DL in Commercial Healthcare Applications

Data Sciences Institute
Topics in Deep Learning

Outline

- Generating value with DL
- Maintaining value of DL applications
- DL in biotechnology
- DL in medical devices
- DL in telemedicine

Generating Value with DL

DL can do cool stuff, so what?

- We've seen how DL models can help fill many knowledge gaps in healthcare research

- However, outside academia, knowledge generated in the form of predictions, classifications, and artificially-generated content are worthless on their own

- The **real-world value** of DL applications lies in how they can influence and improve downstream processes

DL as a decision support tool

- In commercial settings, successful DL applications can be broadly regarded as decision support tools
  - **Prediction:** Stock price prediction models help investors make better investment decisions
  - **Classification:** Email spam detection models help alleviate the decision burden placed on human users by automatically identifying and filtering out potentially harmful emails
  - **Generation:** ChatGPT can accelerate decision making by retrieving and distilling key information from vast amounts of text data

Assessing value of DL applications

- Under this framework, there are three key steps in commercial model development that relate to value, all of which require close stakeholder engagement:

  1. Decision identification (hypothetical value): which downstream decision do we seek to improve upon and why?

  2. Improvement identification (potential value): assuming ideal model performance, can this decision actually be improved?

  3. Downstream action plan: (actual value) which additional workflows have to be in place before decisions can be improved?

Scenario: drug prescriptions

Consider a drug known to incur high morbidity side-effects in 50% of patients. Clinicians have expressed an interest in tools enabling side-effect risk prediction for this drug, given that they want to minimise patient morbidity

- Given just this information, **is there enough value here to motivate building a predictive DL model for commercial purposes?**

Risk of failure due to uncertainties

- The decision of whether or not to prescribe the drug seems like a good target for decision support DL tools
- That being said, this value remains hypothetical, since it is unclear whether or not this decision can be improved
  - In other words, it is possible that clinicians would not change their current prescription decisions even when knowing that a patient will develop unwanted side-effects
  - Maybe this is the only available treatment and its benefits always outweight its risks
- In this case, building a DL model with just this information could have a high risk of failure regardless of predictive performance

The importance of downstream action plans

Suppose now that there does exist an alternative treatment specifically designed for patients at high risk of adverse drug side effects

- There is now potential value in this context, since side-effect risk predictions **can** help improve drug prescription decisions

- The amount of potential value that is translated into actual value hinges on the characteristics of downstream action plans
  - Transmitting raw model outputs to decision makers is the simplest action plan, though often suboptimal
  - In this case, clinicians would probably appreciate receiving detailed reports only for patients at high risk along with suggested care pathways and any relevant patient information

Value is ultimately determined by the consumer

- **Take-home message:** DL models with perfect performance can be worthless in commercial settings, since value is ultimately determined by the consumer

- For this reason, the development of commercial DL applications differs greatly from purely scientific applications, demanding the development of a sensible business model long before the start of any DL work

Maintaining Value of DL

Several factors impact perceived value

- To ensure longlasting revenue streams, dynamic factors governing the perceived value of commercial DL applications have to be taken into account post-deployment
  - These additional considerations further differentiate academic and commercial applications of DL methods

Continued market research

- Continued market research is essential for businesses to stay informed about changes in the marketplace, identify new opportunities, assess risks, and make informed strategic decisions

- It involves monitoring dynamic factors such as:
  - Evolving consumer behaviours
  - Market trends
  - Competitor activities
  - Emerging technologies
  - Brand reputation
  - And more!

