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Cyber Physical Systems: Error Verification and Prediction in Smart Medical Devices

Stephen O. Maitanmi[1]*, Sunday A. Idowu[2], Olawale J. Omotosho[3], Olusegun A. Ojesanmi[4]

[123] Department of Computer Science, Babcock University, Ilisan Remo, Ogun State, Nigeria
[4]Department of Computer Science, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

Abstract: *Embedded software is a piece of software that is built in a system or hardware component to achieve an objective. Cyber-Physical Systems (CPS) are integrations of computation with physical processes which are monitored and controlled by the embedded systems. CPS has positively affected a number of application areas which include communication, consumer energy, infrastructure, healthcare, manufacturing, military, robotics and transportation. This research paper focuses on CPS with particular application interest on error prediction in smart medical devices SMDs. SMDs are used for healthcare services by medical personnels in such a way that they have to interact with the patients in one form or the other. A number of research works has focused on errors arising from the use of SMDs. Errors arise from readings of the SMDs as a result of usability challenges from embedded software leading to malfunctioning of the devices. This research paper is aimed at providing a model for error verification and prediction in the use of SMDs using Euler's method of representation with the aims of establishing safety and reliability of the use of SMDs with possible reduction in risk of accidents. In order to achieve the stated objective, a mathematical model using Euler's method was adopted for its fast convergence rate and simplicity for error prediction. Input data was provided through a critical incident analysis of online database which provide readings from medical experts. These readings were compared to the standard world benchmarks. The difference between the readings and the standard benchmark validates the existence of errors. Due to the complexity of the model, an algorithm was developed to obtain an optimal solution of P_1-P_5 within an acceptable threshold runtime. An implementation was carried out using Java programming language because of its robustness and cross platform advantages which provides an efficient error estimate and result analysis. The analysis showed that the optimum performances of the SMDs were hindered by errors. The results generated from the use of thermometer for the diagnosis of Malaria predicted 98.1% accuracy in measurement, Upper respiratory tract infection predicted 99.3% accuracy in measurement, Tonsilitis predicted 99.6% accuracy in measurement, Severe head injury predicted 99.9% accuracy in measurement and Septicaemia predicted 99.9% accuracy.*
These results show that Malaria generated the highest error in the use of thermometer. In conclusion, CPS generally is an active area of research with a number of application domains in particular health care systems. This particular work has provided a model for error verification in the use of SMDs.
Keywords: *Cyber Physical Systems, Embedded system, SMDs, Euler's method;*

I. Introduction

The availability of the Internet alongside its advantages has led to the pervasive use of networking and information technology (IT) across all sectors [1]. Interestingly, these technologies are combined with elements of the physical world such as machines, devices and structures to create smart or intelligent systems that offer increased usefulness, productivity, safety and speed which enabled previous challenging functions.

Embedded software is a piece of software that is hidden in a system or hardware components written specifically in a coordinated fashion to achieve an objective. Embedded system is not only one of the most important fields for current computer-based applications; it is also one of the most challenging fields of computer science or more precisely, Software Engineering [2]. Embedded systems are used in many areas ranging from vehicles and mobile phones to washing machines and printers to increase and enhance productivity.

Cyber-Physical Systems (CPS) are integrations of computation with physical processes which are monitored and controlled by the embedded systems usually with feedback loops where physical processes affect computations [3]. All CPS have computational processes that interact with physical components. These computational processes can either be simple or complex instructional processes. For example, simple processes include water heater or cutting machine while the complex processes include vehicle, aircraft systems, oil refineries among others. The computational and physical processes of such systems are highly interconnected and coordinated to function together. The following diagram in Fig.1 sheds more light into the meaning of CPS as regards integration of computation with physical processes.

