
Ring×2: Designing Gestures for Smart Rings using Temporal Calculus

Bogdan-Florin Gheran

MintViz Lab | MANSiD Research Center
University Stefan cel Mare of Suceava
Suceava 720229, Romania
bogdan.gheran@gmail.com

Radu-Daniel Vatavu

MintViz Lab | MANSiD Research Center
University Stefan cel Mare of Suceava
Suceava 720229, Romania
vatavu@eed.usv.ro

Jean Vanderdonckt

Louvain School of Management
Université catholique de Louvain
Louvain-la-Neuve, Belgium
jean.vanderdonckt@uclouvain.be

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the Owner/Author.

DIS'18 Companion, June 9–13, 2018, Hong Kong
© 2018 Copyright is held by the owner/author(s).
ACM ISBN 978-1-4503-5631-2/18/06.
<https://doi.org/10.1145/3197391.3205422>

Abstract

We introduce “Ring×2,” a design space for gesture input with two smart rings. Wearing two rings at once opens new input opportunities, unexplored by the community so far, such as bimanual ring gestures or shifting input from one smart ring to the other to effectively manage situational impairments, such as encumbrance. To enable such developments and explorations, we present a formal description of designing two-ring gestures from the perspective of temporal calculus, a logic-based framework for reasoning about events and actions occurring in time, which we exemplify on a dataset of 83 bimanual gestures performed by 24 participants with two rings. We hope that our exploration of two-ring gestures and our design approach rooted in temporal calculus will be provocative and inspiring for the community, leading to new designs of input techniques for smart rings.

Author Keywords

Smart rings; ring gestures; gesture user interfaces; interaction design; design space; wearables; Allen’s interval algebra; temporal calculus.

ACM Classification Keywords

H.5.2. [Information Interfaces and Presentation (e.g., HCI)] User Interfaces: *Input devices and strategies*.



Figure 1: Snapshot of a user wearing two smart rings at once. In this picture, Logbar Inc.'s Ring Zero devices [12] are illustrated.

Potential applications for two-ring input include bimanual gestures [7]; shifting input from one ring to the other to deal effectively with situational impairments, such as encumbrance [15]; or enabling users with motor impairments with more options for effective input using wearables [13] or to assist their touch gesture input on mobile devices [19], two very recent research directions in the community.

Two smart rings worn simultaneously enable a variety of bimanual gesture input, which can be characterized using temporal concepts, such as *precedence*, *simultaneity*, and *temporal overlapping* of the movements performed by the dominant and non-dominant hand. This rich variety of input options requires thorough exploration of a design space for bimanual gestures performed with two smart rings.

Introduction

Smart rings enable users to control applications with a variety of touch and mid-air gestures for eyes-free, mobile scenarios [2,6-8,10]. A wide range of smart rings have been released commercially, while many crowd-funded projects are under way, such as Blinq [3] or Wave [25], to name just two examples. Due to the variety of the embedded electronics, such as micro-controllers, accelerometers, micro touchpads, and even video cameras [2,4,9,14,28], smart rings are attractive for a variety of applications. For instance, “EyeRing” [14] embeds a miniaturized video camera to implement assistive techniques for users with visual impairments.

The design space of ring-based input has been examined in the community [6,18], but prior work has focused exclusively on contexts of use for just one ring, leaving two-ring input unexplored so far. However, two rings enable considerably more options for designers to prototype mobile interactions; see Figure 1. To this end, we examine bimanual gestures for two rings.

Our contributions are as follows:

1. We present Ring×2, a design space for two-ring gestures based on Allen’s interval algebra [1], to address the concepts of precedence, overlapping, and simultaneity of input using two smart rings.
2. We exemplify the gesture categories of our design space by reporting empirical results for two-ring gestures on a publicly-available gesture dataset.

Related Work

Prior work has explored a variety of technology to design features for smart rings, such as input sensing with electric or magnetic fields [2,26,28], infrared reflection [16], computer vision solutions with video

cameras embedded into smart rings [4,14], or using vibrotactile feedback to implement new concepts [23]. We refer readers to Shilkrot et al. [18] that provided a thorough survey of finger augmentation devices.

