

## Chapter 2: The Evolution from Automation to Agentic AI

### 2.1. Introduction

Automation has historically played a crucial role in driving industrial, information, and business evolution; employed wherever possible, it improves operational efficiency, and cybersecurity is no different. Advancements in artificial intelligence (AI) have shifted focus beyond the automation of routine, time-consuming tasks toward employing automation to bolster productivity and effectiveness in previously challenging business areas. This shift towards agentic AI, as the industry begins to realize and embrace AI's potential for autonomous decision-making, has drawn considerable interest within the security community. Agentic AI automates tasks in a manner fundamentally distinct from previous approaches to automation.

Agentic AI encompasses models capable of autonomous memory retrieval, utilization of external tools, and interaction with their environment through actions executed in natural language to achieve a defined objective. While information retrieval often involves directing a specialized retrieval agent, agentic AI integrates such functionality independently through a comprehensive internal memory. It interacts with the real world using tools accessible via open APIs and communicates in natural language, issuing instructions to channel actions back to the environment, thereby closing the operational loop.

#### 2.1.1. Background and Context

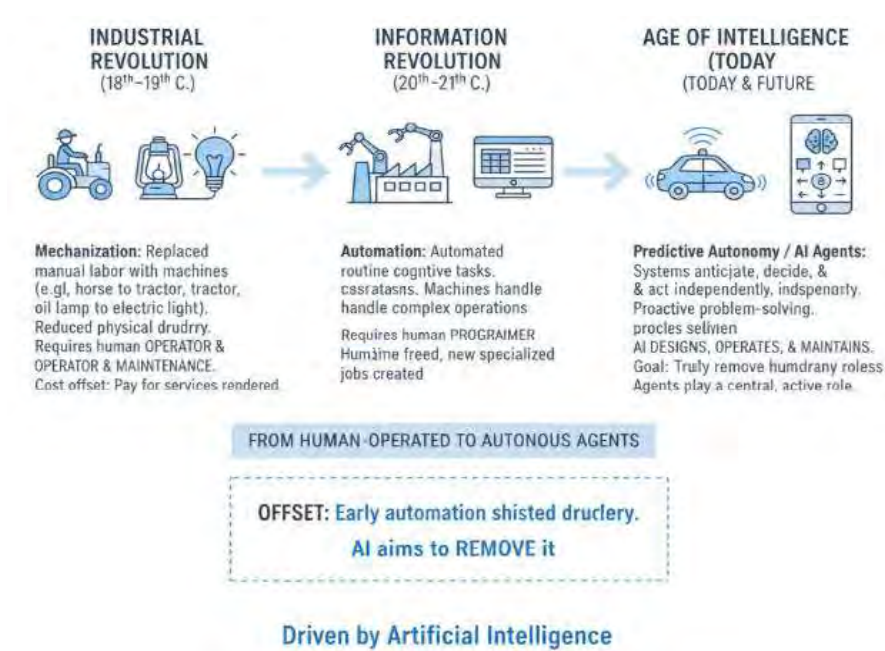
Automation has been an important technological development of the last two centuries. The advances of agentic AI represent an inflection point as systems move beyond simple repetitive tasks toward higher-level cognitive-capacities that have traditionally been uniquely human. The term agentic AI refers to a form of AI that enables agents to have the power and capacity to act and to execute an assigned task or fulfill an assigned

objective. Agentic AI systems have the ability and authority to make decisions and to react and perform activities on their own without having to ask for a user or operator to constantly provide permissions or to continuously instruct them on every action. These characteristics differ significantly from the commonly accepted notion of automation, which generally includes systems that have the ability to perform short repetitive actions automatically, but require a human to at least give the initial actionable direction and continuously operate in the overall system loop.

Several historic and recent technological advances, including breakthroughs in AI, machine learning and deep learning, speech recognition, natural language processing, robotics, reinforcement learning, internet of things and cloud computing, have all collectively contributed to the capabilities of these new agentic AI systems. Agentic AI systems are increasingly being employed in a number of applications such as in the healthcare domain, in self-driving cars, in smart homes and in finance.