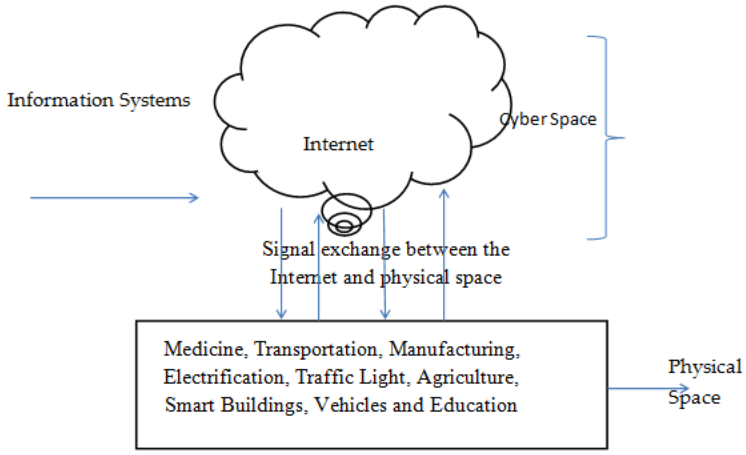

Fig. 1. Cyber-Physical Systems Concept

CPS concepts as illustrated in Fig.1 shows that cyberspace is the Internet which is invisible in information systems and it synergizes the physical operations that we carry out daily either in Computer Science, Medicine or any other professional fields. The importance of the Internet cannot be overemphasized, it harnesses the operations that were formerly carried out independently to a single, faster, robust and more coordinated operation. To further illustrate the usefulness of CPS, a three months old baby can be monitored from an independent room through a wearable body wire while a monitor is placed in the parent's room with the aid of sensors which is a device that detects a change in a physical stimulus and turns it into a signal that is measurable. The movements within the defined locations are known with the aid of the sensors embedded as part of the software.

Error verification is defined as investigating a device or software for the existence of error [4]. Meanwhile, the Institute of Medicine Patient Safety described patient safety as a freedom from accidental injury due to medical care, software error or medical errors. It has increasingly been regarded as the key element of quality in the last two decades [5]. The process began in 1999 with Harvard Medical Practice study that showed adverse events in 3.7% of hospitalization and errors which could be related to 27.6% of adverse events [6]. In 2001, the Institute of Medicine published a study tagged 'to err is human: building a safer health system' [7]. This study estimated that preventable medical errors are responsible for between 44, 000 and 98, 000 deaths annually in United States.

A more heart touching news from the Journal of Patient Safety reports that the numbers may be much higher which was put between 210,000 and 440,000 annually for patients who visit the hospital. Such patients are likely to suffer some type of preventable harm that contributes to their death [5]. This report would make medical errors the third highest cause of death in America after heart disease and cancer.

Lack of patient safety measures make the care unsafe and produce opportunities for medical errors to occur [7] while [8] stated that 2,000,000 defective devices were recalled in the last decades due to deficiencies in outputs such examples include unmanned rocket launched in June 1998 called Ariane 5. Ariane 5 was a project that lasted for ten years and cost $7 billion exploded after 37 seconds into the flight due to software errors; code ported from Ariane 4 rocket did not work [9]. Similarly, on land transportation; a Honda CR-V that cost $1.5M in US was recalled to update the software that controls its automatic transmissions. In similar manner, a Toyota Hybrid was recalled because of software deficiency that made it enters fail-safe mode that shuts down engines frequently [9].

Similarly, in Nigeria health services, [10] affirmed in a conference proceeding that seventy percent of deaths in third world countries occur before age five and are caused by factors that are controllable.

The SMDs studied include thermometer, insulin pump, infusion pump and sphygmomanometer. They are briefly defined as follows; thermometer measures the body temperature, insulin pump maintains the normal body glucose level, infusion pump transfers fluids, medication or nutrients into a patient's circulatory system while sphygmomanometer measure the blood pressure of the body [11].

The objective of this paper was to design a model for error verification and prediction of SMDs in CPS. In fulfilling this mandate, the research carried out a critical evaluation of some frequently used SMDs to verify and predict the existence of errors.

The paper layout

The rest of the paper is organized as follows: apart from the introduction section, subsequent sections handle the methodology of the research, results, discussions and conclusion.

