EDITOR **MARK CAMPBELL**
EVOTEK; mark@evotek.com

Conversational Artificial Intelligence: Changing Tomorrow's Health Care Today

Mark Campbell, EVOTEK
Mlađan Jovanović, Singidunum University

Conversational artificial intelligence (AI) is making inroads into health-care administrative automation and continual care today, and its greatest potential lies in the preventive, therapeutic, and diagnostic care of tomorrow. Although conversational AI won't replace human caregivers, will those who use it replace those who don't?

The health-care industry is predicated on invention. Recent global events have placed an unprecedented demand on health-care ingenuity, way beyond the stress, sweat, and courage endured. Today's evolving health-care innovation methods create many avenues for emerging technologies to improve lives—conversational artificial intelligence (AI) is perhaps the most exciting health-care innovation outside of biotechnology labs.

"Many health-care companies are passionate about innovation but less experienced with fast, iterative software development processes. This is starting to change in a meaningful way, but we are now seeing a more agile innovation cycle, like that used to develop software, built on an adaptable and nimble experimentation platform," observes Evan Macmillan, cofounder of Gridspace, a leader in conversational AI for the health-care industry.[1] Two key examples are Pfizer/BioNTech's messenger RNA (mRNA)-based COVID-19 vaccine platform, which can quickly adapt to the new variants,[2] and CureVac's MRNA printer, which can print myriad genetic fingerprints to combat not just COVID-19 but also Ebola, Zika, and Lassa.[3]

Conversational AI has grown rapidly in sophistication and adoption over the past several years. Recently, Microsoft acquired conversational AI pioneer Nuance,[4] which, among other offerings, provides deep learning voice transcription services for health care. Other conversational AI platforms, such as Amazon Web Services' Alexa,[5] Apple

Digital Object Identifier 10.1109/MC.2021.3083155
Date of current version: 30 July 2021

Siri, Google Assistant, and Microsoft, offer easy-to-build, off-the-shelf services that accelerate the development and deployment of generalized conversational applications.[6] Although these general-purpose platforms allow for easy "assembly" of rudimentary virtual assistants, they are difficult to customize. This is because their internal models, training data, and data pipelines are inaccessible, and their sequential workflow and data-sharing structures increase response latency, which creates awkward user-agent dialogue delays.

There are other purpose-built conversational AI tools emerging that allow engineers under the hood to develop highly sophisticated applications for case-specific dialogues. One such example is Gridspace Grace, which presents a virtual assistant dialogue almost indistinguishable from a real human. Grace was recently used to help schedule COVID-19 vaccines for people without online access by calling them directly, "talking" them through the scheduling process, and answering any questions they might have. Today, conversational AI is having its greatest impact in two key areas: administrative automation and continuous care.

"Many health-care companies are passionate about innovation but less experienced with fast, iterative software development processes."

ADMINISTRATIVE AUTOMATION

Conversational AI has been proven an effective method in replacing human communication steps in administration workflows, such as insurance coverage verification, identify verification, scheduling, information gathering, and cross-organization communications. Once the communication steps are automatic, the entire administrative workflow can be automated using common robotic process automation tools. This frees resources and budget away from repetitive noncognitive tasks to more critical caregiving.

Patient data privacy and sovereignty and regulatory compliance will soon be competitive advantages as well as imperatives for health-care providers. Conversational AI offers a confidential and trustworthy alternative to traditional human-in-the-loop information gathering. Experiments with computational linguistics have shown since the 1960s that people will often trust the discretion of a nonjudging and discrete synthetic assistant over a human.[7] The accuracy, privacy, and efficiency that conversational AI will bring to clinical admission, discharge, and feedback will continue to change the public face of health care.

CONTINUAL CARE

Hospital stays are expensive. In-hospital patient care is often extended for observation and continual care, despite studies showing that patients often recover faster at home than in a hospital.[8] Conversational AI, coupled with smart health monitoring, allows patients to transition from hospital to home care earlier, which saves costs and increases recovery rates. In many situations, the combination of smartphones, mobile applications, Internet-attached medical devices, the Internet of Things (IoT), and conversational AI all provide a platform for continued outpatient care that rivals inpatient care.