## 2.2. Historical Overview of Automation

Throughout human history, people have sought to devise technological solutions to relieve some of the drudgery of work. Until recently, such mechanisation was simply



**Fig 2 . 1 :** Evolution of Automation and the Shift from Drudgery

called automation. Moving the plough with a tractor instead of a horse reduced drudgery. Lighting a room with electricity instead of oil lamps or candles also helped. However, seldom was the work truly removed: the tractor requires an operator and the generator in the power station demands attention too [1,2,3]. And, in typical scenarios, while a person's time is freed up, their money is required as payment for services rendered.

Automation technologies gained prominence with the Industrial Revolution and began to encroach on more cognitively demanding tasks during the Information Revolution. Yet, the term 'automation' rarely applies to activities that are entirely removed from the human sphere. Filling a room with light at the flick of a switch is usually called a convenience rather than automation because it is still expected that a human plans, designs, builds, and maintains that power station. In all cases, there has been a discernible offset: removing drudgery from one person's job means making life harder for another. Agents, in the usual sense of that word, played no role in such activities.

### **2.2.1. Early Automation Technologies**

The quest to develop techniques assisting people in performing repetitive tasks has a long history, beginning with simple mechanisms. The Greeks made use of mechanical hoists and pulleys to ease their burden when performing manual labor, and similar approaches were used throughout the early modern era. Of particular note is the impact of the Industrial Revolution—self-operated looms, railroads, automobiles, and aircraft expanded economic activity and development worldwide.

While automation developed rapidly during the Industrial Revolution, progress continued with the advent of information technology. Devices capable of automating arithmetic computations and basic data processing were introduced in the 17th and 18th centuries; early mechanical clocks acted as feedback mechanisms, adjusting the position of the hands based on input from other components. The Industrial Revolution also saw the creation of basic control systems, such as the centrifugal governor. Subsequent technological advances have led to further applications of automation, including the programming of robots and the use of computer vision in manufacturing, allowing tasks like painting and high-precision inspection to be performed with minimal human attention.

### **2.2.2. Industrial Revolution and Automation**

Automation also began to take its first steps during the Industrial Revolution, nearly three centuries ago in the late eighteenth century. The technologies of that time provided a step change in the ability of human beings to manipulate and adapt the physical

universe. Powered machines greatly enhanced people's abilities to focus their muscle power and, through the introduction of steam power, to transport material from one place to another. Nevertheless, these machines still required the direction and agency of human beings in order to carry out much of the work. A decision process was still required, though largely carried out with the aid of human flesh and blood.

The field of Information Technology (IT) began around two centuries later, when human beings built machines capable of making decisions in order to automate complex management activities. The Dow Jones Industrial Average went on-line in the United States in February 1884 and, more than three decades later, the US Postal Service initiated the automation process for sorting letters and other mail. This gave rise to the rye soup guillotine—a suite of programs chosen to prioritize the delivery of soup to patients in an area devastated by the potato famine.

### **2.2.3. The Rise of Information Technology**

Advancements in information technology have led to further progress in automation. An early and influential attempt to incorporate information technology into business process automation was Business Process Reengineering, widely deployed during the 1990s. Business Process Reengineering was strongly related to the creation and subsequent management of information. As such, automation usually involved identifying manual information-processing activities and automating them using information technology, with the intent of increasing speed, accuracy, and consistency.

Agentic AI, which is a subset of automation, applies specifically to the automation of tasks performed by judgment-workers. Judgment-workers are information workers who utilize information to make decisions, judgments, or recommendations, often taking into account some ethical dimension. Work undertaken by judgment-workers is typically characterized by requirements for a high degree of cognitive function, utilizing such skills as communication, analysis, reasoning, or decision-making. Judgment-workers inhabit roles such as managers, professionals, and clerical support-workers, contrasting with non-judgment workers who generally handle operational tasks.

## **2.3. Defining Agentic AI**

Automation describes the process of delegating repetitive or predictable tasks to machines. The idea goes back to ancient Greece, and tools for automating repetitive physical tasks were developed during the Industrial Revolution. During the second half of the 20th century, automation applications expanded from physically repetitive tasks to repetitive mental tasks, mainly focused on numerical calculations thanks to the

development of cybersecurity and the microprocessor. The term agentic AI denotes a shift in the use of AI concepts from the traditional approach of automation towards a more agentic orientation, where intelligent agents take the place of humans – either to assist humans or to substitute them entirely in various tasks and roles.

