Life-Saving Decision Support System

1. Specifications

Task:

Give advice if resuscitation is required in an emergency case and if it needs to be cardiopulmonary resuscitation (CPR) or mouth-to-mouth only.

Background:

Recently, I witnessed a sad incident. A Saturday night, it was almost bedtime when we (my partner and myself) realised someone is screaming outside. We went close to the front window and saw a man standing next to a car, shouting for help. Being a first aider and my partner, a health care provider, we decided to go out to help. When we went outside, we saw a young man unconscious that was laying on the floor just outside the car and 2 people next to him, one holding a phone and the second was about to start CPR. My partner observed the scene and shouted: “Stop!, this person is breathing, you shouldn’t do CPR”. Seconds after, he took the phone, spoke with the emergency services, which were on the line and tried to assess the patient health situation. Minutes after, the ambulance came and we left. If we haven’t gone out of our home at that moment, the unnecessary CPR could have caused broken ribs on the patient among other side effects.

From this experience, I understood that people in extreme situations, such as when the fear about a close person’s life are incapable of carrying out a simple breathing check and that the NHS emergency line, when it doesn’t have the real-time data, may not be able to correctly advise on life-saving procedures.

Wearable devices, such as fitness trackers, or smartwatches, have become popular in recent years, these are generally capable of counting steps, monitoring the heart rate and oxygen levels in the blood among other things. With the advances of technology and the competitiveness in the technology sector, wearable devices increase their accuracy, increase the number of applications and, reduce the purchase price, hence it is possible to find some fitness trackers at very affordable prices. Although they weren’t designed as medical devices, they could be useful as such in extreme situations while taking into account their inaccuracy with probabilities. Additionally, external factors such as dirt and sweat can influence the accuracy of these devices.

Objective:

Develop a Decision Support System (DSS) that can determine whether a person needs resuscitation using basic inputs into an app and live data from wearable devices.

The background knowledge for the DSS will be designed as a Bayesian Network and will be implemented in python.

Constraints:

The number of nodes is limited to 6 as per recommended guidelines.
Based on live data collected from a smartwatch and people around him, the DSS will be able to decide whether a person needs resuscitation. Therefore, it may not be suitable for resuscitation of babies, toddlers, and small children for whom wearable devices have yet to be developed.

2. Conceptual design

The DSS will work as part of an “emergency app”.
If a person is next to someone whose life is in danger, they should open the app. This will automatically call an emergency number and send an ambulance to their location. Moreover, the app will ask the user if the patient is conscious and ask to connect the app with the patient's smartwatch through Bluetooth if he/she has one. If the patient does not have a smartwatch, the user could use the camera on the phone to measure the patient's heart rate by placing his/her finger next to it, as well as adding their breathing status manually if the user knows how to detect it. The DSS in the app decides whether the patient requires CPR, mouth-to-mouth resuscitation, or none of these first aid options based on real-time data it received. In the event that this is necessary, the App will instruct the user, until the ambulance arrives, on how to proceed.

The DSS nodes:

Node	Possible values	Function	Parents nodes or input	Child nodes
Is conscious	yes/no	Input to the DSS	Input by user	Is breathing, Is heart pumping
Saturation %	<90,90-95, >95	Input to the DSS	Collected from smartwatch	Is breathing
Normal heart rate detected	yes/no	Input to the DSS	Collected from a smartwatch or phone camera	Is heart pumping
Is breathing	yes/ no	Input or Intermediate node	Saturation % is conscious, could be input manually	First Aid
Is heart pumping	yes/ no	Intermediate node	Normal heart rate detected is conscious	First Aid
First Aid	full CPR, mouth2mouth, no rescue	Output node	Is breathing Is heart pumping	

Consciousness will be input by the user. Data about saturation rate and heart rate can be retrieved from a wearable device. Having knowledge of how to check breathing status could allow the user to input it manually. The app could detect and measure the patient's heart rate even when the patient does not have a smartwatch by placing his/her finger on the phone's camera. Using these inputs and the prior probabilities, if some inputs are missing, the DSS calculates the probabilities of the different options for the output node "First aid" and returns the value with the highest probability, along with the subsequent probability.

