Internet of Things cooking safety

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Internet of things devices are beginning to be introduced into households, for example to control heating and lighting (Hive, 2017). Internet enabled cooking devices for the home are beginning to be developed by manufacturers (Riekki et al, 2012) including internet enabled ovens, microwave ovens, and rice cookers. However, such internet enabled cooking devices could potentially increase the risk of kitchen fires occurring, since they would be used in an unattended mode. In this article we examine the requirements for safe use and design for safe use of internet enabled cooking devices in terms of safe operation embedded software controls and mobile telephone alerts regarding potentially unsafe operation.

In particular, we examine a design for embedded control software that could be implemented in each type of internet enabled cooking device to ensure that cooking could not be undertaken for a time and temperature combination that could potentially result in a fire. We examine the design of mobile telephone alerts to advise the user in order to prevent unsafe operation instructions being passed to the cooking device and being undertaken. In addition, we also examine the design of internet enabled cooking devices for use by vulnerable individuals such as dementia patients, where unsafe use alerts could be sent to a relative / carer / neighbour, and for visually impaired users, where an inability to detect the right button and pushing the wrong button, for example, on a microwave oven might lead to fire and accidents (Riazi et al, 2012).

The Internet of Things (IoT) allows people and physical devices to be connected anytime, anyplace, with anything and anyone (Nolin and Olson, 2016). The combination of the Internet and embedded sensors can allow everyday objects to be transformed into smart objects that can understand and react to their environment (Kortuem et al, 2010). Andersson and Mattsson (2015) commented that in the everyday life of individuals many products have become internet enabled, including kitchen equipment and home appliances, lighting and heating products.

In the UK and elsewhere more fires and fire injuries are caused in the kitchen than anywhere else in the home (LFB, 2017; NFPA, 2017; FSE, 2016). Gao et al (2014) commented that kitchen fires are mostly caused by human negligence. In particular, leaving cooking unattended is the predominant cause of cooking fires (Lushaka and Zalok, 2014; Xiong et al, 2017; LFB, 2017;

DSFRS, 2017; SFRS, 2017; ESFRS, 2017). Yared et al (2015) commented that unattended cooking is typically the main factor responsible for fire in the kitchen. In particular, older people and those who may have some form of cognitive impairment such as Alzheimer's disease, which can have a significant impact on both short-term memory and on the level of insight are potentially more at risk from such fires. Other groups potentially more at risk of kitchen fires are drug and alcohol users who may turn on the cooker and forget that they have done so, and people with conditions such as narcolepsy who may fall asleep whilst cooking.

It is important that any cooking devices are used at the correct temperature, and for the correct duration for the food being prepared (Dinaburg and Gottuk, 2016). As well as conventional oven fire incidences, Thambiraj et al (2013) commented upon the increasing rate of inappropriate use of microwave ovens potentially leading to fire. In particular, aluminium, paper and plastics food bags may cause a fire in a microwave oven. In addition, an empty microwave oven may catch fire if used, since if there is nothing to absorb the microwaves, (i.e. foodstuffs), the magnetron within the microwave oven ends up absorbing the microwaves and essentially self-destructs.

Different types of cooking devices can now be controlled via the internet including cookers, microwave ovens, and more specialist cooking devices such as rice cookers (Riekki et al, 2012). Roman et al (2013) commented that fault tolerance is an essential aspect of the design of internet of things devices and applications. Although previous research had examined the generic safe design and operation of internet of things devices, there appears to have been little if any research specifically examining the fire risks associated with internet enabled cooking devices, the requirements for safe use of such devices, and the design aspects of such devices to reduce fire risk.

With sufficiently flammable foodstuffs in an internet enabled cooking device (especially those with a high oil or fat content, or a high sugar content (Dinaburg and Gottuk, 2016; Swain et al, 2004)) a fire could potentially result if unsafe cooking instructions were sent to the device. If such actions were carried out over an area or region, there could be the potential for numerous building fires.

Safe operation of cooking devices includes:

- Not leaving cooking unattended (ESFRS, 2017).
- Not cooking if alcohol has been consumed or prescription drugs have been taken, as this may result in drowsiness or loss of concentration (ESFRS, 2017).
- Ensuring correct cooking temperatures are used and not exceeded. The average oven temperature for oven cooking is approximately 180 C (Dinaburg and Gottuk, 2016).
- Keeping the oven clean, since built-up fat and bits of food can start a fire (ESFRS, 2017)
- Ensuring empty microwave ovens are not used (Swain et al, 2004).

- Ensuring correct cooking times are used and not exceeded (Dinaburg and Gottuk, 2016).