The transition from automation to agentic AI is enabled by unprecedented advances in machine learning, natural-language processing, speech-recognition, robotics, computer vision, knowledge-graph representation, and other fields within artificial intelligence. Breakthroughs in these technologies have rendered the rigid and precise pattern-extraction capabilities of traditional intelligent-automation applications obsolete. Agentic AI applications expand beyond the automation of repetitive or predictable tasks, employing intelligent cognitive techniques to solve tasks that were manageable only by humans less than a decade ago. They also execute repetitive physical tasks with a degree of dexterity and processing speed that greatly exceeds human performance.

2.3.1. Characteristics of Agentic AI

Agentic AI is a technological category distinct from simple automation, possessing several distinguishing characteristics. Three such characteristics are proposed here: (1) usage of an internal model of dimensions of agency, time, and 'self'; (2) positiveness, the ability to take and achieve goals; and (3) interactive, the ability to interact with humans be it pre-determined or spontaneous in nature.

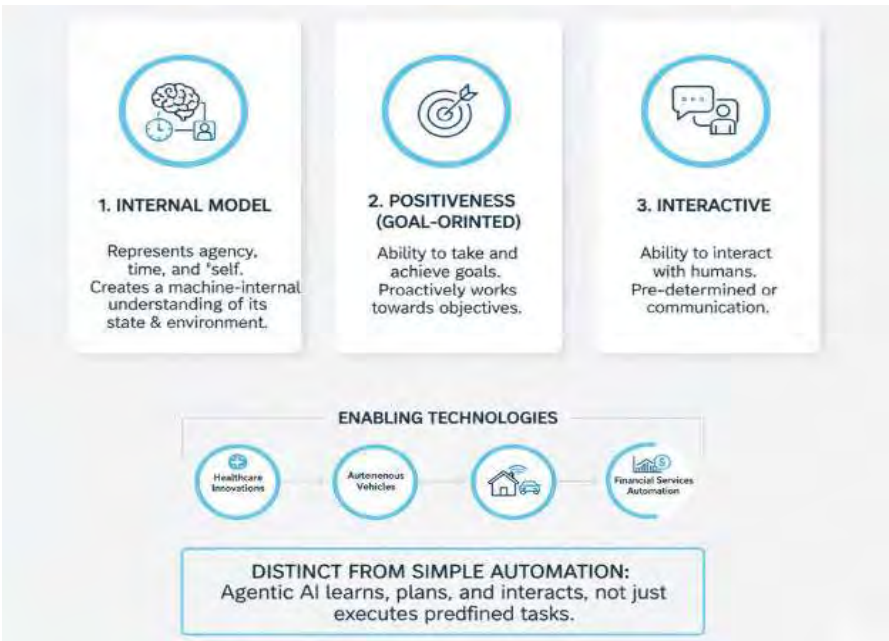


Fig 2 . 2 : Characteristics and Enablers of Agentic AI

Advances in AI have given rise to implementations exhibiting these traits; examples include healthcare innovations, autonomous vehicles, smart home technologies, and financial-services automation. Prepare for that special section through a discussion of the most important technologies enabling agentic AI, thereby highlighting the differences with simple automation.

### **2.3.2. Distinction from Traditional Automation**

Automation has undoubtedly been one of history's most crucial inventions. Yet the hallmark of human thinking is its agentic nature: humans act, perceive, decide, and adapt. Capitalizing on Scholz's vision of the next generation of information technology, agentic artificial intelligence enables the diffusion of this property to machines. The resulting agentic AI applications elevate the spectrum of use cases supported beyond the capabilities of traditional Automation. Google DeepMind's AlphaGo system and OpenAI's ChatGPT exemplify this agentic quality in game playing and conversational interactions respectively, yet ongoing innovation continues to unlock additional domains. Recent advances in healthcare, self-driving cars, smart homes, and financial services illustrate the growing momentum and wide applicability of agentic AI and provide clues to future directions.