A DSS output is an advice on the correct first aid treatment. The DSS could save the life of a person in danger, it could reassure the user that s/he is doing the right thing, and it might save a patient from CPR side effects such as broken ribs, if s/he does not require CPR. In addition to providing immediate advice to the user, the DSS output might also be sent to the medical team in the ambulance, so they can be prepared for the emergency situation.

The app could function as an independent system, or it could be integrated with another NHS app (or with an app for another country's health services) that can access medical history data and extend the Bayesian network. Including a patient's medical history, age, and gender in the DSS's knowledge base could increase or decrease the probability of resuscitation. For example, an old person with heart disease may increase the probability of full CPR treatment in case the person is unconscious.

The potential risk of this DSS development is that fitness tracker demand could increase dramatically and therefore the price might increase too much, thus making the system unaffordable to the general public.

There is also the risk that the app won't be approved by health authorities who may not trust the data coming from wearable devices.

There is an additional risk of making a mistake that can take the patient’s life instead of saving it. There could be a situation where the output advice “no rescue needed” with a probability of 0.55 and the probability of 0.45 for doing CPR. In this case, the user may not do anything but may feel ashamed and angry with the app if the patient dies. Therefore, to improve the DSS, we may need to add utility functions and calculate the maximum expected utility by multiplying the utility function with its probability. However, calculating the expected utility of living given the action CPR and the DSS inputs as evidence is a very difficult task which I can’t help estimating it, but if may be higher than the expected utility of avoiding broken ribs, given the action “not rescue” and the inputs. Hence, the DSS should be checked and be improved to give always higher probabilities into its preferable value on the output, or the DSS should be designed to return the output of the maximum expected utility, but this will need some help of medical and ethical experts to estimate the utility functions.

Stakeholders in this development include emergency health services and the general public. In spite of the fact that the app is designed for all users, due to the complexity of the life-saving procedures, it might be most suitable for people aged 13 and up. The app works better for smartwatch users as patients, so babies, toddlers, small children, and people with skin conditions who can't wear watches all day, won't benefit from this.

Furthermore, the app could request information from the user after the incident to verify whether the DSS decision was accurate. By using this information, the DSS may be able to change and improve its model based on experience.

3. Bayesian network

Textual description of the background knowledge:

People in good health are conscious, breathe 12-16 breaths per second at rest, have an oxygen saturation level higher than 95, usually 97-98, and have a heart rate of 60 to 90 pulses per second that is easily felt at the wrist. In the absence of these vital signs, something is wrong and the body is under stress.

If someone loses consciousness, it could be the result of insufficient oxygen in the brain, which may be caused by a failure in the respiratory system or in the circulatory system, and would increase the chances they are not breathing or their hearts are not pumping.

When the oxygen saturation is lower than 95%, it means the lungs are failing, if the oxygen saturation is lower than 90%, there is a higher probability that the lungs are not working.

When the heart rate is not detected at the wrist, there is a high risk that the heart is not pumping.

When the two pieces of evidence are present (non-consciousness and non-heart rate detected or lower saturation %) there is a higher risk that the heart not pumping or the lungs not working accordingly.

When an individual is not breathing and his heart is not pumping, he certainly needs cardiopulmonary resuscitation which includes, chest compressions and rescue breaths, if the person’s heart is beating, but he is not breathing, then, he needs only mouth-to-mouth resuscitation, if the individual is breathing but his heart rate is not found, it may be due to a failure in the measuring system and there is no need for treatment, similarly, when the person is breathing and the heart is pumping, there is no need for resuscitation and it should not be done, even if the person is unconscious.