II. Methodology

In order to achieve the stated objective which was to develop a model for error verification and prediction of SMDs in CPS.; a critical incident analysis approach was adopted to look into the use of the SMDs because of the sensitivity of the devices. A mathematical model using Euler's method was employed for its fast convergence rate and simplicity. Secondary input data were retrieved from an online database of Medline, Web of Science, Health Technology Assessments and Health and Science Care Information Center which provides database of readings from medical experts. These retrieved data were further compared with the standard world benchmarks from literatures. The following sections consist of the breakdown of each SMD analysed alongside its standard and practicable benchmarks. This input data was considered to achieve accuracy and correctness in the research and experimentation process of the proposed model.

Due to the complexity of the model, an algorithm was developed to obtain an optimal solution within an acceptable threshold runtime. Implementation was carried out using Java programming language because of its robustness and cross platform advantages which provides an efficient error estimate and result analysis.

The SMDs analysed in this research paper include thermometer, sphygmomanometer, infusion pump and insulin pump. These SMDs were chosen because of their relevance in the implementation of CPS as regards technological advancement to health care systems.

Thermometer for both Benchmark and Readings

The following represent the analysis of digital thermometer:

Table 1. Temperature readings and standard benchmark (^{0}C)

Symptoms	Benchmark (P)	Time(t)	Readings P(t)	Error(t)
Malaria	37.9	0	37.9	0
	38.5	10	36.0	2.5
	38.7	20	36.1	2.6
	38.9	30	36.2	2.7
	39.5	40	36.3	3.2
	39.6	50	36.3	3.3
URTI	37.7	0	37.7	0
	38.5	10	37.7	0.8
	39.0	20	37.8	1.2
	39.5	30	37.9	1.6
	39.8	40	38.0	1.8
	40.0	50	38.0	2.0
Tonsilitis	36.4	0	36.4	0
	37.8	10	36.5	0.4
	39.2	20	37.0	2.2
	39.9	30	37.6	2.3
	40.0	40	38.0	2.0
	40.5	50	38.5	2.0
Severe Head Injury	39.8	0	39.8	0
	39.9	10	39.8	0.1
	40.5	20	39.9	0.6
	43.5	30	40.0	3.5
	45.5	40	40.0	5.5
	47.5	50	40.1	7.4
Septicaemia	39.9	0	39.9	0
	40.0	10	39.0	1.0
	45.3	20	39.5	5.8
	47.3	30	39.9	7.4
	47.8	40	40.0	7.8
	48.0	50	40.0	8.0

Source : Appendix A-C
Where URTI= Upper respiratory tract infection.

Sphygmomanometer (mmHg) for both Benchmark and Readings

Table 2. Sphygmomanometer readings and standard Benchmark (mmhg)
Source: Appendix D

Systolic		**Diastolic**			
	BM/RD/error	BM/RD/error	BM/RD/error	BM/RD/error	BM/RD/error
	≤84	85-89	90-99	100-109	110-119
≤129	2 1 1	3 2 1	4 3 1	5 4 1	6 5 1
<130-139	2 2 0	3 2 1	4 3 1	5 4 1	6 5 1
<140-159	3 3 0	3 3 0	4 3 1	5 4 1	6 5 1
<160-179	5 4 1	5 4 1	4 3 1	5 4 1	6 5 1
<180-209	5 5 0	5 5 0	5 4 1	6 5 1	6 5 1
≥210	7 6 1	6 6 0	5 4 1	7 6 1	7 6 1

Where N=161, BM= benchmark and RD= readings

Infusion Pump for both Benchmark and Readings

Table 3. Infusion Pump readings and standard Benchmark (Msl/hr.)
Source: [13]

Benchmark	**Readings**	**Error**	**Time (Mins)**
Adult -100mls/hr	80mls/hr	10	60
500mls/hr	480mls/hr	20	60
500mls/hr	490mls/hr	10	60
4 litres/day	4litres/day	0	1,440
500mls/12rs	480mls/12rs	20	720
500mls/day	495mls/day	5	1,440
Children 300mls/day	280mls/day	20	1,440
10mls/hr	10mls/hr	0	60
1 liter/day	1 litre/day	0	1,440
2 litres/day	2 litres/day	0	1,440