Agentic AI is distinguished from traditional automation by its capability to function as an agent. An agent exhibits conditions that transcend mere automation, which include (1) practical efficacy within its application domain, (2) a capable perception apparatus, (3) an attained level of persistent environmental control, and (4) a capacity to explain its decisions and actions. When these conditions are fulfilled, it signifies that the system operates as an agent and can thus be regarded as agentic AI [2,4,5].

## **2.4. Technological Advancements Leading to Agentic AI**

Automation systems, enabled by machine memory and computing power, provide immense levels of computational, routing, and dispatching support that can relieve Technicians and Operators from repetitive drudge work. The Technology Revolution during the Industrial Age created the automation concept, which has been validated by a multitude of applications in both the manufacturing and information-technology domains. When combined with internal and external technological breakthroughs, such as deep learning algorithms in Machine Learning (ML), Natural Language Processing (NLP), Computer Vision (CV), Generative AI, Digital Twins, Simulated 3-Dimensional Environment, Robotics, Augmented & Mixed Reality (AR/MR), and the Quantum Revolution, the automation capabilities can be elevated to a qualitatively new level. This new level is generally discussed under the umbrella term of agentic AI.

Agentic AI, enabled by the next generation of Machine Learning (ML), particularly Deep Learning techniques, is reshaping the activities and relationships of the System Stakeholders in a fundamentally different way. The rapid development and success of agentic AI constitute a major breakthrough in Artificial Intelligence (AI) after the invention of Automation during the pre-information age. It represents a substantial step beyond the traditional discoveries in the Automation domain.

#### **2.4.1. Machine Learning Breakthroughs**

Machine-learning breakthroughs have paved the way for a transition from simple assistance and automation toward fully fledged agentic AI. The journey from assistance to agency has been recognized as transformative, with the UK Centre for Data Ethics and Innovation suggesting that the capability for AI to act with significant autonomy may represent "the most important step change in AI capability". Experts from Google Brain have acknowledged recent developments in Large Language Models as constituting a phase shift, ushering in the era of agentic AI.

Automation has been a driving force throughout history during which technical progress has freed humans from certain repetitive tasks. Early examples of automation include the irrigation systems of Mesopotamians. During the Industrial Revolution, many workers were replaced by machines while the growing volume of trade also increased wealth. In the era of information technology, computers automatize various aspects of office work. Agentic AI, in comparison to mere automation, significantly decreases the need for human work.

#### **2.4.2. Natural Language Processing Developments**

Reinforcement learning utilizes a system of rewards and punishments to guide the agent toward achieving the assigned task, thus forming the basis for machine learning, which encompassing natural language processing. In recent years, the development of natural language processing has enabled AI to more precisely understand human language, voice, and gestures. Assistant technologies such as Amazon Alexa, Apple Siri, and Google Translate serve as daily tools for billions of users worldwide. The primary mechanism behind natural language processing is the generation of large language models like BERT, GPT-2, and LaMDA.

The GPT language models utilize deep learning transformer architectures to encode and decode extensive language datasets [1,4,6]. These models are capable of generating speeches, poems, or other text styles based on task instructions. They have been successfully adapted to manage various tasks, ranging from a simple chatbot to smart

home controls, and even performing research analysis. Modern search engines have integrated large language models to enhance user interaction, enabling conversational searches where the engine comprehends and responds to direct questions. Another application of natural language processing lies in creating chatbots that offer text and voice assistance to information technology service desks. These chatbots have the potential to manage tasks as straightforward as providing status updates to delivering detailed information synthesis in response to user inquiries.

### **2.4.3. Robotics and Physical Interaction**

Robotic technology dates back to the fourth century BCE and the community continues to innovate to the present day. Even simple mechanical automata demonstrated, from the outset, a symbolic implication: the possibility, even in principle, of eliminating human intervention or involvement in processes otherwise associated with physical or manual effort. This intuition was borne out initially by the industrial revolution and later, with the rise of information technology and digital electronics, with first the production and then the control of automated machinery and systems. More recent breakthroughs paved the way for robots able to perform complex and diverse motor operations, particularly in unstructured and unpredictable environments.

