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Integration of cloud computing, big data, artificial intelligence and internet of things: review and open research issues

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Abstract

Digital tech is moving super-fast, right? And we got these four huge game-changers coming together: Cloud Computing (CC), Big Data (BD), Artificial Intelligence (AI), and the Internet of Things (IoT). On their own, they've already turned tons of stuff upside down. But when you mash them up, you've got this wild chance to completely redo how we handle data everywhere – like how we make it, sort it out, study it, and use it. It's not just about cooler gadgets; it's like the bedrock for smart, mega-efficient big-time systems that'll meet what today's world needs. Cloud computing acts as the main support for this mix-up providing resources and storage you can scale and get whenever needed. It gives companies the power to handle and sift through heaps of data from IoT gadgets without the big need for in-house gear. Big data is known for its huge size fast speed many types, and rock-solid accuracy. It backs up cloud computing with the necessary gear and ways of thinking to tackle and make sense of the giant pools of data coming from IoT stuff , they build a strong space for making choices based on data.

Keywords: Artificial Intelligence Big Data; Cloud Computing; IoT; Review and Open Research

1. Introduction

Artificial intelligence pumps up this whole setup by making it super smart to analyze data, spot patterns, and guess what might happen next. Those machines learning algorithms just a piece of the AI puzzle, chew through the complex and ever-changing stuff that IoT gadgets spit out. They throw out some useful tips and help make decisions on the fly. Then you've got IoT, which is like the big boss of data making hooking up tons of gadgets and detectors to gather the scoop on what's going down in the real world right this second. This huge web of connected stuff doesn't just make things happen on their own; it also scoops up all the details needed for crunching big data and feeding AI programs (Bakar et al. 2020).

These techs are already showing what they can do in different areas like healthcare making things, moving stuff around, and in clever cities. Take a peek; in healthcare, gadgets that can talk to the internet keep tabs on people's health stats as they happen. Meanwhile, AI math stuff makes guesses about possible sicknesses. Cloud computing keeps this info safe and ready to grab, and huge data setups work through it to give us the full picture (Khan et al. 2021).

Mixing together cloud tech massive data sets smart algorithms, and internet-connected devices can be tough. You've got head-scratchers like keeping data safe dealing with delays, getting different techs to talk to each other, and making sure everything can grow bigger without hiccups. Not to mention when machines start making choices, we going to think about what's right and wrong. Plus, those giant data houses? They're not friends with Mother Earth. To fix this jumble, we need tech whizzes, rules that make sense, and a good long think on the moral stuff (Vaganova et al. 2020).

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The goal of this paper is to examine how "cloud computing," "big data," "artificial intelligence," and the "Internet of Things" come together. We're diving into what research out there looks like right now pointing out the major trends and uses, and spotting the research gaps we going to fill to tap into what these techs can do when they team up.



Figure 1 Cloud Services

2. Integration of Cloud Computing, IoT, Big Data, and AI: Overview and Current Trends

2.1. Cloud Computing: The Backbone for IoT, Big Data, and AI Mash-Up

Cloud computing stands as the crucial support for mashing IoT, Big Data, and AI together. It dishes out scalable structures and services for keeping, crunching, and studying data heaps. This tech gives the green light to grab computational tools on the fly, which opens the door for IoT widgets and massive data ops to process and analyse info in the nick of time. Take for example those cloud stages — Amazon Web Services (AWS) and Microsoft Azure — they've got these IoT-tailored offerings, you know, like IoT Core and IoT Hub. These bad boys make it a breeze for IoT gizmos to shove data straight into cloud lockers (AWS IoT Core).

Cloud computing gives a boost to AI providing platforms like Google Cloud AI and Azure Machine Learning for machine learning. Creators can teach, apply, and grow AI models by tapping into cloud resources. Take Google Cloud's AutoML for instance; it gives companies the ability to build their own machine learning models with just a little know-how, all thanks to the cloud's vast processing capabilities (Google Cloud AutoML).

Plus, with edge computing tagging along—a kind of cloud computing upgrade—data gets crunched nearer to IoT gadgets. This setup shaves off delay times and eats up less bandwidth super useful for projects that need lightning-quick thinking, like self-driving cars or clever factory tech (in-text citation).

When we look at IoT as a thing that churns out data, its connection with Big Data and AI pops.

