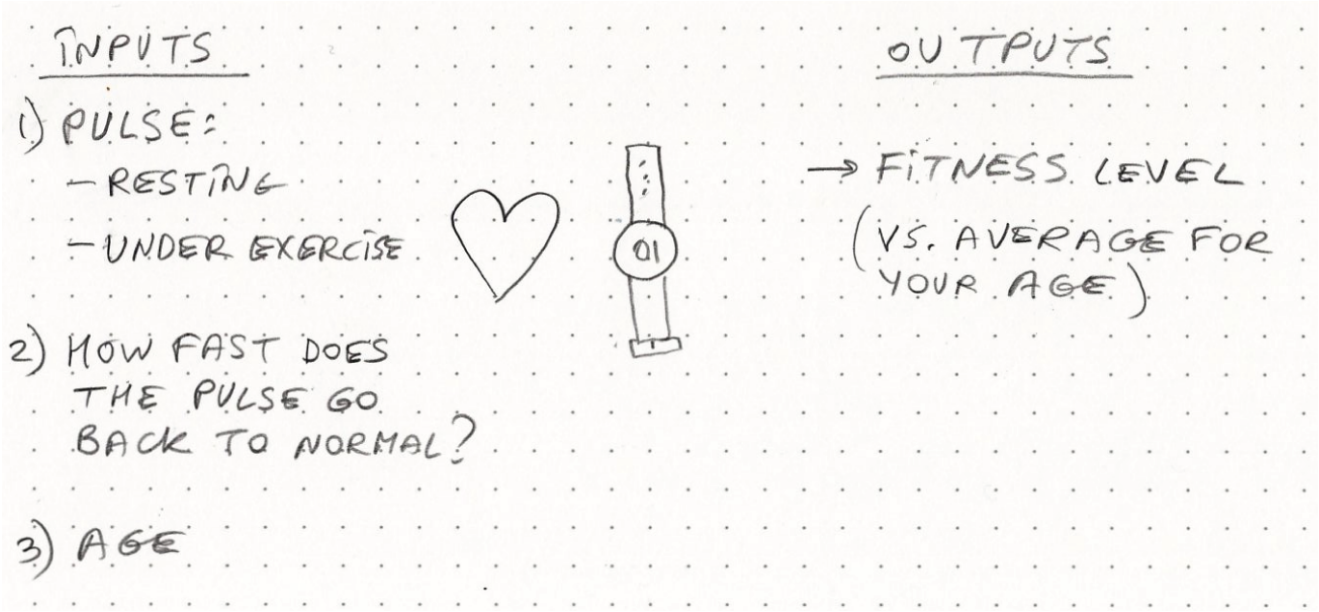

圖 4.7 數位孿生迭代 1：單獨使用智慧手錶

Figure 4.7 Digital twin iteration 1: smartwatch alone

然後，您可能會認為智能手錶通常也連接到智能手機。智慧型手機收集大量數據，例如 GPS 座標和運動步行每個點的海拔。透過使用智慧手錶與智慧型手機配對，我們可以收集各種有趣的附加數據。因此，數位孿生的下一次迭代可能包括地形圖片、綜合海拔以及（如果我們也知道該人的體重）該人上下這些卑鄙山坡所花費的工作量（見圖 4.8）。

Then, you might consider that a smartwatch is also usually connected to a smartphone. A smartphone collects a wealth of data, such as GPS coordinates and elevation of each point of the exercise walk. By using a smartwatch paired with a smartphone, we can collect all sorts of interesting additional data. Thus, the next iteration of the digital twin might include a picture of the terrain, combined elevation, and (if we also know the person ’ s weight) the amount of work the person expended to get themselves up and down those mean hills (see Figure 4.8).