Today, artificial intelligence incorporated into physical robot structures confers the traits that mark the transition from automation to agency. Artificial intelligence indeed enables robots to manage all processes related to creative, adaptive and proactive problem-solving tasks. It supports self-learning through experience as well as through direct communication with other robots, either independently or in the cloud, in order to achieve defined and coordinated objectives.

## **2.5. Applications of Agentic AI**

After establishing the background-history of automation technology and providing justifications for the designation "agentic AI," applications now illustrate the transformative advances beyond automation. Diverse examples include Healthcare: Conversational AI for pandemic assistance; cocktail-robot for elderly reticence reduction; the meditation-trainer for patient relaxation; the CEO-of-the-month award presented to Jennifer; Autonomous Vehicles: Tesla's full self-driving beta release and commitment to level 5 automation by 2025; Smart Home: The smart kitchen aid that greets and complements the cook, emphasizing conversational interaction; Financial Services: eradicate debt detection and eradicate money replacement, performing dylchect tasks that require significant judgment from within the business.



Recent demonstrations underscore these applications. The new contagious-respiratory-disease conversational agent supports the public during the pandemic. The cocktail-serving robot aims to boost confidence and reduce drinking alone among older adults. An interactive voice-response meditation trainer liaises with clinicians to enhance patient relaxation. ActivNet, a closed-system demonstrator of the Activ agent, functions as a personal chef, engaging in meaningful conversations with the user, including a jar of peanut butter encountered during meal preparation. Additionally, the TELUS Long-Haul team recently conducted a Virtual AI hackathon, culminating in a Financial Services Agency prototype with the dual objectives of eradicating debt and replacing money.

2.5.1. Healthcare Innovations

Applications of Agentic AI

Agentic AI refers to software agents with a non-trivial degree of freedom in acting towards a goal or objective. Unlike automation, which involves performing predetermined tasks, agentic AI possesses the capability to make independent decisions and adapt actions to achieve set objectives, sometimes arising organically through the need for more general intelligent behaviour.

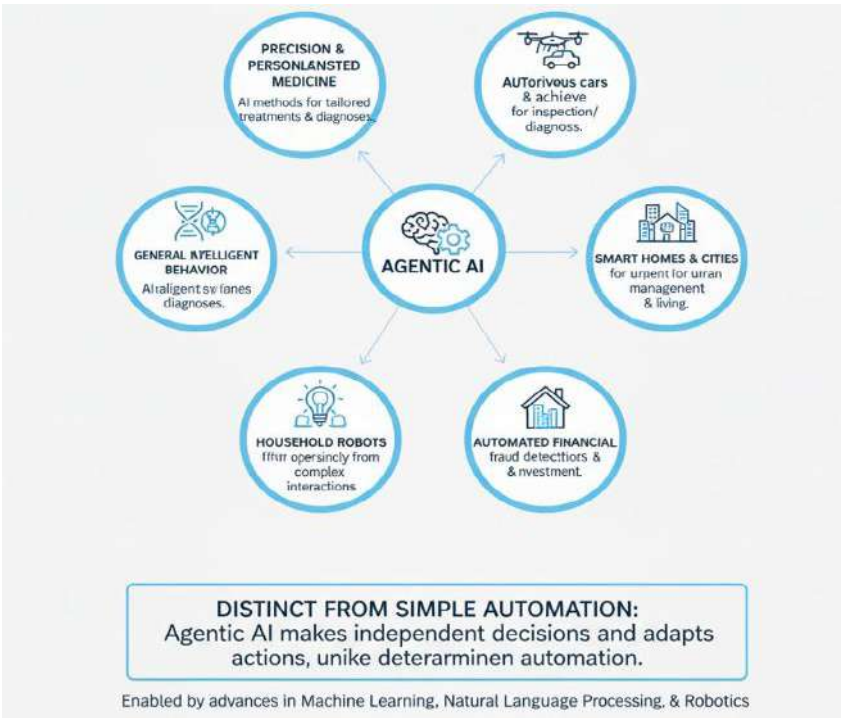


Fig 2 . 3 : Applications of Agentic AI

Advances in machine learning, natural language processing, and robotics have facilitated the emergence of agentic AI systems across various fields. Examples include AI methods for precision and personalised medicine; autonomous diagnoses using self-driving cars and aerial drones; smart homes and cities; household robots; and automated financial services and operations.

