From Controls on the Steering Wheel to Controls on the Finger: Using Smart Rings for In-Vehicle Interactions

Bogdan-Florin Gheran
MintViz Lab | MANSiD Research Center
University Ștefan cel Mare of Suceava
Suceava 720229, Romania
bogdan.gheran@gmail.com

Radu-Daniel Vatavu
MintViz Lab | MANSiD Research Center
University Ștefan cel Mare of Suceava
Suceava 720229, Romania
radu.vatavu@usm.ro

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Abstract
We explore the opportunity of shifting car controls from the steering wheel to the driver’s fingers by means of smart rings that enable tap, touch, and mid-air gesture input. We also discuss the opportunity of using smart rings together with other input modalities toward more efficient and safer in-vehicle interactions. By accounting for the driver’s *location*, *activity*, and *distance* from the car, we identify unique characteristics of smart rings to control the connected car compared to steering wheel controls, smartphones and in-vehicle touchscreens, mid-air gestures, and voice commands. We also present application opportunities for smart ring input for both *in-vehicle* and *outside-the-vehicle* interaction.

Author Keywords
Smart rings; In-vehicle interaction; Outside-the-vehicle interaction; Steering wheel controls.

CSS Concepts
• Human-centered computing~Interaction devices.

Introduction
According to the Annual Global Road Crash Statistics Report of the Association for Safe International Road Driving [2], nearly 1.35 million people die in road crashes each year and an additional 20 to 50 million are injured or disabled, which generates global costs of

Figure 1. A smart ring enables tap-based input with the thumb while the hands are kept on the steering wheel (top image) and removes the need to move the hand and fingers to use controls placed on the steering wheel. The smart ring can also be used to articulate mid-air gesture commands (bottom image), removing the need for gesture acquisition sensors to be installed inside the vehicle. *Note:* for these photographs depicting illustrative use case scenarios for smart rings inside the vehicle, we used the Ring Zero device (https://www.amazon.com/Ring-R001-PB01-ZERO-S-Black/dp/B00U8IX7DQ).

USD $518 billion. Shifting the eyes off the road and the hands off the steering wheel while driving in order to control car functions or to use smart devices, such as for texting, are among the causes of such outcomes. Designing better interaction techniques for inside the vehicle that do not distract from driving is paramount in this context; *e.g.*, car controls placed on the steering wheel are closer to the drivers’ fingers and, thus, can be accessed more ergonomically and safely while driving compared to other controls from the vehicle.

The goal of having steering wheel controls is for drivers to keep their hands on the steering wheel. However, the available space for mechanical buttons on the steering wheel limits their number and arrangement,[1] while movement of fingers and hands is still necessary. In this paper, *we propose transferring controls from the steering wheel to the drivers’ fingers with smart rings*; see Figure 1 for illustrations. Our contributions are:

1. We introduce and analyze the opportunity of using smart rings to interact with the car while driving. We identify unique features of ring input compared to other input modalities inside the vehicle, *e.g.*, steering wheel controls, gesture, and voice input.
2. We present application opportunities for smart rings inside the vehicle, including input modalities used in conjunction with rings, such as smart rings expanding steering wheel controls and substituting in-vehicle sensors for mid-air gesture input.
3. Since smart rings are wearable devices, we suggest that they can also be employed for *outside-the-vehicle* interactions (*e.g.*, for locking and unlocking the car, opening the trunk, etc.) that complement interactions performed *inside the vehicle*.

[1] See international standards ISO 3958 and ISO 4040 [11,12].

According to a 2016 Ericsson Report [6] on consumer views on wearables beyond health/wellness, wearables have become the most personal devices and users believe that they will replace smartphones; while PwC’s Wearable Life 2.0 Report [19] showed wearables eliciting more positive reactions. It is thus high time to explore applications of wearable computing to new areas where they can provide added value. To the best of our knowledge, this paper is the first exploration of using smart rings for in-vehicle interaction, and we hope to foster more research in this direction toward ergonomic and safe in-vehicle input while driving.