For an internet enabled cooker, embedded safe operation control logic could include:

If cooking temperature > 250 C
    Then safety alert “Cooking temperature too high”

If cooking duration time > 5 hours
    Then safety alert “Cooking time too long”

If cooking temperature multiplied by cooking duration time (in hours) > 500
    Then safety alert “Cooking time too long for this temperature”

If temperature > 40 C at start time of cooking
    Then safety alert “Cooker still warm”

The embedded safe operation control logic “If temperature > 40 C at start time of cooking” could help to prevent attempts to override safe operation of the internet enabled cooker by repeatedly turning the cooker on and off and thus building up the temperature.

In summary a mobile telephone alert would be sent to the user of the internet enabled cooking device under the following potentially unsafe conditions:

- If the cooking temperature value was outside a pre-set range stored on the internet enabled cooker

- If the cooking time duration was outside a pre-set range stored on the internet enabled cooker

- If the product of the temperature and cooking time was greater than a pre-set value stored on the internet enabled cooker

- If the cooker temperature was above a set value stored on the internet enabled cooker at the start time of the cooking instruction.

For an internet enabled microwave, embedded safe operation control logic could include:

If weight of food < 100 g
    Then safety alert “Insufficient food present for cooking”

(The 100 g minimum weight for an item to be cooked in a microwave oven was based upon a minimum food weight of 50 g (for example and egg without shell) and a 50 g cooking receptacle (for example a microwave safe plastic bowl)).

If microwave setting (in watts) multiplied by cooking duration time (in minutes) > 10,000
Then safety alert "Excessive cooking time for this setting"

The weight of the food (and cooking receptacle) would be measured by a load sensor in the base of the microwave oven. In summary, a mobile telephone alert would be sent to the user of the internet enabled microwave oven under the following potentially unsafe conditions:

- If no food, or only a small amount of food is in the microwave oven

- If the product of the microwave oven setting and cooking time is greater than a pre-set value stored on the internet enabled microwave oven

For an internet enabled rice cooker, embedded safe operation control logic could include:

If weight of rice and water < 100 g
Then safety alert "Insufficient rice / water present for cooking"

(The 100 g minimum weight for the contents of a rice cooker was based upon a minimum weight of rice and water, 33 g of rice and 67 g of water based upon the typical 2 : 1 cooking ratio of water to rice, and water being slightly denser than rice).

If cooking duration time (in minutes) > 150
Then safety alert "Cooking time too long"

If rice and water weight (grams) divided by cooking duration time (in minutes) < 2
Then safety alert "Cooking time too long for this amount of rice / water"

The weight of the rice and water would be measured by a load sensor in the base of the rice cooker.
In summary, a mobile telephone alert would be sent to the user of the internet enabled rice cooker under the following potentially unsafe conditions:

- If no water and rice, or only a small amount is in the rice cooker

- If the cooking time is greater than a pre-set value stored on the internet enabled rice cooker

- If the weight of rice and water divided by the cooking duration time is less than a pre-set value stored on the internet enabled rice cooker

The unsafe use mobile telephone alerts could be sent to a specified relative / carer / neighbour for a vulnerable individual such as a dementia patient, and for visually impaired users, the mobile telephone alert could include a text to speech function. The above design safety features could easily be incorporated into the internet enabled cooking devices concerned and the mobile telephone applications that control such at minimal cost to the manufacturer.

Fire and rescue services universally advise that cooking should not be left unattended. However, internet enabled cooking devices allow exactly that. There can be different fire risks that can arise from the use of internet enabled cooking devices including:

- Cooking at too high a temperature
- Cooking for too long
- Cooking for an inappropriate temperature and time duration combination
- Using an empty microwave oven or rice cooker, or cooking with too little contents.

In an attended cooking mode, such unsafe actions would hopefully be noticed. However, in an unattended cooking mode such unsafe actions would be more likely to occur. In this paper we have examined how the inclusion of low-cost embedded software operational controls, weight sensors in microwave ovens and rice cookers, and warning mobile telephone alerts could assist in reducing the aforementioned cooking fire risks.

These could prevent unsafe cooking instructions from being actioned by internet enabled cooking devices, and warn the users that such actions are unsafe. In addition, such an approach could benefit vulnerable individuals, since the warning mobile telephone alerts could be sent to appropriate others, and could also assist the visually impaired, with the warning mobile telephone alerts being “spoken” via a text to speech function in the mobile telephone application.

In order to reduce the potential risk of cooking fires resulting from unsafe use of internet enabled cooking devices, embedded software safe operation controls and mobile telephone alerts could prevent users from inputting unsafe cooking instructions, prevent the cooking device from carrying out unsafe cooking actions, and inform the user (or relevant other in the case of vulnerable individuals) if unsafe cooking actions have been attempted to be entered manually (for example by a vulnerable individual) or by malicious individuals or software.

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