### **2.5.2. Autonomous Vehicles**

Agentic AI fulfills many long-coveted ambitions for automation, most notably lecturing students, commuting, washing laundry, ironing, and cleaning the windows of a high rise building. Autonomous vehicles have been called the killer app of agentic AI and indeed self-driving cars are the aspiration for self-driving hammers and robots of every description. While the level of autonomy that current vehicles are able to reach is limited, progress has been steady and results are promising.

The basic idea of autonomous vehicles is that control of the vehicle shifts from the driver to the car itself. The car can make decisions on acceleration, steering, braking, signaling, and interactions with other road users and responds to emergencies and hazards. All else being equal, these decisions can be expected to be better than those of fallible and frequently inebriated humans. Aside from the various advantages of using the recaptured time and mental effort required for driving, autonomy may also allow the elderly to remain socially connected and the disabled to become mobile. Other potential benefits include more efficient path planning for both the vehicle and the passengers, optimized traffic flow, and reduction in the need for parking spaces.

### **2.5.3. Smart Home Technologies**

Although smart home devices do not generally effect physical changes, some of them have the potential to issue real-world commands—turning lights or appliances on and off, adjusting thermostats, locking doors, or activating security cameras. Voice assistants, such as Apple’s Siri, Amazon’s Alexa, and Google Assistant, conform reasonably well to the definition of agentic AI: They possess social ability; they can operate in unstructured environments via natural language; and they can make decisions to achieve a user’s goals. However, with current hardware, smart assistants can carry out only limited functions [3,7,8]. Nonetheless, the steady accumulation of their capabilities, fed by the massive amounts of data generated by users, creates a potentially large market for a future, more capable set of assistant agents that will act autonomously.

2.5.4. Financial Services Automation

Modern finance is a rapidly changing and evolving field that often stands at the centre of a variety of innovations in agentic AI. Automated Financial Media Analytics and Reporting are already a reality: advances in natural language processing and other deep learning methods have made it possible to collect, process, analyse, and generate basic financial reports in response to user prompts. Supervised and exploratory machine learning methods, as well as reinforcement learning, are used for portfolio management, risk management, and strategy design.

Financial markets and the external environment, however, are so dynamic and complex that there is a limit to what machine learning currently can achieve using structured data only. In particular, machine learning models paid little attention to the potential value of unstructured data in the form of textual news, which are also known to exert strong influence on financial behaviour. The richness of natural language expression contained in various textual documents could better assist decision-making tasks in Finance Complex, adaptive behaviours in human language are revealing new subtleties of financial operations and accompanying reactions to continuous change.

2.6. Future Directions

Agentic AI systems represent the next stage of technological evolution beyond automation.