Related Work

ISO standards no. 3958 (“Driver hand-control reach”) [11] and 4040 (“Location of hand controls, indicators, and tell-tales in motor vehicles”) [12] concern the placement and reachability of in-vehicle controls and indicators. The former specifies hand reach distances for the steering wheel, *e.g.*, primary commands must be reached by 95% of the population, while the latter addresses locations of indicator units, control lamps, and hand controls, according to the boundaries of the physical space in which drivers can reach safely.

Prior work has examined various input modalities for in-vehicle interactions, among which gesture input is relevant to the scope of our work. For example, the steering wheel was found suitable for gesture input [5,7], while mid-air gestures can be performed in the gearshift area [22] to control infotainment [14], audio, and climate features [3]. Prior work has focused on the ergonomics of gesture input [21,34], the intuitiveness of gesture commands [20], usability aspects [36], and the design of gesture sets [13,15,16], including the use of gesture elicitation and analysis methods [8,32].

Smart ring gestures

According to Gheran *et al.* [9], a ring gesture is "*any action performed with or on a smart ring or any movement of the wearing finger and/or hand that causes a detectable change in the ring's position and/or orientation in a system of reference centered on the user's finger or body*" (p. 625).

Gheran *et al.* [9] used five dimensions to inform gesture input design for smart rings:

- *Nature*: symbolic, metaphorical, and abstract gestures.
- *Structure*: buttons, hand poses, hand motion, hand poses & motion, and mixed structure.
- *Complexity*: simple and compound gestures.
- *Symmetry*: dominant and nondominant unimanual, symmetric and asymmetric bimanual. Bimanual gestures were further examined in [10].
- *Locale:* on-the-ring, on-other-surface, in-air, and mixed.

For example, a double tap performed with the thumb finger on the smart ring to effect "turn radio on" is an abstract, buttons only, compound, unimanual dominant, on-the-ring gesture.

To identify relevant papers about smart rings and in-vehicle input, we ran the following query: (`"ring"` OR `"gesture"`) AND (`"car"` OR `"vehicle"`) on the title and abstracts of papers from the ACM DL and IEEE Xplore, and found 19 and 38 references, respectively. However, none of this prior work applied smart rings to in-vehicle interactions. For a comprehensive discussion about ring-based input and, more generically, about finger augmentation devices, we refer readers to [26].

Toward Smart Ring Gesture Input for Interactions Inside and Outside the Vehicle

We explore smart ring input for connected vehicles and, toward this goal, we start with an analysis of the unique characteristics of smart rings compared to other input modalities. We distinguish between *in-vehicle* input, vastly addressed by prior work [3,5,7,14-16,20-22,25,32,36], and interactions performed *outside the vehicle* where the driver controls the car (*e.g.*, opens the car trunk when near the car or locates the parked vehicle[2]) from a distance. Figure 2 illustrates the suitability of various input devices and modalities to implement interactions *inside* and *outside* the vehicle. The horizontal axis enumerates combinations of location (inside/outside), activity (driving/not driving), and distance from the vehicle (near/far) to highlight the relative merits of each input modality. For example, smartphones can be used inside the vehicle but not while driving, and also outside the vehicle for control and communication with the car from a distance. In-car controls and gestures acquired by in-vehicle sensors can only be used inside the vehicle. Voice input can be used inside and near the vehicle, but is useless when the driver is far away, unless voice input is mediated by the smartphone or smart watch. Just like voice input, smart rings are suitable for all the interaction scenarios from Figure 2, making them attractive for AutoUIs. However, we believe that rings are preferable to voice for "outside, far" interactions, since voice commands are not socially acceptable in all public places; for this reason, we use a "question mark" symbol in Figure 2 for voice input and "outside, far" interactions.