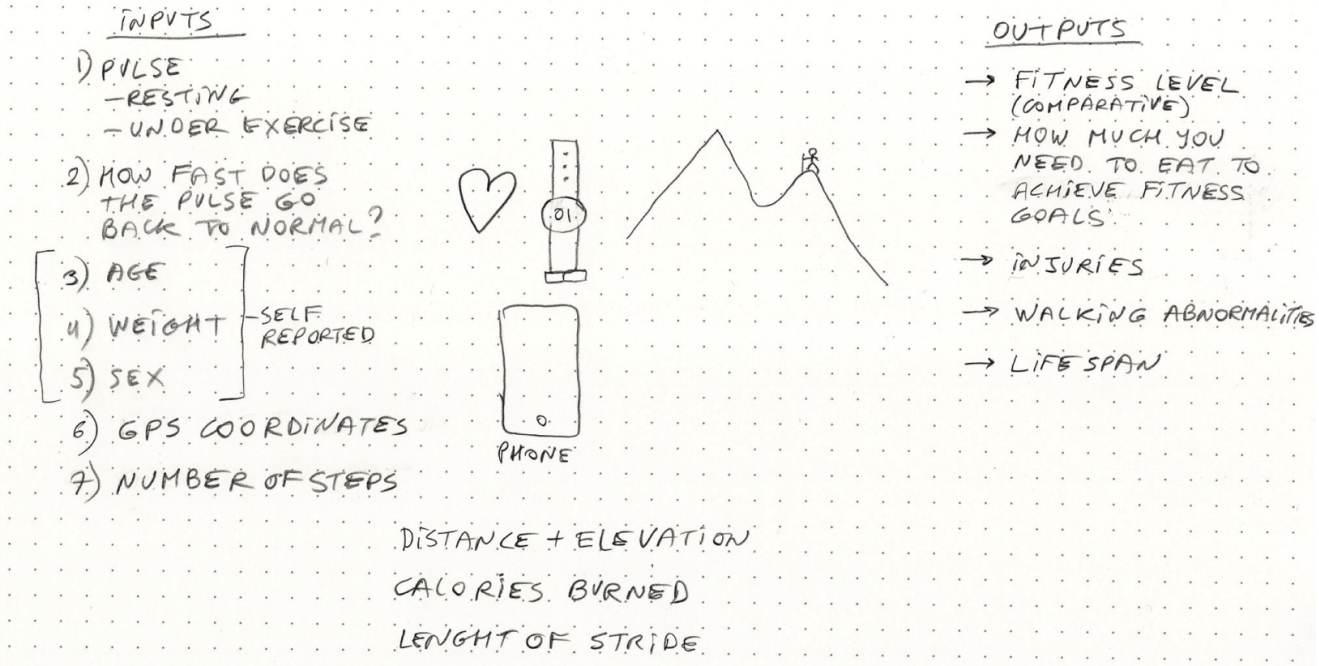

圖 4.8 數位孿生迭代 2：智慧手錶 + 帶有 GPS 追蹤器的智慧型手機

Figure 4.8 Digital twin iteration 2: smartwatch + smartphone with a GPS tracker

現在我們知道了輸入，這些資訊可以讓我們計算什麼樣的東西？如果我們知道這個人的體重，我們也知道工作，所以我們可以計算燃燒的卡路里。燃燒的卡路里是一個非常有用的測量方法，因為它們可以幫助人們在當今注重健康的世界中實現和保持健康的體重。

Now that we know the inputs, what kind of things would this information let us compute? If we know the person ’ s weight, we also know the work, so we can calculate calories burned. Calories burned are a very useful measurement because they help people achieve and maintain a healthy weight in today ’ s health-conscious world.