From posttreatment recovery to wellness checks, a "virtual caregiver" platform equipped with conversational AI and connected devices will revolutionize elderly care, digital therapy, and continual care. "Imagine taking home a few IoT devices that can talk to both you and your doctor from home in natural language," posits MacMillan.[1]

Dr. Milica Pejović-Milovančević, a child psychiatrist at Belgrade's Institute of Mental Health, notes that "although conversational technologies lack the human touch, they can successfully automate many activities in mental health-care provision[s]. Examples include diagnostics, reaching out and contacting new patients, progress monitoring, reminders, and initiating small talk to elicit important information from patients during depression treatment."[9]

CONCEPTUAL ARCHITECTURE

The breakneck maturation speed of conversational AI across various industries and applications in recent years means that one can develop the conceptual architecture for a virtual caregiver built on interdependent layers, as presented in Figure 1:

- The data layer contains the sources of structured (for example, personal health records) and unstructured data (such as health training data).
- At the knowledge layer, health information is retrieved or created from the existing sources or the virtual caregiver's data layer. This layer contains medical knowledge bases (that is, ontologies) and a live repository of patient-related information that is built and updated using automated data analysis and interpretation tools.
- The information generated at the knowledge layer is input for the service layer, where automated health-care decisions are made for prevention, diagnosis, and therapy.
- Once the decisions for users are ready, they are communicated to a dialog layer, which accomplishes the following tasks:
  - It processes the input information from the service layer or

from end users using natural language understanding (NLU) techniques.
- It creates conversation threads, either by following predefined dialog rules or with probabilistic machine learning tools selected driven by the dialog management module.
- It outputs from the dialogue management module produce responses using natural language generation tools.

› The dialog layer responses are then delivered to the presentation layer and on to the patient via an array of presentation methods (for example, text, image, voice, and multimode).

The conversational threads take a round-trip journey through the layers where the patient and/or the connected medical device requests are ingested, interpreted, and enriched with health-specific information from the data, knowledge, and service layers. This information is fed to the dialog layer, which delivers the response to the patient via the presentation layer.

THREE KEY CLINICAL USE CASES

Prevention

Conversational AI is being applied in three settings: prevention, therapy, and diagnostics. Various caregivers help maintain the specific aspects of human health. They do so by facilitating the desirable well-being behaviors connected with that particular health aspect(s) to avoid degradation and decline. The examples include physical activity, nutrition, and regular sleep. The immediate goal behind the different applications is sustained user engagement in these behavior, while the critical long-term goal is that the behaviors become a person's self-care habits or everyday routines.

Caregivers act as a companion, advisor, or coach who tries to establish deeper social bonds with their users. This way, it is assumed that users will perceive them as peers with authority, follow their inputs, and engage in target behaviors. Over time, the caregivers learn about their collocutors and personalize their suggestions to the user's needs and preferences. Forksy is an example of automated nutrition advising.[10] A female persona conducts conversations on food-related topics, keeps a diary of the user's food intake, and provides a diet schedule with nutrition recommendations and a fitness program. Ally is an embodied, virtual fitness coach that facilitates an active lifestyle.[11] It promotes a healthy way of life by offering and following personalized workout plans for weight management.

Therapy

The advancements in natural language processing technologies have enabled conversational AI to conduct more human-like conversations. Also, the ability to recognize and interpret the user's mental and emotional states during and from spoken or written discourse have made these technologies more humane and trusted. They have become a natural fit for certain medical practices, such as cognitive behavioral therapy and medication monitoring.

> Conversational AI offers a confidential and trustworthy alternative to traditional human-in-the-loop information gathering.

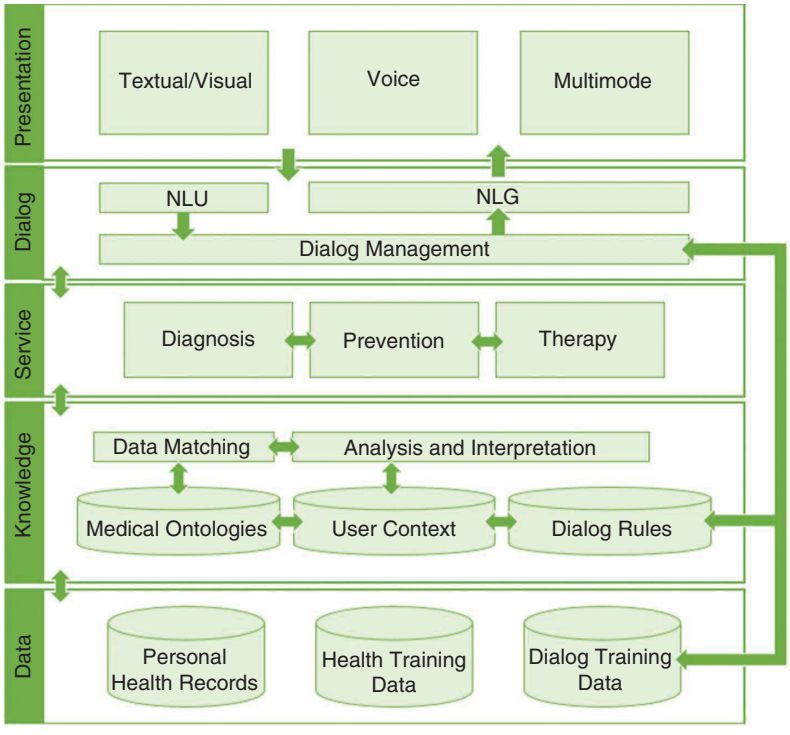

FIGURE 1. A conceptual conversational AI architecture for health care. NLU: natural language understanding; NLG: natural language generation.