Continued development

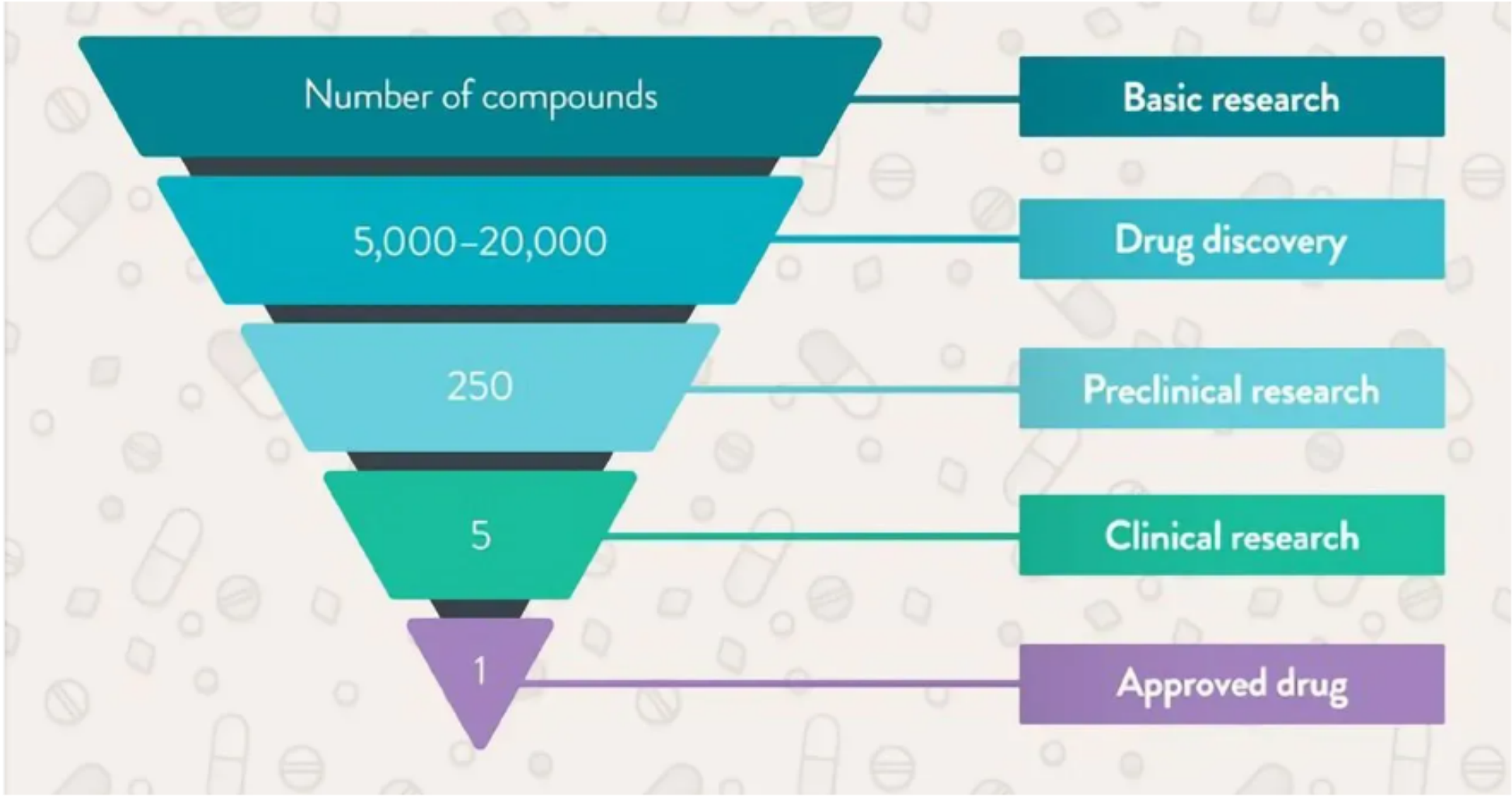
- Continued development is crucial to maintain and/or enhance the performance, efficiency, and relevance of a DL application over time

- It involves monitoring and adapting to dynamic factors within the deployment environment such as:
  - Distribution and performance drift
  - Infrastructure changes
  - Regulatory changes
  - Security threats
  - Resource availability

Commercial Applications: Biotechnology

The high cost of drug discovery

- Drug discovery is a very time-consuming and expensive process
  - In 2013, the cost of developing a new drug was estimated to be **$5 billion per successful drug** for large pharmaceutical companies[1]
  - These high costs were associated with many factors, including high failure rates in early stages of development and massive R&D costs


Number of compounds
5,000–20,000
250
5
1
Basic research
Drug discovery
Preclinical research
Clinical research
Approved drug

2

How DL could revolutionise drug discovery

- Leveraging large banks of biochemical data, DL has the capacity to analyse intricate disease pathways, enhance the efficiency of identifying potential drug targets and candidates, and ultimately mitigate failure rates during the initial phases of discovery

2023: first DL-developed drug enters phase 2

- In June of 2023, Insilico Medicine announced the first DL-developed drug to enter phase 2 clinical trials[3]
  - The drug is meant to treat idiopathic pulmonary fibrosis (IPF) and started being developed in 2019

- Hundreds of generative DL models played a role in:
  1. identifying potential target proteins associated with IPF, and
  2. identifying molecules that could disrupt the activity of a target protein

- Alex Zhavoronkov, co-founder of Insilico Medicine, thinks this approach shaved off a couple of years from the usual R&D process