要完成這張照片，除了人的體重外，我們還需要知道他們的年齡和性別。所有這些信息都是自我報告的，這意味著我們無法僅通過技術來檢測它。然而，一旦我們有了這些數據，我們就可以將特定運動水平和脈搏恢復產生的脈搏聯繫起來，並得出特定個人與世界各地其他智能手錶所有者的比較健康狀況的衡量標準。換句話說，我們可以告訴人們這個特定人的健康狀況如何與同齡的其他人相比（以及富裕程度，人們認為，因為智能手錶並不便宜）。

To complete the picture, in addition to the person ’ s weight, we need to know their age and sex. All this information is self-reported, which means we cannot detect it through technology alone. However, once we have this data, we can correlate the pulse resulting from a particular level of exercise and pulse recovery and come up with a measure of the comparative fitness of the specific individual

versus other owners of smartwatches around the world. In other words, we could tell people how this particular individual ’ s fitness measures up against others of a similar age (and affluence, one presumes, as smartwatches are not cheap).

便條

NOTE

創建數位孿生的力量是一項練習，旨在弄清楚模型中哪些是必不可少的，哪些是不必要的，並確定了模型將提供的用例。

The power of creating a digital twin is an exercise in figuring out what is essential and not essential to include in the model and nailing down the use cases the model will deliver.

我們還可以測量步數，知道人的身高和預期步幅。在這種情況下，我們可以估計它們的靈活性並檢測任何行走異常，例如一條腿比另一條腿短以及膝蓋和腳踝受傷。使用這些額外的輸入數據，人們可以更準確地預測個人的壽命。如果這還沒有進入一個超級令人毛骨悚然的人壽和健康保險費用領域.....

We can also measure the number of steps and know the person's height and the expected length of stride. In that case, we can estimate how limber they are and detect any walking abnormalities, such as one leg being shorter than the other and knee and ankle injuries. Using this additional input data, one could more accurately predict the individual ’ s lifespan. And if this is not already getting into an uber-creepy life and health insurance costs territory …

等等，還有更多！

Wait, There ’ s More!

運動只是智慧型手機產業創造的一個孤島。應用程式通常會建立不必要的孤島，這些孤島不共享資料。如果我們真的想釋放更高水平的 AI，我們必須遍歷多個應用程式來收集更多數據，並為這個特定個體建立更完整的數位孿生模型。例如，我們可能還記得許多人在睡覺時也會佩戴智慧手錶。雖然這可能是在不同的應用程序中收集的數據，但它是關於同一個人收集的。如果我們從整體上處理這個問題，就會有一組令人興奮的新輸入：休息的質量和數量（見圖 4.9）。

Exercise is but one silo created by the smartphone industry. Apps often create unnecessary siloes that do not share data. If we truly want to unleash the next level of AI, we must traverse multiple apps to gather more data and build an even more complete digital twin model of this particular individual. For instance, we might recall that many people also wear their smartwatch while they sleep. And while this may be data collected in a different app, it is collected about the same exact individual. If we approach the problem holistically, an exciting new set of inputs becomes available: the quality and quantity of rest (see Figure 4.9).

但為什麼要停在那裡呢？您可以將其與典型智慧型手機可以執行的其他類型的追蹤結合，例如

But why stop there? You can combine it with other kinds of tracking that a typical smartphone can do, such as

- 在超市花錢而不是出去吃飯Spending money at the supermarket versus going out to eat
- 咖啡消費Coffee consumption
- 飛機旅行Airplane travel
- 使用的語言Languages spoken
- 每天駕車通勤的小時數Number of hours per day of driving commute
- 社區位置（加上犯罪、空氣污染、噪音等）Neighborhood location (plus crime, air pollution, noise, etc.)
- 您聽什麼樣的音樂（以及每天聽多少小時）What kind of music you listen to (and for how many hours a day)
- 螢幕時間（您花在捲動上花費的時間）Screen time (how much time you spend scrolling)
- 來自 23 和我等 DNA 追踪器的數據Data from DNA trackers like 23 and Me
- 日曆中的數據可跟踪您的社交聯繫Data from your calendar to track your social connectedness
- 職業Occupation
- 教育程度Education level
- 儲蓄Savings

- 投資風險Investments risk

- 還有很多！And many more!