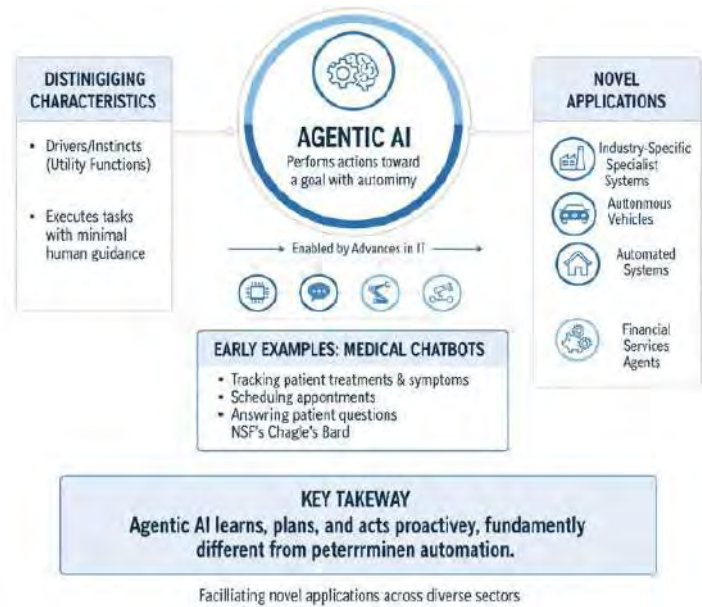


Fig 2 . 4 : Agentic AI Systems and Technological Evolution

They are capable of performing a set of actions through a series of steps toward a goal, all with some degree of autonomy. These AI systems, also known as AI agents, are equipped with drivers or instincts encoded as utility functions and are able to execute tasks with minimal to no human guidance. Early examples of agentic AI include medical chatbots such as NSF’s ChatGPT and Google’s Bard, particularly in their application to healthcare for tasks such as tracking patient treatments and symptoms, scheduling appointments, answering patient questions, and other patient-facing functions.

Significant advances in associated areas of information technology are driving the emergence of agentic AI systems. Breakthroughs in microchips, natural language processing, robotics, and related fields are incrementally enhancing the capabilities and autonomy of AI. These technological developments are facilitating novel applications across diverse sectors—extending the evolution from automation toward increasingly agentic AI systems. The scope includes industry-specific specialist systems, autonomous vehicles, automated home systems, and financial services agents, among others.

### **2.6.1. Potential Innovations**

For many years, sociotechnical systems have relied on just a limited range of automation technologies and methods. The technological advances of the last decade, however, have made agentic artificial intelligence (AI) a feasible alternative. Agentic AI adds significant powers to automation, allowing a system to set its own subgoals. It is thus essential to explore what the new powers of agentic AI make possible. Four areas of potential innovation emerge: agentic AI as a foundation for many advanced applications, the long-term outlook for agentic AI, the challenge to find innovations that surpass agentic AI, and the complementarity between agentic AI and the classic applications that remain.

After considering the transformative effects agentic AI can have across a broad spectrum of applications, the prospects for AI with constructive goals and superhuman powers will be examined. Next, it is necessary to ask whether the trajectory of innovation will soon be dominated by agentic AI or if other promising areas of research and development remain. Finally, the importance of the still-operational classic application domains identifies avenues that extend beyond the capabilities the new technologies provide.

### **2.6.2. Long-term Societal Impacts**

The movement from abstraction to concretion in automation spans multiple dimensions, including cognition, motive, and action. Early automation—dating back several millennia—free[d] humans from unconscious, repetitive, action-element tasks. Later,

cognition-oriented automation conquered tacit knowledge access processes, so that functional knowledge could be embedded in software and made available unconsciously. More recently, formal analysis-related processes started to be incorporated in automation. The early phase of agentic AI involves overcoming two hurdles. Additional discussion of the technological advances that culminated in the emergence of agentic AI can be found in §6.1.

Today, agentic AI is emerging in a variety of applications. In healthcare, it manifests in avatars conducting intake interviews and offering diagnostic suggestions, in diagnostic monitors, and in robot surgeons. In transportation, it features in autonomous vehicles. It appears in smart-home features such as home security, leak detection, and fire detection. Finally, a broad range of financial transactions—from mortgage executions to insurance claims to investment decisions—are moving toward or past the agentic frontier. These applications underscore the transformational nature of agentic AI in the contemporary computational landscape. Further consideration of long-term societal impacts, including anticipated advances and key questions, is provided in §6.2.

### **2.6.3. Interdisciplinary Approaches**

Impressive progress has been made in a wide range of AI/ML techniques—including foundational models for language, vision, online world models, and robotics—and in scalable infrastructure. Although autonomous agents still remain a research frontier today, rapid progress is ongoing [7,9,9,10]. The capabilities being developed have the potential of transforming a wide range of industries and daily life in the coming years and decades. It will be necessary to engage complementary analytic fields such as economics, law, sociology, system engineering, etc. in order to understand intermediate- and long-run societal implications and plan appropriate policy responses.