Background knowledge

In the model, I used estimated probabilities based on first-aid knowledge I gained in previous training. In order to use this app in real life, there would need to be a scientific investigation to create more realistic probabilities or the creation of a team of biomedical engineers, wearable device specialists, emergency medicine physicians, and medical scientists, who could work together to create more accurate estimates. Furthermore, some first aid protocols allow only health professionals to perform only mouth-to-mouth resuscitation while advising first aiders to perform full CPR if a person is not breathing, regardless of whether the heart is beating. Hence, it is crucial that the DSS is checked by health authorities. Moreover, they could advise not to perform rescue breaths at all due to the Covid-19 pandemic.

Selection of the nodes and links

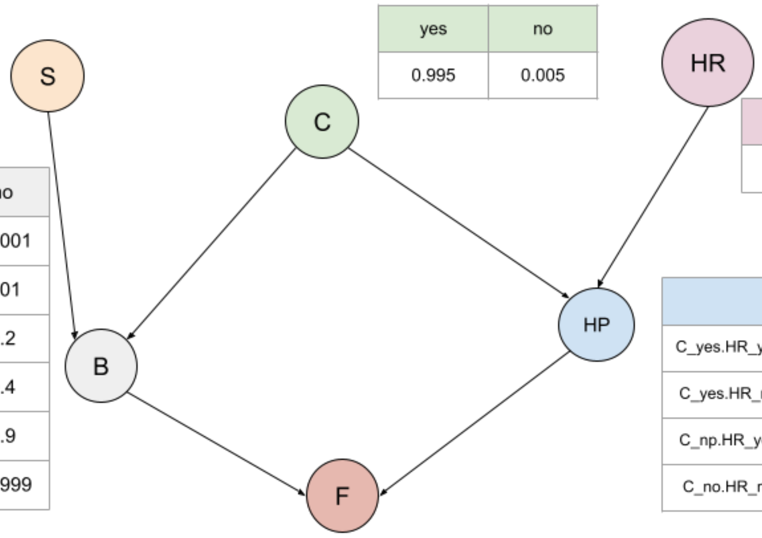
The BSS is built with 6 nodes: The top 3 nodes (is conscious, saturation, and normal heart rate detected) represent the inputs that can be easily spotted or detected with a wearable device or phone camera. From their status, we could infer the probabilities of the internal status of a patient, (is breathing, is heart pumping). From the internal statuses of the heart and respiratory system, we can infer the probabilities of a resuscitation treatment needed, which is represented in the output node (first aid)

The top 3 links represent: Effect->Cause or Signs/Meausurements->Diagnosis

The bottom 2 links represent: Diagnosis->Treatment.

Graphical representation and associated probabilities

Fig.1 Conditional Probability Table and Graphical Representation



>95	90-95	<90
0.99	0.009	0.001

yes	no
0.995	0.005

yes	no
0.999	0.001

	yes	no
C_yes.S_>95	0.9999	0.0001
C_yes.S_90-95	0.99	0.01
C_yes.S_<90	0.8	0.2
C_no.S_>95	0.6	0.4
C_no.S_90-95	0.1	0.9
C_no.S_<90	0.0001	0.9999

	yes	no
C_yes.HR_yes	0.9999	0.0001
C_yes.HR_no	0.999	0.001
C_np.HR_yes	0.99	0.01
C_no.HR_no	0.001	0.999

	Full CPR	Mouth to Mouth	No Rescue
B_yes.HP_yes	0.0	0.0	1
B_yes.HR_no	0.1	0.0	0.9
B_no.HR_yes	0.1	0.89	0.01
B_no.HR_no	1	0.0	0.0

S: Saturation%
C: Is conscious
HR: Normal heart rate detected
HP: Is heart pumping
B: Is Breathing
F: First Aid

References

Ltd, 2022. *First Aid Courses & Training From Qualified Instructors* | *Aid Training*. [online] Aid-training.co.uk. Available at: <https://www.aid-training.co.uk/> [Accessed 6 January 2022].
En.wikipedia.org. 2022. *Mouth-to-mouth resuscitation - Wikipedia*. [online] Available at: <https://en.wikipedia.org/wiki/Mouth-to-mouth_resuscitation> [Accessed 6 January 2022].