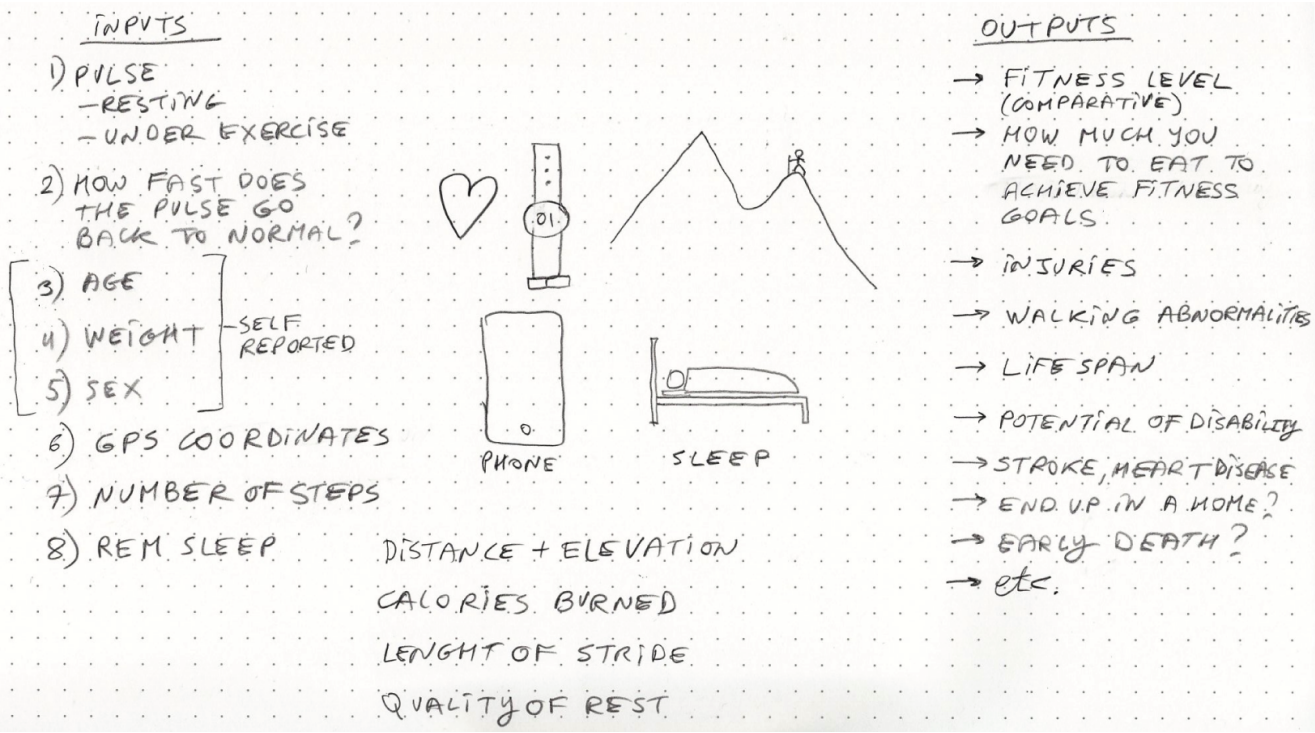

圖4.9 數位孿生迭代3：智慧手錶+智慧型手機，配備GPS追蹤器+睡眠追蹤器

Figure 4.9 Digital twin iteration 3: smartwatch + smartphone with a GPS tracker + sleep tracker

你可以看到我要去哪裡。使用這些數據，您可以非常全面地了解該人的預測壽命、運動表現、健康問題、最終接受輔助生活的可能性、過早死亡的可能性以及.....哦，還有更多。

You can see where I am going with this. Using this data, you can have a pretty complete picture of the person’s predicted lifespan, athletic performance, health problems, the likelihood of ending up in assisted living, the likelihood of early death, and … Oh, so much more.