Insulin Pump for both Benchmark and Readings

Table 4. Insulin Pump readings and standard Benchmark
1 unit of insulin for every 15g Carbohydrates taken. Insulin Pump Workbook.
Source: [14]

Time	**Benchmark Blood Glucose**	**Amount of Carbohydrates**	**Benchmark Insulin intake**	**Readings Insulin intake**	**Errors**
Day 1					
7:30am	5.7	60g	4	8	4
1:30pm	11.2	50g	3.3	6.6	3.3
6:00pm	7.2	72g	5	10	5
10:00pm	8				
Day 2					
7:30am	6.8	60g	4	8	4
1:30pm	12.3	50g	3.3	6.6	3.3
6:00pm	7.1	90g	6	12	6
10:00pm	11.3				

2.1 Relationship between Model and Thermometer table

Performance at optimum level is represented in Table 1 as the Benchmark of temperature taken when error is not involved (P) which is equivalent to 100%.

Performance with respect to time is represented in Table 1 taking note of the time in minutes when temperatures were taken P(t). The recorded time were decimated to reduce the magnitudes of error such as 0.1, 0.2, 0.3 and so on for Malaria. These values are not constant for other ailments.

Error as shown in Table 1 gives the difference between benchmark and actual readings which was also decimated to reduce error value ther eby realizing (E) of Malaria to be 0.25, 0.26, 0.27, 0.32 and 0.33

P_1-P_5 is the performance level of the SMDs and the model with respect to the introduced error.

2.2 Mathematical Modeling of Error Prediction in the use of Thermometer

$P =$ Performance at optimum level

$P(t) =$ Performance with respect to t

$E(t) =$ Error introduced at any time t

$$P(t) = P - E(t) ------------------------------ (1)$$

(1) gives the difference between the benchmark and the actual reading which is a function of time.

$P^1(t) \propto E(t)P(t)$

Where $P^1(t)$ is the change in performance which is proportional to the product of performance and the error at any time t

$P^1(t) = -KE(t)P(t)$
where K is assumed to be 1

$P^1(t) = -E(t)P(t)$

substituting $P(t)$ in (1) gives

$$P^1(t) = -E(t)[P - E(t)] \text{ - } (2)$$

By Using Euler's iteration method to project a possible outcome when variables such as error, and time are used as input

$$P_{n+1} = P_n + h(P^1)_n \text{ - } (3)$$

Where n= 0-4 (five variables from temperature readings on malaria from Table 1)

While E_0 = 0.25, E_1=0.26, E_2 = 0.27, E_3 =0.32 and E_4 =0.33 decimated values from temperature readings in Table 1

$h = dt$ and dt =0.1 from model time used from Table 1

From (2) at optimum level when $t=0$ and $E=0$

$P(0)=P_0$ from (2) = 1 or 100% when there is no error, meaning performance at best level

Starting Iteration

From (2)

$(P^1)_0 = -(0.25*0.1)[1-0.25*0.1] = -0.025*0.975) = -0.024$

$P_1 = P_0 + h(P^1)_0 = 1 + (0.1)(-0.024) = 1 - 0.0024 = 0.9976$ or 99.8%

$(P^1)_1 = -(0.26*0.1)[1-0.26*0.1] = -0.026*0.974) = -0.025$

$P_2 = P_1 + h(P^1)_1 = 0.998 + (0.1)(-0.025) = 0.998 - 0.0025 = 0.995$ or 99.5%

$(P^1)_2 = -(0.27*0.1)[1-0.27*0.1] = -0.027*0.973) = -0.026$

$P_3 = P_2 + h(P^1)_2 = 0.995 + (0.1)(-0.026) = 0.995 - 0.0026 = 0.992$ or 99.2%

$(P^1)_3 = -(0.32*0.1)[1-0.32*0.1] = -0.032*0.968) = -0.031$

$P_4 = P_3 + h(P^1)_3 = 0.992 + (0.1)(-0.031) = 0.992 - 0.031 = 0.989$ or 98.9%

$(P^1)_4 = -(1.33*0.1)[1-0.33*0.1] = -0.033*0.967) = -0.0319$

$P_5 = P_4 + h(P^1)_4 = 0.989 + (0.1)(-0.0319) = 0.989 - 0.00319 = 0.986$ or 98.6%