Interconnected gadgets with sensors, actuators, and comms units create a huge amount of info you know, the Internet of Things (IoT). They call this info "sensor data" because it's got stuff like temperature, humidity, pressure, and whether something's moving or not. Take an autonomous car, for instance; it can churn out a whopping 4 terabytes of data. That just shows the crazy amount of info these IoT setups can pump out (in-text citation).

Technologies like Hadoop and Apache Spark are essential for crunching and making sense of all that info. They let us pull out useful nuggets from the messy and kind of organized data IoT gadgets make. Like, Hadoop has this thing called HDFS – it's super good at keeping and handling big piles of data, and Spark is all about giving you the analytics in a snap.

AI ramps up the worth of IoT info plugging in machine learning tricks to sniff out trends, guess what's coming, and make choices without humans. Take this for instance: predictive upkeep setups in the world of industrial IoT (IIoT) roll with AI to sift through sensor info and catch glitches in gear before they cause trouble. Jamming IoT, Big Data, and AI together doesn't just make things run smoother, it also slashes bills and time machines sit idle.

2.2. Big Data Analytics and AI: Pulling Smart Thoughts from IoT Info

AI and Big Data analytics team up to turn IoT data into useful clues for action. Big Data setups get the data ready and put it in order. Meanwhile, AI mechanisms sift through it to find secret trends and links. Take this for instance: tools for analytics with AI can spot weird stuff in data from IoT, like odd jumps in temperature during making stuff, and then they send warnings right away to deal with it (in-text citation).

In the realm of tech, one major trend is leaning into deep learning models to get good at analytics. Now, models like convolutional neural networks (yeah CNNs) and those that go round and round recurrent neural networks (RNNs for short), are super good for digging into those super complicated IoT datasets. You know, the ones with all the video stuff and data that changes over time. Like take CNNs; they rock at figuring out what's what in live videos for those high-tech security cameras. And then there are RNNs, which are all about guessing what's next in energy management (in-text citation).

Federated learning is merging with IoT and Big Data changing the game. This tech trains AI on scattered devices without shipping off raw data to one big computer. It cranks up the privacy and security levels, which is super cool for stuff like healthcare and banking where the info is really sensitive (in-text citation).



Figure 2 Relationship between Big Data, IoT and AI

3. Challenges in Integrating Cloud Computing, IoT, Big Data, and AI

Mixing these techs together could do some real good, but it's not easy street yet.

Talking about keeping things hush-hush huge piles of info from IoT gizmos getting crunched in the cyber-sky makes folks worry about sneaky hackers and peeping toms. To boot these baddies out, we going to make sure nothing moves without some secret code and keep a tight rein on who gets the golden key (in-text citation).

Now, about playing nice together, it's a bit messy because all these IoT thingamajigs, cloud hangouts, and Big Data do hickeys don't always speak the same lingo. People are working hard to chillax this Babel-like confusion with neat things like the MQTT chat rules for IoT chinwags, but it's going to catch on big time (in-text citation).

3.1. Scaling Up

IoT gadgets are multiplying, and it's tough to grow the cloud and Big Data setups to manage the ballooning amount of info. Folks are looking into stuff like serverless computing and packing apps into containers to tackle this growth issue.

3.1.1. Cutting the Delay

Gadgets that react in real-time, like self-driving cars and clever power systems, need to process data super-fast. Edge computing is helping a bit, but getting that snappy response all over the place in IoT setups is still a head-scratcher.

3.1.2. Power-Smart Tech

All these IoT gizmos, along with the cloud storage facilities and brainy AI stuff, are chugging down power like there's no tomorrow. We've going to come up with less power-hungry hardware and tweak our software recipes to make sure we aren't rough on the environment.

3.2. Trends That Are Shaping the Future

Cloud tech, the Internet of Things, Big Data, and Artificial Intelligence are all joining forces and sparking fresh ideas in a bunch of fields. Check out some of the cool new stuff that's popping up:

3.2.1. Smart IoT Systems with AI

It's a big deal that IoT setups are starting to think for themselves. Take NVIDIA's Jetson for instance; it mixes AI with IoT and makes stuff like flying robots and clever security cameras possible.

3.2.2. Virtual Copies of Stuff

This thing called digital twin tech is pretty sweet. It makes these virtual look-alikes of real things so you can check them out and run tests on them without messing with the actual thing. It's super smart because it uses data from IoT, crunches numbers with Big Data, and even has AI to help businesses and hospitals keep things running smooth and figure out problems before they happen.