您應該收集這些數據並建立模型嗎？就像我們之前討論的風力渦輪機偏航電機一樣，這取決於！這取決於您要預測的內容，以及擁有這些設備的人類將允許共享哪些類型的數據，以獲得您的數字孿生提供的特定見解。

Should you collect and model this data? As in the case of the wind turbine yaw motor we discussed earlier, it depends! It depends on what you are trying to predict and what types of data the humans who own these devices will allow to be shared to gain the specific insight your digital twin provides.

便條

NOTE

我們是否應該收集特定數據還取決於您建模的法律和道德考慮。請記住，並非所有資料都會被收集資料的實體使用，或用於其最初的預期目的！

Whether we should be collecting particular data also depends on the legal and ethical considerations of your modeling. Remember, not all data will be used by the entity that collected it—or for its original intended purpose!

這些討論是我們這個時代技術、人類和道德考慮的核心。（有關人工智慧倫理的更多資訊，請參閱本書的第 4 部分。

These discussions lie at the heart of our age ’ s technological, human, and ethical considerations. (See Part 4 of this book for more on AI ethics.)

便條

NOTE

數位孿生建模是關於正在測量的內容、預測的內容、要按下哪些按鈕以及針對什麼用例進行的高質量討論。在與您的團隊討論期間，首先在頁面中間繪製代表您系統的圖片。在左側標記您的資料輸入，並指出傳入的資料類型（時間序列、摘要資料、JSON 物件、圖片等）。然後，在頁面右側，標記系統將嘗試預測的變數。瞧！這就是您的數位孿生模型圖。請務必與您的團隊一起審查此模型，並討論數據來源和預測的道德影響。

Digital twin modeling is a high-quality discussion about what is being measured, what is being predicted, what buttons to push, and for what use case. During the discussion with your team, start by drawing the picture representing your system in the middle of the page. Label your data inputs on the left and indicate the kind of data coming in (time series, summary data, JSON objects, pictures, etc.). Then, on the right side of the page, label the variable your system will be trying to predict. Voil à ! That ’ s your digital twin model diagram. Be sure to review this model with your team and discuss sources of data and the ethical implications of your predictions.

設計練習：創建您自己的數字孿生

Design Exercise: Create Your Own Digital Twin

現在，輪到您為您的使用案例建立數位孿生模型了。回想一下，這通常不是單獨的活動！在現實世界中，您將與您的團隊一起執行此操作。然而，雖然運動“只是為了練習”，但不要跳過它。正如我們在第 1 章「案例研究：如何徹底搞砸你的人工智慧專案」中所討論的，以一鍋沸騰的義大利麵為例，即使是簡單的 15
分鐘數位孿生建模練習也絕對可以決定人工智慧驅動專案的成敗。

Now, it’s your turn to create a digital twin model for your use case. Recall that this is not normally a solo activity! In the real world, you would be doing this with your team. However, although exercise is “just for practice,” do not skip it. As we discussed in Chapter 1, “Case Study: How to Completely F*ck Up Your AI Project,” using a boiling pot of spaghetti as an example, even a simple 15-minute digital twin modeling exercise can absolutely make a difference between success and failure of your AI-driven project.

要在短短 10 分鐘內繪製出數位孿生草圖，請按照以下一組簡單的步驟操作：

To sketch your digital twin in just 10 minutes, follow this simple set of steps:

1. 在頁面中間，繪製一張直觀地代表系統模型的圖片。In the middle of the page, draw a picture visually representing the model of your system.
2. 傳感器收集哪些信息？標籤輸入在圖片左側。What information is collected by sensors? Label inputs to the left of the picture.
3. 請注意某些輸入是否需要自我報告或使用外部資料庫引入。您將如何訪問這些信息？Note if some inputs will need to be self-reported or brought in using external databases. How will you get access to this information?
4. 您可以計算哪些額外的輸入？把這些寫在圖片下面。（例如，可以使用體重和 GPS 坐標計算燃燒的卡路里。What additional inputs can you compute? Write those below the picture. (For example, calories burned can be calculated using weight and GPS coordinates.)
5. 您希望模型預測什麼？將輸出標記在圖片右側。What do you want the model to predict? Label outputs to the right of the picture.
6. 您的模型中有哪些類型的控制“旋鈕”可以幫助用戶影響結果？（注意：可能沒有，就像偏航電機一樣。What sort of control “knobs” are there in your model to help the user affect the outcomes? (Note: There may not be any, as in the case of the yaw motor.)