Woebot[12,13] is a digital therapist that guides its users through open conversations to estimate their current mood (for example, small talk about current events and happenings in the patient's life). It then initiates structured dialog sessions, such as mirroring/paraphrasing what users have previously said or labeling/acknowledging how they might feel at the moment. The former shows the person that it is listening and understands them, while the latter tries to counterbalance negative emotions and reinforce positive ones ("You look like ..." or "It seems like ..."). The approach attests to positive health outcomes—neutralizing anxiety/depression[12] and reducing substance use[13] in younger people. Florence is a virtual nurse that supports users in specific treatment/rehabilitation activities.[14] It speaks with its users to remind them to take their prescribed medications(s), keep track of their health (body weight and women's health), and provide real-time information on nearby doctors/pharmacies.

In mental therapy, virtual caregivers can reduce the overburden on doctors of routine patient check-ins that complement face-to-face treatments. Dr. Pejović-Milovančević observes that, "At the moment, we have even 25 such controls per day, while the norm is up to 12." Moreover, she states, "Digital communicators are technical means to make the conversation ongoing. This is crucial for helping some technology-literate populations, such as children with speech-linguistic and nonverbal developmental issues (that is, autism)."[9]

Diagnosis

Some conversational applications can recognize symptoms of illnesses to inform users about the changes/declines in their health and recommend a course of action. They conduct a structured Q&A dialog to elicit the necessary user information. The collected data are a basis for making a diagnosis. The information is mainly subjective (self-reported by users) and may influence an accurate diagnosis. The course of action is often a medication program or doctor visit. For example, Symptomate is a diagnostic caregiver that screens its patients and provides the diagnosis for a range of conditions (roughly 700).[15] The screening is done through a conversational Q&A session from which the virtual caregiver establishes a diagnosis as a ranked list of possible conditions with a confidence level (for example, strong, moderate, or weak).

The screening is done through a conversational Q&A session from which the virtual caregiver establishes a diagnosis.

The different virtual caregivers help people quickly find information regarding their health. Even the demographic groups with a lower technological literacy, such as older adults, primarily use commercial voice assistants (such as Amazon Alexa) to search for health-related information online.[16] These caregivers extract keywords from conversations with their users and query the available knowledge bases to find answers. They can deliver responses in a textual or document form. Some caregivers, such as Gridspace Grace, automate health-care customer services, including medical advising on COVID-19.[17]

As Dr. Pejović-Milovančević highlights, "Conversational AI provides opportunities for teletherapy by engaging patients' families (that is, parents) to work with their children under the continuous supervision of doctors so they do not feel alone."[9]

A LOOK INTO THE FUTURE

There are several key areas where conversational AI in health care will grow and mature.

- *Admission avoidance*: Conversational AI can provide the autonomous screening and treatment of outpatient ailments, thus reducing the number of hospital admissions.
- *Explainability*: Conversational AI systems typically use black-box models to take a set of inputs to produce dialogue. Exposing the details of this process in a patient-friendly manner will become crucial as virtual caregivers increase their role in diagnosing a user's current health and prognosis and making treatment recommendations.
- *Transparency*: Conversational AI's capabilities in health care still fall short of human medical professionals. As this gap shrinks in the coming years, there will be increased demand for transparency on where the conversational AI limits lie and where consulting a professional is needed. Added transparency on how patient information is collected and used will also help foster trust in virtual caregivers.
- *Continuous health care*: As mentioned previously, conversational AI holds great potential for continual care, which shortens hospitalizations by providing autonomous care once the patient transitions back home. However, in the future, this will not just continual be but constant—assisting the patient "in sickness and in health" with nutrition, prevention, diagnostics, exercise, real-time check-ups, and alerts.
- *Automated application creation*: Advancements in automated application development will democratize health-care solutions

creation process by enabling medical experts to develop, deploy, and test applications without involving designers and programmers.[8]

- *Multiparty communications*: The systems involving patients, health-care professionals, and families through mediated or separate peer-to-peer multiparty dialogs, while challenging, are feasible and will take on a central role in health-care communications in the future.[18]
- *Integration with legacy systems*: Aside from the practical concerns regarding security and privacy, a better connectivity of digital medical records, medical devices, hospital procedures, and health-care staff will reduce the burden on health-care services and provide faster and more effective care.