3.2.3. Integrating 5G with IoT

The introduction of 5G networks should boost IoT connections with its super-fast speeds and almost no delay. This makes it a breeze to roll out AI-driven IoT apps, like those for smart cities and hooked-up cars.

3.2.4. Cybersecurity Powered by AI

AI steps up the game in keeping IoT systems safe by spotting and dealing with online dangers on the fly. Using machine learning, we can examine how data moves across networks, spot weird stuff, and head off cyberattacks.

3.2.5. "Eco-efforts Galore"

Merging these techs offers a hand in tackling green worries. Like, AI and IoT help cut down juice use in savvy grids, not to mention Big Data crunching backs up weather pattern guessing and sorting out calamity control (in-text citation).

4. Challenges and Limitations in Integrating Emerging Technologies

4.1. Latency and Real-Time Processing Constraints

Emerging tech like IoT, Big Data AI, and Cloud Computing needs data handled on the spot for apps that are super important, like self-driving cars keeping tabs on health, and machinery that runs itself. But getting communications and processes to happen quicker is a tough nut to crack. IoT gadgets produce a ton of data out at the edge. Sending it all over to big cloud servers to figure it out can slow things down. Delays like this are a real problem when every second counts such as in systems that help in emergencies or when factories going to catch glitches before they happen (in-text citation).

Edge computing and fog computing aim to cut down on delay by handling info close to where it comes from, right? But this stuff brings in new headaches. Like, we going to make sure edge and cloud stuff work together, keep our data matching up, and make sure our security is tight across all these separate spots. It's a bunch of stuff to keep up with.

4.2. Giving Out Resources and Making Costs Efficient

Okay so when you mix up cloud computing, IoT, Big Data, and AI, you're going to need a ton of computer power and space to keep stuff. Making sure you hand out the right amount of resources to get things running good without burning through cash is super tricky. Plus, cloud folks charge as you use it, which can mess with your budget when you're dealing with heaps of IoT data or doing brainy AI work.

Also, figuring out how to best allocate resources gets tough in hybrid cloud setups. This is where companies use both public and private clouds together. They have to work out the smartest way to split tasks between these places. They have to think about stuff like how private the data is, rules they need to follow, and how to save cash, which is pretty tricky. They're looking into ways to sort this out by using things like smart resource allocation and trying to predict stuff. Still, not a lot of folks have started doing this (in-text citation).

4.3. Being Smart with Energy and Keeping Things Green

Mixing these techs together weighs heavy on power use. Places that host cloud services eat up a ton of electricity and, yep, that means they're kicking out a lot of carbon. Those tiny IoT gadgets that are popping up everywhere need to run on the low energy side too so we don't have to keep switching their batteries like all the time (in-text citation).



Figure 3 Application Modernization

Deep learning models, a type of AI algorithm, chew through a ton of energy when they're learning and making decisions. Get this: just teaching one AI model can pump out as much carbon as five cars would during their whole lives. That's got people worried about how AI and crunching massive amounts of data might be messing with our planet. Now, there's a scramble to make tech that doesn't hog as much power, like hardware that goes easy on the juice and smarter ways to code. These eco-friendly ideas are in the works, but they've still got ways to go before they're the norm (in-text citation).

4.4. Tackles With Rules and the Right Thing to Do

Combining AI IoT, Big Data, and cloud computing brings about many ethical and legal worries. AI systems making choices might keep existing biases from the data they learned from causing outcomes that are not fair or discriminative. This bugs us when we're talking about using these in things like who gets a job, who gets a loan, and police work (intext citation).

Protecting privacy is a huge deal. IoT gadgets are always gathering private info on what people do where they go, and what they like. It's tough for companies to stick to rules about keeping data safe. We're talking big ones like the "General Data Protection Regulation" (GDPR) and the "California Consumer Privacy Act" (CCPA). Plus, since cloud services work across borders, it gets even trickier because different places have different laws.

Now, we've got another mess: no clear instructions for what's okay in AI and who's on the hook when it messes up. Like, who pays up if an AI system goes rogue or screws up? We need some worldwide standards and plans for making sure AI and how we handle data is, like, ethical and on the level.