2.3 Development of Algorithm

The algorithm is based on the following formulae:

$$P^1(t) = -E(t)[P - E(t)] \text{ - } (4)$$

$$P_{n+1} = P_n + h(P^1)_n \text{ - } (5)$$

Declarations

Step 1: Initialize fractional variables (double) h, t, E

Step 2: Initialize whole numbers (Int) P, n

Step 3: let all values of n be between 0 to 4

Step 4: Let E_0=0.25, E_1=0.26, E_2=0.27, E_3=0.32 and E_4=1.85

Step 5: Let 0.1 be stored in t as fractional number

Step 6: Let 1 be stored in P as whole number

Step 7: Let 0.1 be stored in h as fractional number

Starting the Euler's iterations

Step 8: making reference to (4) above where $(P^1)_0 = -E_0(t)[P - E_0(t)]$

Find $(P^1)_0$ to $(P^1)_4$

Step 9: starting iteration where the values of n= 0 to 4 starting with n=0 to begin

$P_1 = P_0 + h(P^1)_0$ store the result in P_1

Step 10: Use the value obtained above in step 8 on $(P^1)_1$ to find $P_2 = P_1 + h(P^1)_1$ and store the result in P_2

Step 11: Use the value obtained above in step 8 on $(P^1)_2$ to find $P_3 = P_2 + h(P^1)_2$ and store the result in P_3

Step 12: Use the value obtained above in step 8 on $(P^1)_3$ to find $P_4 = P_3 + h(P^1)_3$ and store the result in P_4

Step 13: Use the value obtained above in step 8 on $(P^1)_4$ to find $P_5 = P_4 + h(P^1)_4$ and store the value in P_5

Step 14: Display the values of P_1, P_2, P_3, P_4, P_5

III. Results & Discussions

Table 5 Error Prediction in the use of Thermometer for the diagnosis of Malaria

RESULT TABLE

E	t	P	P%
0.3	0.1	0.981	98.1
0.3	0.1	0.962	96.2
0.3	0.1	0.942	94.2
0.3	0.1	0.921	92.1
0.3	0.1	0.898	89.8

Table 5. shows the output of the error prediction that resulted in the use of thermometer for the diagnosis of

Table 5 shows the output of the error prediction that resulted in the use of thermometer for the diagnosis of patient suspected to be having malaria fever. The variables displayed include E= error rate which are values of 0.25, 0.26, 0.27, 0.32 and 0.33 taken from Table 1, it appears that the higher the values, the weaker the functionality of the SMDs in terms of precision. P% refers to percentage analysis of the performance of the predicted error, the higher the error, the lower the performance of the SMDs, t=time which is 0.1and constant as discussed in the model development stages. P = performance, meaning maximum performance when there is no error. The first output on column 1 therefore shows that the prediction generated 98.1% accuracy in measurement. It appears also that the percentage error increases as the error in prediction increases.

Consequently, the rates of error increases down the column. The last column shows the highest error rate with low performance. The performance value was 89.8%. From this value it is evidenced that performance was affected.

RESULT TABLE

E	t	P	P%
0.1	0.1	0.993	99.3
0.1	0.1	0.982	98.2
0.2	0.1	0.969	96.9
0.2	0.1	0.954	95.4
0.2	0.1	0.938	93.8

Table 6. Error Prediction in the use of Thermometer for the diagnosis of Urinary Tract Infection (URTI)

Table 6 shows the output of the error prediction that resulted in the use of thermometer for the diagnosis of patient suspected to be having URTI fever. The variables displayed include E= error rate which are values of 0.08, 0.12, 0.16, 0.18 and 0.2 taken from Table 1, the higher the values, the weaker the functionality of the SMDs in terms of correctness in measurement. P% refers to percentage analysis of the performance of the predicted error, the higher the error, the lower the performance of the SMDs, t=time which is 0.1 and constant as discussed in the model development stages. P = performance, meaning maximum performance when there is no error. The first output on column 1 therefore shows that the prediction generated 99.3% accuracy in measurement. It appears also that the percentage error increases as the error in prediction increases.