Example business model

- **Target decision-maker:** pharma companies
- **Target downstream decision:** which drugs should be developed next?
- **Action plan:** given a particular disease context, provide pharma companies with a list of candidate drugs ordered by expected development success
- **Expected value for the end-user:** lower failure rates at early R&D stages, and, ultimately, cheaper and faster drug development

Great interest in DL for biotechnology

- Many drug developers have recently established partnerships with AI giant NVIDIA over the past few years, including Amgen, AstraZeneca, GSK, Genentech, and the very own Insilico Medicine[4]

- These partnerships reflect a shift within the biotechnology industry towards AI-based life sciences for cheaper and faster drug discovery

Commercial Applications: Medical Devices

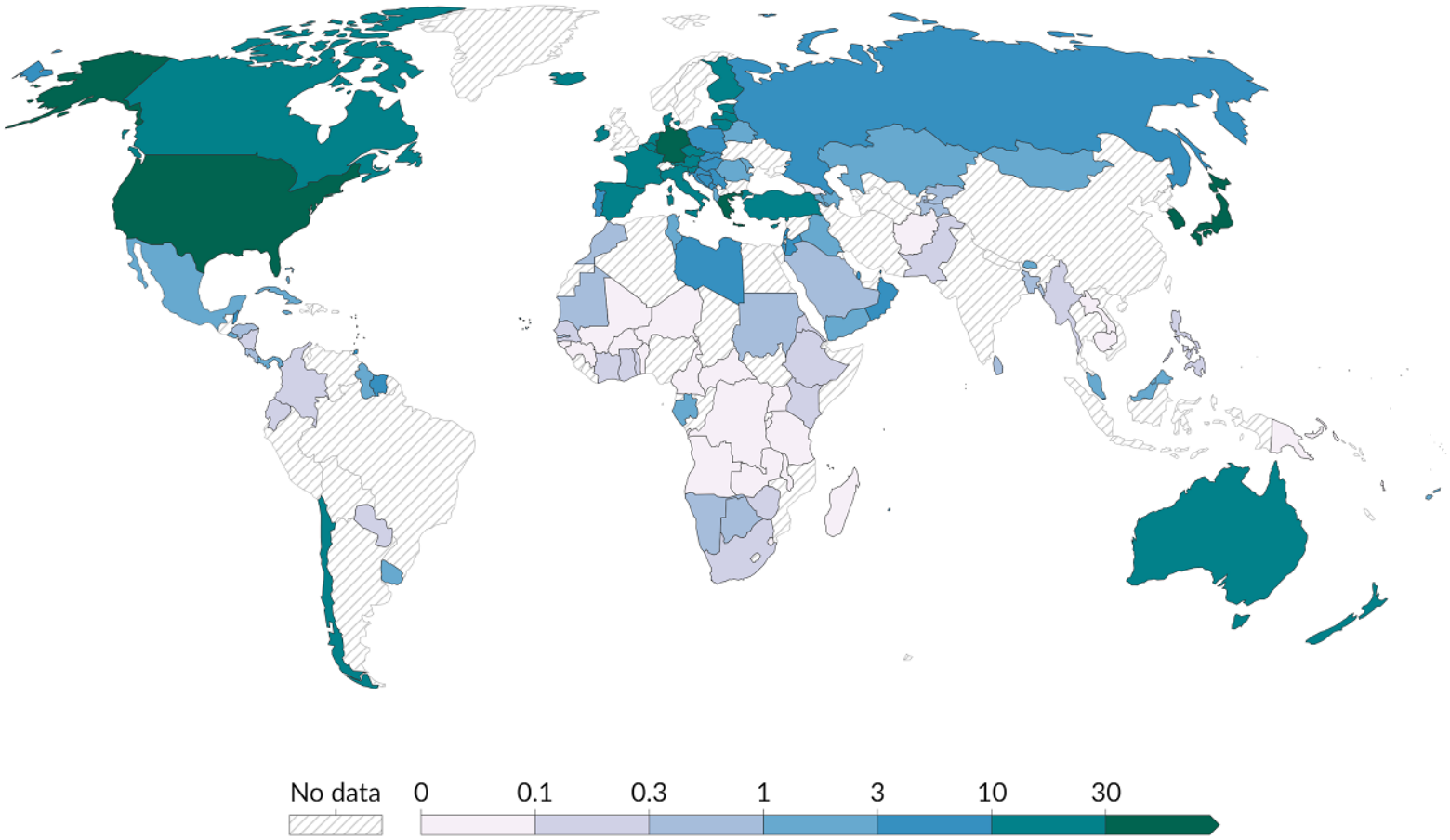
Limited global access to medical imaging