Although conversational AI is making rapid inroads in the health-care industry, particularly in administrative automation and continual care, its greatest potential could be in preventive, therapeutic, and diagnostic care. This space is maturing rapidly, and even though the future looks bright for virtual caregivers, there are significant hurdles yet to be cleared. At present, conversational AI cannot replace health-care professionals, but doctors who use it will replace those who do not.

REFERENCES

1. M. Campbell, interview with E. Macmillian, Apr. 28, 2021.
2. P. Wnuk, "Pfizer invests in mRNA vaccine powerhouse BioNTech," PharmaPhorum, Surrey, U.K. Aug. 16, 2018. [Online]. Available: https://pharmaphorum.com/news/pfizer-invests-mrna-vaccine-biontech/
3. "Epidemic group invests $34 million in potential vaccine printer tech." Reuters, Feb. 27, 2019. https://www.reuters.com/article/us-health-vaccines-curevac-idUSKCN1QG1MD (accessed May 6, 2021).
4. B. Dickson. "Why Microsoft's new AI acquisition is a big deal." TechTalks, Apr. 15, 2021. https://bdtechtalks.com/2021/04/15/microsoft-nuance-acquisition/ (accessed May 25, 2021).
5. M. Turea. "10 ways Alexa is revolutionizing healthcare." Healthcare Weekly, Apr. 8, 2021. https://healthcareweekly.com/alexa-in-healthcare/
6. P. Cox and J. M. Geyer, "Voice assistants in healthcare," Smart Business - Great Medicine, May 16, 2020. https://www.smartbusinessgreatmedicine.com/voice-assistant-technology-healthcare/
7. J. Weizenbaum and J. Weizenbaum, "Computational linguistics," *Commun. ACM*, vol. 9, no. 1, pp. 36–45, 1966. doi: 10.1145/365153.365168.
8. D. M. Levine et al., "Hospital-level care at home for acutely ill adults: A randomized controlled trial," *Ann. Internal Med.*, vol. 172, no. 2, pp. 77–85, Jan. 21, 2020. doi: 10.7326/M19-0600.
9. M. Campbell, interview with M. Pejović-Milovančević, May 10, 2021.
10. C. Wiedemann. "Die Therapeuten in der Tasche (The therapists in your pocket)." Frankfurter Allgemeine, Apr. 26, 2018. https://www.faz.net/aktuell/stil/quarterly/koennen-chatbots-einen-echten-therapeuten-oder-coach-ersetzen-15549081.html (accessed Apr. 21, 2021).
11. J. Zhang, Y. J. Oh, P. Lange, and Y. Fukuoka, "Artificial intelligence chatbot behavior change model for designing artificial intelligence chatbots to promote physical activity and a healthy diet: Viewpoint," *J. Med. Internet Res.*, vol. 22, no. 9, p. e22845, Sept. 30, 2020. doi: 10.2196/22845.
12. K. K. Fitzpatrick, A. Darcy, and M. Vierhile, "Delivering cognitive behavior therapy to young adults with symptoms of depression and anxiety using a fully automated conversational agent (Woebot): A randomized controlled trial," *JMIR Mental Health*, vol. 4, no. 2, p. e19, 2017. doi: 10.2196/mental.7785.
13. J. J. Prochaska et al., "A therapeutic relational agent for reducing problematic substance use (Woebot): Development and usability study," *J. Med. Intern Res.*, vol. 23, no. 3, p. e24850, Mar. 23, 2021.
14. "Researcher develops a chatbot that already is a reference in healthcare," Phys.org, Aug. 31, 2017. https://phys.org/news/2017-08-chatbot-healthcare.html (accessed Apr. 29, 2021).
15. "Feeling sick? There's an app for that! – The big symptom checker review." The Medical Futurist, Apr. 11, 2019. https://medicalfuturist.com/the-big-symptom-checker-review/ (accessed May 13, 2021).
16. A. Pradhan, A. Lazar, and L. Findlater, "Use of intelligent voice assistants by older adults with low technology use," *ACM Trans. Comput.-Hum. Interaction*, vol. 27, no. 4, pp. 1–27, Sept. 2020. doi: 10.1145/3373759.
17. "Grace, the best conversational AI virtual agent in the market," EVOTEK, Apr. 2, 2021. https://www.youtube.com/watch?v=17X1kJbNLMA (accessed May 7, 2021).
18. R. J. Moore and R. Arar, *Conversational UX Design*. New York: ACM Books, 2019.

MARK CAMPBELL is the chief innovation officer for EVOTEK, San Diego, California, 92121, USA. Contact him at mark@evotek.com.

MLAĐAN JOVANOVIĆ is with Singidunum University, Belgrade, 11000, Serbia. Contact him at mjovanovic@singidunum.ac.rs.