Therefore, the rates of error increases down the column. The last column shows the highest involvement of errors. The performance value was 93.8%.From this value it is evidenced that performance was affected.

RESULT TABLE

E	t	P	P%
0.0	0.1	0.996	99.6
0.2	0.1	0.979	97.9
0.2	0.1	0.961	96.1
0.2	0.1	0.945	94.5
0.2	0.1	0.929	92.9

Table 7. Error Prediction in the use of Thermometer for the diagnosis of Tonsilitis

Table 7 shows the output of the error prediction that resulted in the use of thermometer for the diagnosis of patient suspected to be having Tonsilitis fever. The variables displayed include E= error rate which are values of 0.04, 0.22, 0.23, 0.2 and 0.2 taken from Table 1, the higher the values, the weaker the functionality of the SMDs in terms of correctness in measurement. P% refers to percentage analysis of the performance of the predicted error, the higher the error, the lower the performance of the SMDs, t=time which is 0.1 and constant as discussed in the model development stages. P = performance (benchmark), meaning maximum performance when there is no error. The first output on column 1 shows that the prediction generated 99.6% accuracy in measurement. It appears also that the percentage error increases with respect to increase in error.
Therefore, the rates of error increases down the column. The performance value was 92.9%. From this value it is evidenced that performance was affected.

RESULT TABLE

E	t	P	P%
0.0	0.1	0.999	99.9
0.1	0.1	0.993	99.3
0.4	0.1	0.971	97.1
0.6	0.1	0.946	94.6
0.7	0.1	0.927	92.7

Table 8. Error Prediction in the use of Thermometer for the diagnosis of Severe Head Injury

Table 8 shows the output of the error prediction that resulted in the use of thermometer for the diagnosis of patient suspected to be having severe head injury fever. The variables displayed include E= error rate which are values of 0.01, 0.06, 0.35, 0.55 and 0.74 taken from Table 1, the higher the values, the weaker the functionality of the SMDs in terms of correctness in measurement. P% refers to percentage analysis of the performance of the predicted error, the higher the error, the lower the performance of the SMDs, t=time which is 0.1 and constant as discussed in the model development stages. P = performance (benchmark), meaning maximum performance when there is no error. The first output on column 1 therefore shows that the prediction generated 99.9% accuracy in measurement.

Therefore, the rates of error increases down the column. The last column shows the highest involvement of errors. The performance value was 92.7%. It is evidenced from this value that performance was affected.

RESULT TABLE

E	t	P	P%
0.0	0.1	0.999	99.9
0.6	0.1	0.975	97.5
0.7	0.1	0.955	95.5
0.8	0.1	0.938	93.8
0.8	0.1	0.922	92.2

Table 9. Error Prediction in the use of Thermometer for the diagnosis of Septicaemia

Table 9 shows the output of the error prediction that resulted in the use of thermometer for the diagnosis of patient suspected to be having Septicaemia fever. The variables displayed include E= error rate which are values of 0.01, 0.06, 0.35, 0.55 and 0.74 taken from Table 1, it appears that the higher the values, the weaker the functionality of the SMDs in terms of precision. P% refers to percentage analysis of the performance of the predicted error, the higher the error, the lower the performance of the SMDs, t=time which is 0.1 and constant as discussed in the model development stages. P = performance (benchmark), meaning maximum performance when there is no error. The first output on column 1 therefore shows that the prediction generated 99.9% accuracy in measurement. It appears also that the percentage error increases as the error in prediction increases.

In addition, the rates of error increases down the column. The last column shows the highest error rate with low performance. The performance value was 92.2%. It is therefore evidenced that performance was affected.

IV. Conclusion

In conclusion, CPS generally is an active area of research with a number of evolving application domains in particular, health care systems. The research paper investigated a number of SMDs and discovered error in its applications. Based on these findings, a model was developed to guide medical personnel and individual users in the appropriate use of SMDs.`

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Appendix A Temperature Measurement
Fever in adults
If you or a family member has a fever, it means your body temperature is above normal.