Several interaction techniques have been proposed for ring-based input. For example, Colley et al. [6] identified twelve distinct ring gestures, which were classified according to the placement of the ring on the finger, the movements of the ring, squeezing, putting and removing the ring, and placing the ring in contact with a surface. Gheran et al. [7] examined users’ preferences for smart ring gestures by conducting a gesture elicitation study [22,27]. The findings revealed an overall low agreement rate (mean .112 and maximum .225 on the unit scale across 24 participants), similar to results obtained for other input scenarios with a large number of degrees of freedom for gesture articulation [11,17,20,21]. The authors outlined design guidelines for smart ring gestures [7].

In a recent work, Cioatǎ and Vatavu [5] looked at the benefits of wearing two smartwatches for generic I/O tasks. Following this line of investigation on multi-wearable input, we draw the community’s attention towards the rich design space of two-ring gestures.

Ring×2: A Design Space for Gesture Input with Two Smart Rings

We present in this section a formalization of two-ring gestures using Allen’s interval algebra for temporal calculus [1] that enables us to discuss a variety of gesture types in terms of input *precedence* or *sequentiality* (i.e., bimanual gestures for which the movements of the two hands are separated in time), *temporal overlapping* (i.e., the movements of the two

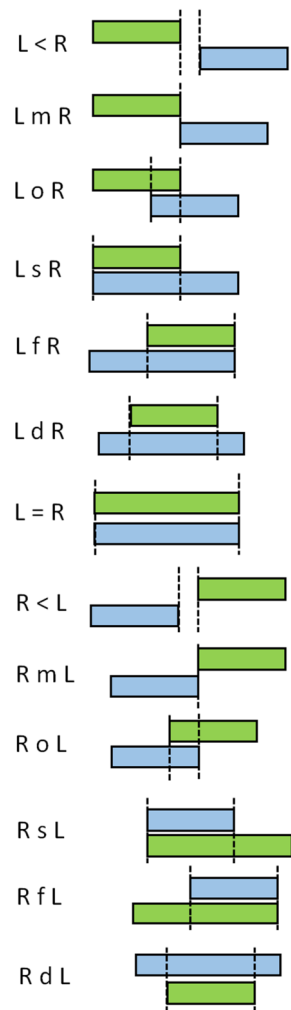


Figure 2: Visual illustrations of all the thirteen possibilities to combine input with two smart rings in the time dimension.

hands overlap in time during gesture input), and *simultaneity* (i.e., the two hands move simultaneously for the entire duration of the bimanual gesture); see Figure 2 for illustrations of all the thirteen distinct, exhaustive, and qualitative possibilities to combine input with two smart rings in the time dimension. In the following, we detail on these possibilities:

- ♦ **$L < R$ (Left before Right)**¹: Input on the left ring takes place before input on the right ring; e.g., a tap on the left ring is followed by a tap on the right ring, after a short pause (see Figure 3a for an illustration).
- ♦ **$L m R$ (Left meets Right)**: Input on the left ring is followed immediately by input on the right ring; e.g., draw a circle in mid-air with both hands, but start the first half of the circle with the left hand and continue the other half with the right (Figure 3b).
- ♦ **$L o R$ (Left overlaps Right)**: Input on the left and right rings overlap in time, but input starts on the left ring; e.g., bring the two hands together, the right hand on top of the left hand, left hand moves first (Figure 3c).
- ♦ **$L s R$ (Left starts Right)**: Both hands start input at the same time, but the left hand finishes first; e.g., move both hands to the right (slide to right) and tap the right ring (Figure 3d).
- ♦ **$L f R$ (Left finishes Right)**: The right hand starts the gesture, followed by the left hand, and the two hands finish at the same time; e.g., tap twice on the right ring, then tap both rings at once (Figure 3e).
- ♦ **$L d R$ (Left during Right)**: While input is performed with the right hand, the left hand starts and finishes

input; e.g., draw a circle in mid-air with the right hand and, during this time, tap the left ring (Figure 3f).