- Healthcare centres in low-and-middle income countries (LMIC) lack access to medical imaging devices as well as the expertise required to operate them[5]
  - Given that these technologies enable early detection and intervention in various disease contexts, this translates into increased morbidity and mortality from preventable causes in these regions

Magnetic resonance imaging (MRI) units per million people, 2021

Our World in Data

Number of MRI[1] units, machines that use magnetic fields and radio waves for detailed body imaging, per million people in the population.



Data source: World Health Organisation (2022)

OurWorldInData.org/cardiovascular-diseases | CC BY

1. Magnetic Resonance Imaging (MRI): Magnetic Resonance Imaging (MRI) is a medical imaging technique that utilizes powerful magnets and radio waves to produce detailed images of internal body structures. MRI is known for its safety and is used for diagnosing various medical conditions, including those affecting the brain, spine, joints, liver, kidneys, breasts, heart, and blood vessels.

How DL could increase access to quality care

- DL applications can expand access to medical imaging technologies by reducing the level of expertise needed for image acquisition and interpretation
  - **Assisted imaging** enables the use of imaging devices by lesser-skilled users
  - **Automated analyses** alleviates the need for highly specialised expertise when interpreting imaging results

2023: GE Secures $44M grant to develop assisted ultrasound technology for LMIC

- The Bill & Melinda Gates Foundation awarded GE with $44M to enable quick and accurate ultrasound scans by healthcare professionals with less experience, seeking to improve maternal and fetal health outcomes[6]

Example business model

- **Target decision-maker:** healthcare practitioners with general, nonspecific expertise in LMIC or rural areas
- **Target downstream decision:** which steps should be followed when examining pregnant women?
- **Action plan:** develop user-friendly DL interfaces for assisted imaging and automated image analysis, integrate these into affordable ultrasound technologies, and develop suggested care pathways for various imaging results
- **Expected value for the end-user:** increased screening, early detection and early intervention for common complications of pregnancy, leading to a decreases in preventable mortality

Other medical device applications: robotics

- Cutting edge applications of DL in medical devices extend to its integration with robotics in various medical domains[7], such as:
  - robot-assisted biopsies,
  - fully-autonomous surgical procedures,
  - and smart exoskeletons rehabilitation assistance

Commercial Applications: Telemedicine

Healthcare system strain

- Aging populations and healthcare workforce shortages along with a higher incidence of chronic disease, addiction and respiratory illness over the past few years have resulted in an overly strained Canadian healthcare system [8]
    - This has led to decreased quality of care, staff burnout, and public distrust, all of which further exacerbate healthcare system strain in a vicious cycle

Telemedicine: an incomplete solution

- Telemedicine refers to the remote delivery of healthcare services enabled by telecommunications technologies

- By enabling remote consultations, telemedicine can help alleviate some healthcare system strain. However, it has some glaring drawbacks
  - The requirement of a healthcare practitioner at the other end of the line means this solution remains hindered by labor shortages
  - Voice and video assessments do not provide sufficient information to properly screen for various conditions, which dramatically reduces the usefulness of many remote appointments