照

Reflect

- 您的 AI 模型是否需要任何其他數據來產生您想要的預測？（回想一下第一章中意大利面鍋上需要一個透明的蓋子才能看到沸騰液體的表面。Will your AI model need any other data to generate the predictions you want? (Recall the need for a transparent lid on the spaghetti pot to see the surface of the boiling liquid from Chapter 1.)
- 如果是這樣，如何/在哪裡獲得這些額外數據？If so, how/where can you get this additional data?
- 你試圖預測的是否合乎道德？Is what you are trying to predict ethical?
- 這個系統怎麼可能被濫用？How can this system potentially be misused?

便條

NOTE

如果您需要靈感，請考慮以下範例。在完成自己的設計練習之前，不要繼續下一章。

If you need inspiration, consider the following example. Do not proceed to the next chapter until you have completed your own design exercise.

設計練習範例：生命時鐘數位孿生

Design Exercise Example: Life Clock Digital Twin

回想一下我們在第 3 章「人工智慧專案的故事板」中的「生命時鐘」故事板。這是我們故事板中描述的系統的數位孿生模型（見圖 4.10）。

Recall our “ Life Clock ” storyboard from Chapter 3, “ Storyboarding for AI Projects. ” Here ’ s the digital twin model for the system described in our storyboard (see Figure 4.10).