Around 37ºC is normal
A digital thermometer is the best type to use to get an accurate temperature reading.
A fever is usually a normal response of your immune system to a virus or bacterial infection. Most healthy adults can tolerate a fever well.

Fever ranges and symptoms
38–38.9°C – mild fever
With a mild fever you might have flushed cheeks, feel a little lethargic, and be warm to touch. You will generally be able to carry out normal daily activities.

39–39.9°C – high fever
With a high fever you may not feel well enough to go to work, you may have aches and pains, and you'll feel hot to touch.

40°C or higher – very high fever
With a very high fever you will usually want to stay in bed or be inactive – you won't feel well enough to carry out normal activities. You may have lost your appetite. You'll feel hot to touch.

When to see your doctor
Some mild diseases produce very high fevers – and severe illnesses can produce mild fever. Therefore, when considering what medical attention you need, it's important to look at other symptoms and how unwell you feel.
You should see your doctor if you or a family member:
- has a very high fever (over 40ºC)
- is still feverish after three days of home treatment, or seems to be getting sicker
- is shivering or shaking uncontrollably, or has chattering teeth
- has a severe headache that doesn't get better after taking painkillers

Appendix A Cont'd
- is having trouble breathing
- is getting confused or is unusually drowsy
- has recently travelled overseas.

When it's urgent
See your doctor or go to the Emergency Department immediately if you notice the following symptoms (along with a fever):
- Hallucinations
- Vomiting
- A stiff neck (they're unable to put their chin on their chest or have pain when moving their neck forward)
- A skin rash
- A rapid heart rate.

Also get medical help if the person has a seizure (fit), or has signs of a seizure about to happen, such as regular twitching or jerking.

Call Healthline 0800 611 116 if you are unsure what you should do.
Fever in pregnancy
If you're pregnant and have a temperature of 38.5ºC – or any fever lasting for three days or more – you must see your lead maternity carer. They'll need to monitor the effects of the fever on your baby.

Self care
Most fevers last only three to four days – and a mild fever may not need any treatment at all.
Try these ideas if your fever is mild and you don't have any other worrying symptoms:
- Drink plenty of fluids – water is best.

- Get plenty of rest.
- Wear light weight clothes and use lighter bedding. Keep the room temperature normal.
- Put cool cloths on your face, arms and neck to help you cool down. Don't use any rapid cooling methods that may make you shiver. (The muscle movement in shivering will actually raise your temperature and can make your fever worse.)

Appendix B Temperature Measurement
Fever and Night Sweats

Fever is a common sign that on its own is usually little help in making a diagnosis. Persistent high fever needs urgent treatment. Fever over 42.2°C (108°F) producesunconsciousness and leads to permanent brain damage if sustained. Fever can be classified as:

- Low: 37.2-38°C (99°-100.4°F).
- Moderate: 38.1-40°C (100.5°-104°F).
- High: >40°C (104°F).

Fever may also be described as:

- Remitting - the most common type with daily temperatures fluctuating above the normal range.
- Intermittent - daily temperature drops into the normal range and then rises back above normal. If temperature fluctuates widely causing chills and sweating, it is called a hectic fever.
- Sustained - persistent raised temperature with little fluctuation.
- Relapsing - alternating feverish and a febrile periods.
- Undulant - gradual increase in temperature, which stays high for a few days then gradually reduces.

Fever may also be described in terms of its duration; brief (<3 weeks), or prolonged. The term pyrexia of unknown origin (PUO) is used to describe a condition where no underlying cause can be found.[1]

Night sweats are common and there is a long list of possible causes, mostly benign but important to diagnose in order to manage effectively. Serious causes of night sweats can usually be excluded by a thorough history, examination and simple investigations if required.[2]

Appendix C Body Temperature
What is body temperature?

Body temperature is a measure of the body's ability to generate and get rid of heat. The body is very good at keeping its temperature within a narrow, safe range in spite of large variations in temperatures outside the body.

