

## Report on non-intrusive methods of heart rate monitoring

Traditional methods of heart rate monitoring such as ECG and pulse oximeters are intrusive and require skin contact in order to measure vital signs.

In recent years there has been growing interest in developing non-intrusive methods for heart rate monitoring. Methods for doing so mainly centre around either use of a camera or use of RF technologies such as WIFI and radar.

Traditional ECG requires the use of adhesive electrodes which is intrusive, non-mobile and has the potential to cause discomfort to the patient. Non-contact ECG takes measurements using capacitive electrodes as opposed to adhesive ones, these capacitive electrodes don't have to be in contact with the skin however they still require being in close proximity of the patient (a few cm).

Camera based methods fall into two categories photoplethysmography that can extract a patient's heart rate through examining miniscule colour variations in the skin usually on the face; and Ballistocardiography which relies on the motion of the heart which causes microscopic displacement in the location of the body which can be measured by a camera. Camera methods can also analyse the pupil to extract heart rate data.

Cameras are advantageous as they are universally available to the majority of people whom often own several, in devices such as phones laptops etc. Another advantage of camera-based monitoring is that several of these methods can be implemented in a single system to improve accuracy of readings.

However, camera based techniques do have downsides. Many of these methods require suitable lighting conditions which is not going to be practical in all use cases. Another disadvantage is the patient needs to be in the line of sight of the camera, and most methods specifically require the head to be visible by the camera. There are also practical problems with using cameras in existing devices. One such issue is that many devices only allow a single program to access camera data at a time meaning that if heart rate monitoring is in the process of being captured a user might not be able to use their device to make a video call or take a picture. Use of camera-based methods also raises privacy concerns. Also, most camera based techniques require close proximity the camera usually within a meter if not closer.

RF technologies include use of things such as WIFI and radar. WIFI based techniques share the advantage cameras possess of being already available to the majority of people however use of WIFI is very dependent on a patient's position and body orientation.

mmWave radar is almost perfect for remote monitoring of heart rate this is because it possesses almost all of the advantages of the above mentioned techniques as well as some of its own with very few downsides. With use of mmWave radar a user's privacy is respected as point cloud data is obtained from the radar. The system has a range of at least a few meters and is less demanding in regard to the area of the body that needs to be measured (i.e mmWave can take heart rate measurements by examining just the leg, although areas such as the chest are easier to take measurements from). mmWave radar can take measurements in all lighting conditions and can also take measurements through clothing,

curtains and through a lot of visual clutter. Whilst at the moment mmWave sensors might not be prevalent in people's homes like technologies such as cameras and WIFI technology this is likely to change over time as more companies implement the technology in their products and adoption of new products such as robot vacuum cleaners (a product where mmWave radar is a great improvement on currently implemented sensors ) increase.