Agentic AI is a new paradigm beyond the many new technologies that have recently been labeled AI. The growing wave of agents clearly marks this new paradigm. Humans now have computer systems that provide a new form of delegated agency: the system can make decisions on its own, one-by-one, in order to advance an overall goal. Indeed, humans have a nearly unlimited new form of delegated agency: we can automate any task that we can describe. The marketing and product development efforts of the leading agentic AI companies enable and encourage users to delegate any task or process for which they can articulate a goal.

2.7. Conclusion

While automation has long been a domain of continual innovation with a profound societal impact, the same degree of novelty does not extend to the recently introduced agentic AI. Nevertheless, agentic AI represents a distinctive departure from traditional automation, resembling a new scientific discipline in tandem with the information technology revolution. The contemporary surge in agentic AI is attributed to breakthroughs in machine learning, natural language processing, and robotics—advances that confer upon AI systems the capabilities to act independently, make decisions, and iteratively self-improve.

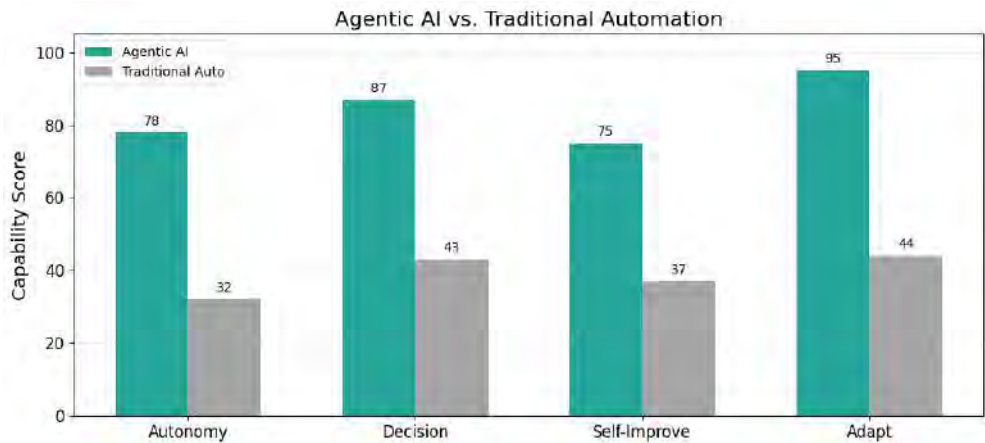


Fig 2 . 5 : Agentic AI vs. Traditional Automation

Agentic AI has found applications across myriad sectors, including healthcare, autonomous vehicles, smart homes, and financial services. Looking ahead, its potential trajectory may traverse new technological domains, engender technological convergence, or unfold over centurial timeframes. Future inquiries, therefore, must transcend a mere focus on current agentic AI technologies to embrace a multidimensional exploration of the field's long-term prospective landscape.

2.7.1. Summary and Key Takeaways

Automation has long been considered an important and as yet unrealized aspect of the promise of computer power. The general idea dates back at least as far as the Industrial Revolution, when functionality such as that of the Jacquard loom, archetypes of the modern algorithm, were created. Further progress was made in later manufacturing applications such as the General Motors NUMMI plant. The computer generated code revolution week at insurance companies such as Blue Cross-Blue Shield showed the promise of automation for IT functions. More recently, Software Development

Automation has been the topic of some limited discussion and hype. Finally, a recent McKinsey study suggests that automation is one of the important trends of the next decade.

Agentic AI clearly represents a step beyond automation. Agentic AI incorporates proactive goal-directed behavior at a level of sophistication beyond that of reactive systems responding only to explicit user commands. An agent of this kind can act without specific user actions or requests; it is capable of setting intermediate sub-goals and acting to fulfill these in the service of overt user-defined goals. It can also pursue multiple goals and act to satisfy each of them concurrently. This general capability has long been considered one of the key ambitions of the AI community and is among the four characteristics that anthropomorphize AI and that, perhaps, distinguish it from automation. These characteristics are a sense of identity and continuity, goal-directed behavior, a sense of autonomy, and the ability to relate to others (agency). Some of the enabling technology for agentic AI has been developing steadily for many years—especially the underlying hardware capabilities. Additional important recent advances in sensing and other AI areas have also contributed to the rapid acceleration.

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