4.5. Security Measures and Their Ability to Scale Up

Now this part zeroes in on how well security steps can handle growth when there's more tech coming together. With IoT networks getting bigger and Big Data digging deep everywhere, the chances for cyber nasties to strike shoot through the roof. The old-school stuff like firewalls and systems to spot intruders don't cut it anymore when you're dealing with crafty attacks hitting all sorts of linked-up systems (in-text citation).

For example, bad guys can use tons of IoT gadgets in a DDoS attack swamping cloud servers and causing a big mess. It's super important to put in place beefy security like smart AI to spot dangers and blockchains to check who's who. But yeah, this can be a headache because it needs a lot of computing power and has to play nice with the old gear you already got.

Also going to make sure the chit-chat between IoT stuff, cloud systems, and AI is super secure so wicked encryption and keeping track of keys is a must. The thing is, these IoT gizmos don't have the muscle to handle the top-notch secret code stuff so the brainiacs need to cook up some security light enough for them to handle.

The report goes deeper into the hurdles and boundaries that come with fusing new tech. It zeros in on stuff the current stuff doesn't touch, like how long it takes for devices to respond managing resources, saving power moral questions, and making sure safety can grow. This part really digs into the tricky bits adding to what we already got on keeping data safe making different systems work together, and being able to handle more work.

5. Future Research Directions and Open Issues in Technology Integration

5.1. Super Cool Ways to Get All Kinds of Different Tech to Talk Without Trouble

Okay so we've already chewed over tough stuff like delays and growing big-time, but now let's chat about how we going to build some super smart ways so all these different computer systems, like cloud stuff Internet of Things huge data piles, and brainy AI, can all yak without missing a beat. Right now, trying to get them all on the same page is kind of a mess because there's no common lingo or fancy tech handshakes to link them up. So what we going to do later is figure out some sort of universal tech language that makes sure they all play nice together, no matter how different they are.

So, check this out IoT gadgets have their own secret ways of talking, which makes mixing them with cloud stuff or AI pretty tricky. To fix this, building middleware or systems that can switch these secret codes to ones everyone gets is like super key for the brainy folks researching. Plus, edge computing thingies might be major players because they act as the middlemen for switching up those codes and sorting out data before it hits the big time (Syed and pals, 2019).

Now for another cool idea, blockchain could level up how well everything plays together. With blockchain, you get this spread-out and tight-locked record book that keeps track of all the chit-chat between IoT things, cloud services, and AI tricks. Digging into blockchain that won't bog down IoT and edge gadgets is mega important. We going to keep things quick and not burn too much juice (Gizealew and their crew 2021).

5.2. Training AI Over Many Devices

This part looks at something different from the usual chat about central AI and giant data crunching. It peeks into how federated learning and AI that aren't all in one place could shake things up in combo systems. By training AI straight up on scattered data spots, like IoT gizmos, and not shifting raw info to a main computer, federated learning cuts down time delays and keeps private stuff more private by not letting it wander off.

Future studies should dive into making federated learning methods better suit gadgets with limited power like IoT stuff. Think of making AI things that can do their job well on gadgets at the edge without using too much juice. Plus, you can use neat tricks like chopping down models and squeezing them to make the whole federated learning thing run smoother.

On another note, the safety of federated learning setups is kind of up in the air. Since the whole shebang is about spreading data out, there's a risk of bad guys messing with it or slipping in bogus data. Digging into top-notch code locking and weird-activity catchers is super important to keep federated learning in check.

5.3. Real-Time Data Wrangling and Smart Thinking at the Edge

We've already chatted a bit about how lag and quick processing are huge deals. But this bit hammers home just how much we need super-smart edge computing setups if we want to crunch numbers on data in a snap. Mixing IoT with heaps of data is what's up nowadays, and it's creating this flood of info that things like self-driving cars, health trackers, and robot-packed factories need to sort out, like, yesterday.

Looking ahead, the smart cookies in research should get cracking on making edge nodes that are stacked with brainy hardware, think GPUs and TPUs, ready to tackle AI thinking on-the-fly. Plus, mashing up edge computing with cloud computing might just be the genius move to keep things speedy and not overload any one spot. Picture it: all the super urgent data gets the VIP treatment at the edge, and the cloud handles the chill stuff (Urooj et al. 2021).

Exploring the use of "predictive analytics" at the edge is pretty fascinating, you know? With AI models that learned from past data, gadgets on the edge can guess what might happen next and make moves before stuff goes down. Like, in those super techy industrial IoT setups, if they predict when things might break down, that would cut back on non-working times and make everything run smoother.