When you are too hot, the blood vessels in your skin expand (dilate) to carry the excess heat to your skin's surface. You may begin to sweat, and as the sweat evaporates, it helps cool your body. When you are too cold, your blood vessels narrow (contract) so that blood flow to your skin is reduced to conserve body heat. You may start shivering, which is an involuntary, rapid contraction of the muscles. This extra muscle activity helps generate more heat. Under normal conditions, this keeps your body temperature within a narrow, safe range.

Where is body temperature measured?

Your body temperature can be measured in many locations on your body. The mouth, ear, armpit, and rectum are the most commonly used places. Temperature can also be measured on your forehead.

What are Fahrenheit and Celsius?

Thermometers are calibrated in either degrees Fahrenheit (°F) or degrees Celsius (°C), depending on the custom of the region. Temperatures in the United States are often measured in degrees Fahrenheit, but the standard in most other countries is degrees Celsius.

What is normal body temperature?

Most people think of a "normal" body temperature as an oral temperature of 98.6°F (37°C). This is an average of normal body temperatures. Your temperature may actually be 1°F (0.6°C) or more above or below 98.6°F (37°C). Also, your normal body temperature changes by as much as 1°F (0.6°C) throughout the day, depending on how active you are and the time of day. Body temperature is very sensitive to hormone levels and may be higher or lower when a woman is ovulating or having her menstrual period.

Appendix D Blood pressure chart

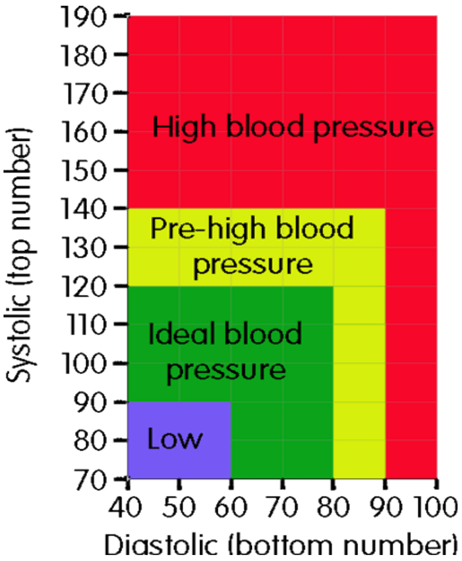
Use the blood pressure chart below to see what your blood pressure means. The blood pressure chart is suitable for adults of any age. (The level for high blood pressure does not change with age.)

Blood pressure readings have two numbers, for example 140/90mmHg.

The top number is your **systolic** blood pressure. (The highest pressure when your heart beats and pushes the blood round your body.) The bottom one is your **diastolic**blood pressure. (The lowest pressure when your heart relaxes between beats.)

The blood pressure chart below shows ranges of high, low and healthy blood pressure readings.

Blood pressure chart for adults



Using this blood pressure chart: To work out what your blood pressure readings mean, just find your top number (systolic) on the left side of the blood pressure chart and read across, and your bottom number (diastolic) on the bottom of the blood pressure chart. Where the two meet is your blood pressure.

Appendix D Cont'd

What blood pressure readings mean

As you can see from the blood pressure chart,**only one of the numbers has to be higher or lower than it should be** to count as either high blood pressure or low blood pressure:

- **90 over 60 (90/60) or less:** You may have low blood pressure. More on low blood pressure.
- **More than 90 over 60 (90/60) and less than 120 over 80 (120/80):** Your blood pressure reading is ideal and healthy. Follow a healthy lifestyle to keep it at this level.
- **More than 120 over 80 and less than 140 over 90 (120/80-140/90):** You have a normal blood pressure reading but it is a little higher than it should be, and you should try to lower it. Make healthy changes to your lifestyle.
- **140 over 90 (140/90) or higher (over a number of weeks):** You may have high blood pressure (hypertension).Change your lifestyle - see your doctor or nurse and take any medicines they may give you. More on high blood pressure

So:

- **if your top number is 140 or more** - then you may have high blood pressure, regardless of your bottom number.
- **if your bottom number is 90 or more** - then you may have high blood pressure, regardless your top number.
- **if your top number is 90 or less** - then you may have low blood pressure, regardless of your bottom number.
- **if your bottom number is 60 or less** - then you may have low blood pressure, regardless of your top number.