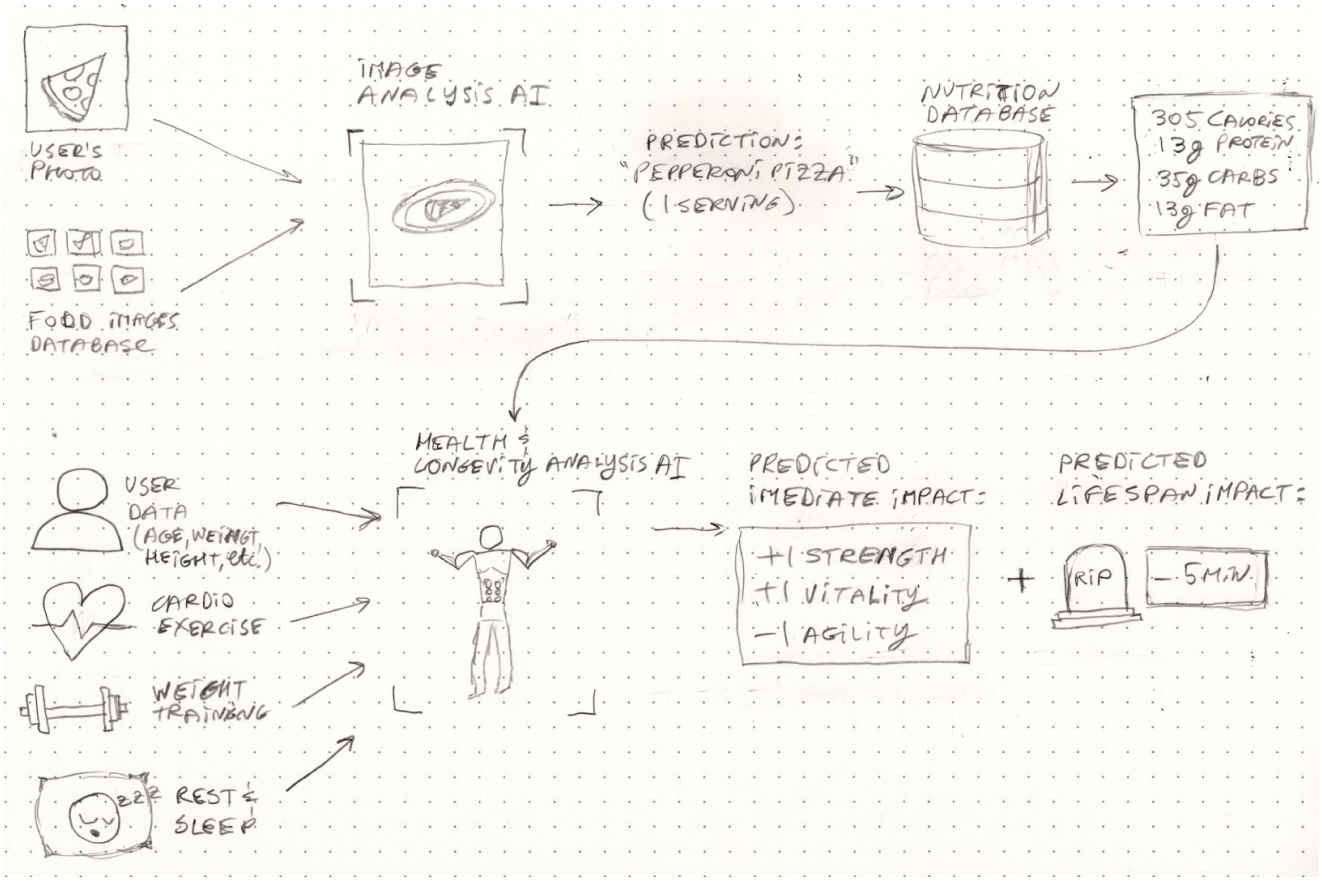

圖 4.10 生命時鐘應用程式的完整數位孿生練習

Figure 4.10 Complete digital twin exercise for the Life Clock app

在圖表的第一行中，我們向 AI 提供了標記食物圖像的數據庫，我們將用它來訓練我們的模型。當用戶提供食物圖片時，我們將其傳遞到圖像分析 AI 模塊中，該模塊返回對食物是什麼和份量的預測（例如，“ 意大利辣香腸披薩，一份 ”）。營養數據庫中的查找提供了卡路里和宏量（蛋白質、碳水化合物、脂肪）的基本數量。

In the first row of the diagram, we provide the AI with the database of labeled food images with which we will train our model. When the user provides a picture of the food, we pass it into an image analysis AI module, which returns a prediction of what the food is and the number of servings (e.g., “ pepperoni pizza, one serving ”). A lookup in the nutrition database provides a base number of calories and macros (protein, carbs, fat).

在第二行，營養數據與用戶的個人數據、有氧運動、體重、運動和休息相結合，並輸入到健康和長壽分析AI模型中。該模型返回預測的即時影響、D&D
風格（由於蛋白質而產生的 +1 力量、由於高脂肪和高加工碳水化合物含量而導致的 -1 敏捷性等），以及對此人壽命的整體預測影響（-5

分鐘，因為意大利辣香腸片不是久坐生活方式中最健康的膳食）。

In the second row, the nutrition data is combined with the user’s personal data, cardio, weight, exercise, and rest, and fed into a health and longevity analysis AI model. This model returns the predicted immediate impact, D&D style (+1 Strength due to protein, −1 Agility due to high fat and high processed carb content, etc.), as well as the overall prediction impact on this person’s lifespan (−5 minutes as the pepperoni slice is not the healthiest meal as part of a sedentary lifestyle).

如果您正確地進行了數位孿生練習，您最終應該會得到類似的圖表，但當然，對於您自己的用例來說，這可能會略有不同。如果您還沒有做過練習，請現在停下來做。（已經完成了？來一塊餅乾——你賺來的！

If you did the digital twin exercise correctly, you should end up with a similar diagram, but of course, for your own use case, which might be slightly different. If you have not done the exercise yet, please stop and do it now. (Done already? Have a cookie—you earned it!)