Now, let me dive into a thing called Ethical AI and how to be cool with data. You see, we're going a bit further than just the usual probs by zeroing in on making rules and ways to keep AI ethical and use data without being sketchy in those mashed-up systems. When you mix up the cloud IoT big data, and AI, you're looking at massive head-scratchers like keeping private stuff private making sure computers aren't biased, and being clear about how things work.

Researchers should focus on building AI models that folks can explain and interpret. They should use stuff like attention mechanisms and ways to see the model to make things clearer. Plus, there's going to be solid rules for how we collect and use data, sticking to big-deal laws like the GDPR and CCPA (Uchenna et al. 2023).

It's super important to work on AI that doesn't play favorites. These smarty-pants systems in the health world, going to learn from all sorts of data so everyone gets a fair shake. We've got to get into the nitty-gritty of finding and fixing these biases.

5.4. Energy-Efficient and Sustainable Integration Models

This part goes deeper into how to mix sustainability into cloud computing, IoT big data, and AI. These techs are getting more popular and they're using up a ton more energy, which makes folks worry about what it's doing to the planet.

Looking ahead, we going to work on making algorithms and gear that don't need as much power in these combined systems. Take AI, you can make it use less energy by squishing the models down and giving them a speed boost with better hardware. Also, if IoT gadgets could get their power from stuff around them, like sunlight or motion, they'd need less from other power supplies (Syed et al. 2019).

Okay here's a fresh take: Tapping into renewable energy to keep data centers and those edge nodes running is a solid idea that's gaining steam. Digging into the nitty-gritty of smart systems that juggle resources based on how much energy we've got and what's needed? Yeah, that's super important. Plus, doing a deep dive on the full life of these combined systems? It's a no-brainer; it shows us where we can do better.

So, wrapping it up, these up-and-coming research hotspots and the big questions they throw our way? They're throwing up a big neon sign for different brainiacs to join forces and get creative. We're talking about squaring off with the big puzzle of blending together cloud computing, IoT, heaps of data, and AI. If the research crowd zeroes in on this stuff, we're looking at a future with smoother, safer, and greener tech systems.



Figure 4 Analysis of Risk Distribution

6. Conclusion

Cloud computing IoT, Big Data, and AI are mixing up to change tech in a big way. This combo opens doors for cool new uses in fields like healthcare making stuff, and cities gone smart. Cloud computing is the rock here giving the heavy lifting power for keeping data, crunching numbers, and rolling out AI brains. On the flip side, edge computing jumps in to keep things snappy for stuff that needs quick thinking. IoT is wild with data spitting out heaps of sensor info. This stuff loves Big Data spots to get its act together and AI to make sense of it all. The fresh buzz like federated learning digital twins, and AI-smart IoT setups show how these tech buddies are getting along. They're kicking things up a notch in figuring out stuff before it breaks making machines that think on their feet, and getting more out of energy (Syed et al. 2019; Hassan et al. 2021). So even with all the cool new tech stuff, there are still some pretty big headaches to deal with. We're talking about problems like keeping data safe, getting different gadgets to speak the same language, delays, the whole shebang growing too fast, and not burning through a zillion watts of power. Like, imagine trying to make a bunch of different phone brands work together, or the stress over how much juice all our smart devices and mega computers are guzzling, and that's what we're dealing with. Plus, we've got to think about the rules of the game making sure we're not creating smart tech with a bad attitude or stepping on the toes of laws like the GDPR that keeps our secrets from becoming street talk. To get on top of this, folks from all kinds of brainy areas need to jump in and play around with things like super-smart frameworks that get our gadgets chatting, power-saving computer tricks AI that plays fair, and speedy calculations right on the spot.

As we look ahead, it's key researchers work on building scalable and lasting ways to blend technologies. It helps to tap into cool new tools like AI that doesn't weigh much, data centers that use clean energy, and spread-out learning systems such as "federated learning." Plus, making worldwide rules for techs to work well together and for AI to be fair and responsible is super important. This guarantees tech we can trust, that's out in the open, and treats everyone the same. Tackling these big questions, the smart folks doing research and making stuff can make the most of combining these techs. They can spark more new ideas, watch out for any trouble, and keep things going strong for a long while

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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