[2] Several apps are available to assist with locating parked cars, *e.g.* https://play.google.com/store/apps/details?id=it.carfind

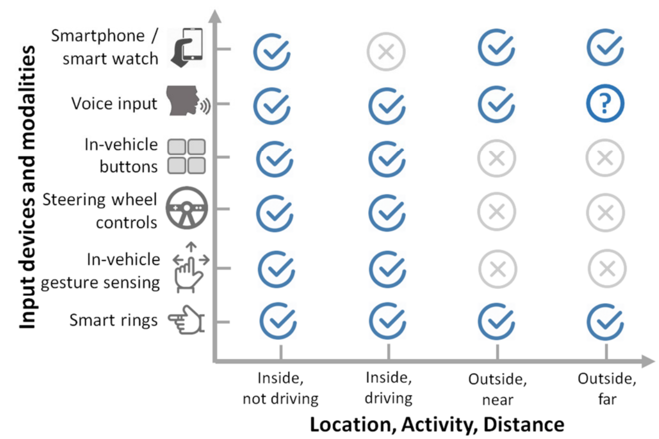

Figure 2. A representation space highlighting the capabilities of various input modalities and devices (on the vertical axis) for interactions performed inside and outside the vehicle (the horizontal axis).

A notable feature of Figure 2 is the combination of several dimensions (location, activity, and distance) to enumerate interactions that can be performed inside and outside the vehicle. As exemplified in prior work [9,10], smart rings accommodate tap and touch input, mid-air gestures, and combinations thereof. The side bar lists a variety of ring gesture types according to the design dimensions of *Gheran et al*. [9,10].

Mid-air gestures in the car

Several studies have implemented the user-defined gesture elicitation method [27,33] to unveil users’ preferences for gestures inside the car [8,13,16,32]. For example, May *et al.* [16] were interested in mid-air gesture input to control a menu displayed on the car screen, and found preferences for swipe and point right for *select*, swipe left and index finger flick right for *return*, index finger wheeling and swipe down/up for *fluid control*, index finger flick for *incremental movement*, letter trace for *direct movement*, and knob twist, hand flip, large swipe down, and letter trace gestures for *pagination* [16] (p. 77). Examinations of other gesture elicitation studies for in-vehicle input reveal other mid-air gestures detectable using the motion sensors (accelerometers) embedded in smart rings.

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Figure 3. *Top:* combining smart rings with other input modalities inside the car: steering wheel controls and touch input. *Bottom-left:* using two rings for bimanual gestures. *Bottom-right*: interaction outside the vehicle.

Tap and touch input on smart rings can replace steering wheel controls, while mid-air stroke gestures performed with the ring can replace the need for gesture sensors installed in the car. The side bar from this page shows examples of in-vehicle gestures examined by prior work that can be sensed by smart rings as well. Moreover, since rings are wearable devices, they can implement the adaptability quality property for gesture input in the form of nomadic gestures [29] or by reusing gesture knowledge across multiple contexts of use [31].

Smart rings can complement existing input modalities. Figure 3, top shows smart rings used in conjunction with controls on the steering wheel and in-vehicle touchscreens. Wearing two smart rings (Figure 3, bottom-left) enables bimanual input [4,10], which expands the design space of in-vehicle gestures, *e.g.*, a tap on the left ring followed by two taps on the right ring while not taking the hands off the steering wheel.

When outside the vehicle, smart rings can be used to control specific car functions: when near the car, a ring gesture can lock/unlock the vehicle or open the trunk; see Figure 3, bottom-right. In this scenario, the ring is connected via Bluetooth to the car system or the command may be sent via NFC [17]. When the user is farther away, rings can be used in conjunction with a smartphone app that communicates with the connected vehicle and gives feedback to the user, *e.g.*, via vibrations on the ring to locate the parked car. We leave explorations of such scenarios for future work toward integration of wearables and connected cars.

Conclusion and Future Work

We introduced the idea of using smart rings to design interactions inside and outside the vehicle. As smart rings are light and easy to wear, they can turn into ergonomic input devices to foster safer driving via tap, touch, and mid-air gestures, and be used in conjunction with other in-vehicle input systems. Smart rings can also implement fluid transitions between in-vehicle and outside-the-vehicle scenarios, *e.g.*, by reusing gesture commands [29,31]. While rings do present limitations in terms of the type of gestures they can sense (*e.g.*, hand poses cannot be discriminated via ring sensors alone), the embedded IMU sensors can report a wide variety of motion input performed with the finger, hand, and arm [26]. Future work will explore user-defined gestures [33] for smart rings in the car, specific gesture types [9,10,28], recognizers for ring gestures [30], feedback modalities [24,25], and integration of smart rings with other wearables [1,4,18] and gesture sensors [35] into in-vehicle software architecture [23].

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