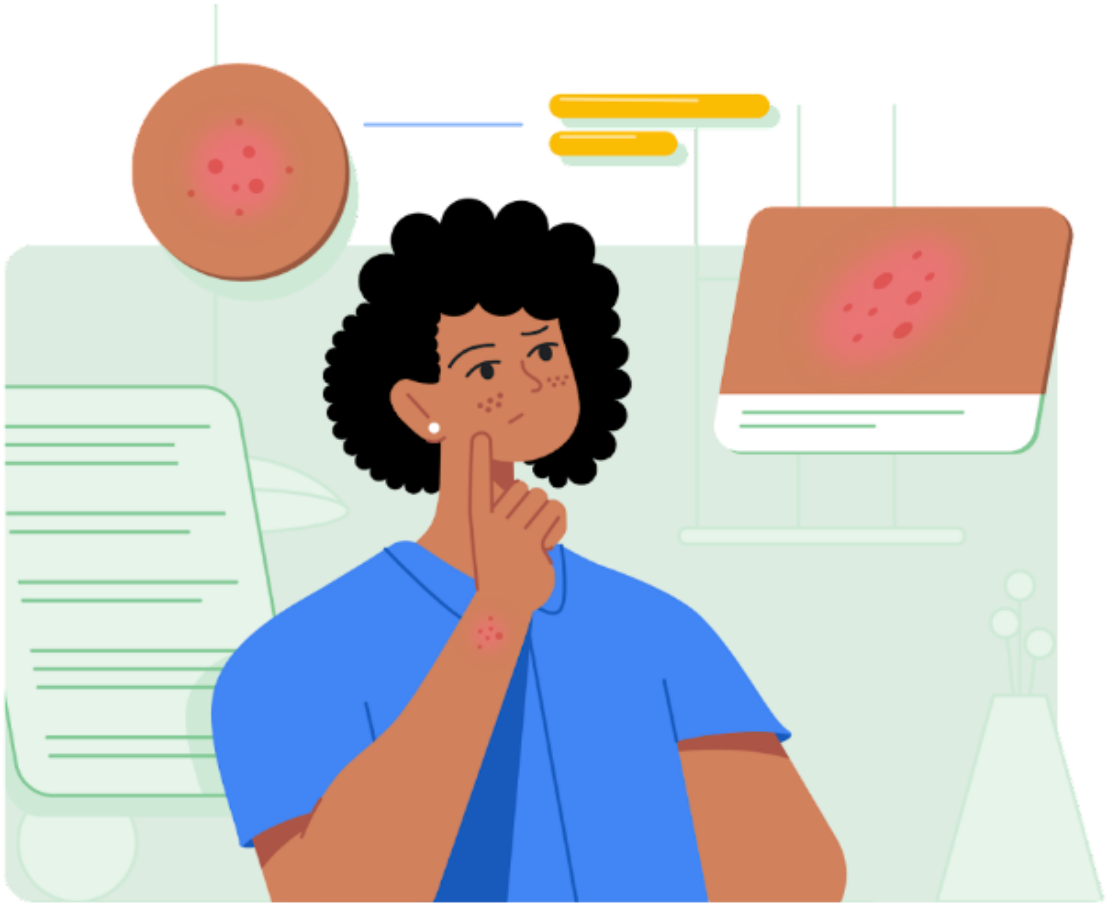
DL and telemedicine

- DL can leverage the increasing abundance of portable and wearable sensors to enable AI-assisted (and maybe eventually fully automated) remote symptom screening

Google's DermAssist

- In 2021, Google announced the release of DermAssist, a DL-powered tool designed to assist in screening and diagnosing skin conditions[9]
  - The app asks the user for 3 pictures of a skin concern, along with some additional questions, then provides the closest matches it can find within its database

- Later, in 2023, it was announced that Google Lens would be equipped with a similar functionality, being able to search skin conditions that are visually similar to what you a user may see on their skin[10]
- **NB:** in both cases, Google stressed their intentions to **assist**, but not replace, the symptom screening process



Identifies 288 skin, hair, and nail conditions

Built with dermatologists

DermAssist is the culmination of years of machine learning research, dermatologist-reviewed content, user testing, and product development. Our image search technology is constantly improving, and we've come a long way from our foundational research paper.

Built to be comprehensive

Trained using millions of skin images, DermAssist can identify more than 90 percent of the most commonly searched-for skin conditions, and research demonstrates that the underlying technology can help clinicians better identify skin conditions across all populations.

Example business model

- **Target decision-maker:** patients and/or healthcare practitioners involved in remote symptom screening for skin conditions
- **Target downstream decision:** what should the next steps be in addressing this skin concern?
- **Action plan:** provide end-users with a list of known skin conditions that best match their concern
- **Expected value for the end-user:** better-informed decision making around skin conditions that are being screened remotely, enhancing the effectiveness and efficiency of telemedicine appointments

Mostly emerging applications

- Regulatory agencies and tech companies remain cautious when defining the potential of DL tools in remote symptom screening
  - Currently, the goal is to assist, but not replace, routine screens

- Nevertheless, with further expected advances in portable and wearable sensors, the future of DL-enhanced remote symptom screening remains promising[11,12]

Conclusion

DL applications have a bright future in commercial healthcare

- DL offers significant potential for enhancing patient outcomes and streamlining healthcare delivery

- Value identification, continued market research and continued development efforts are essential to ensure the relevance and effectiveness of deep learning applications in commercial healthcare settings

- Collaboration between technology developers, healthcare providers, and regulatory bodies is crucial for driving innovation and facilitating the adoption of deep learning solutions in healthcare while prioritising consumer safety

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