- ♦ **$L = R$ (Left and Right occur simultaneously)**: Input is performed with both the left and right rings at once; e.g., hands clapping (Figure 3g).
- ♦ **$R < L$ (Right before Left)**: The inverse of $L < R$.
- ♦ **$R m L$ (Right meets Left)**: The inverse of $L m R$.
- ♦ **$R o L$ (Right overlaps Left)**: The inverse of $L o R$.
- ♦ **$R s L$ (Right starts Left)**: The inverse of $L s R$.
- ♦ **$R d L$ (Right during Left)**: The inverse of $L d R$.
- ♦ **$R f L$ (Right finishes Left)**: The inverse of $L f R$.

Note how the last six categories represent the inverses in the time dimension of the first six categories, for which the right ring receives precedence over the left, e.g., Right starts Left instead of Left starts Right.

Practitioners can readily employ the above categories to inform and explore many variations of bimanual ring gestures. For instance, starting from a gesture performed with one ring only (e.g., a flick to the right), another flick with the second ring can be added in 13 different ways, leading to a rich set of gestures to choose from. Also, a two-ring gesture (e.g., a tap on the left ring followed by a tap on the right ring) can be easily extended in many ways, e.g., reverse tapping order ($R < L$), simultaneous taps ($L = R$), making one tap longer ($L s R$, $L s R$, $L d R$, or $R d L$), etc.

Preliminary Empirical Results

We report in the following preliminary empirical results on bimanual ring gesture input by analyzing the dataset of Gheran et al. [7] that is publicly available at the address <http://www.eed.usv.ro/~vatavu>. The dataset contains ring gesture preferences elicited from 24 participants (15 male, 9 female; 21–45 years old, mean

¹ Note that the terms “dominant” and “non-dominant” could be employed as well to describe two-ring gestures, but we prefer to work with “left” and “right,” as they are self-explanatory and easy to understand for generic applications of our concepts.

Gesture category	Freq.	Percent
$L = R$	58	69.9%
$L s R$	7	8.4%
$L d R$	6	7.2%
$R m L$	4	4.8%
$R d L$	3	3.6%
$L m R$	2	2.4%
$L f R$	1	1.2%
$L o R$	1	1.2%
$R o L$	1	1.2%
Total	83	100%

Table 1: Frequencies of the smart ring gesture categories identified in the dataset of Gheran et al. [7].

age 27.5, SD 7.9 years; 22 right-handed). According to the principles of the elicitation methodology [27], participants were asked to provide one-ring and two-ring gestures for several common tasks to execute in a home environment; see [7] for details. For the purpose of our work, we are interested in just the two-ring gestures, which represent a proportion of 37.7% of all the gestures proposed by the participants of [7], i.e., 83 out of 220 proposals. We found that the large majority of gestures (69.9%) fell under category $L = R$ (i.e., simultaneous input), followed by $L s R$ with 8.4% and $L d R$ with 7.2%, respectively; see Table 1 for detailed results. A Pearson test for the equality of proportions revealed a significant effect of gesture category ($\chi^2_{(8)} = 331.27$, $p < .001$). These preliminary results show that simultaneous input is preferred by users, but also that there are still many opportunities for expert design, as end-users seem not to be aware of the richness of the input space for two-ring gestures.

Conclusion and Future Work

We examined in this work gestures performed with two rings, for which we proposed a design approach based on temporal concepts. Future work will look at algebraic operations, such as composition of multiple smart ring gestures in the time domain (e.g., $L m R o L$), and exploring applications, such as practical implementations of mobile concepts [23,24,29], evaluations for situational impairments during mobile contexts of use [15], and designing accessible interactions for users with impairments [13,19] enabled by wearing and employing multiple smart devices.

Acknowledgements

This work was supported from project PN-III-P2-2.1-PED-2016-0688 (209PED/2017), UEFISCDI, Romania.

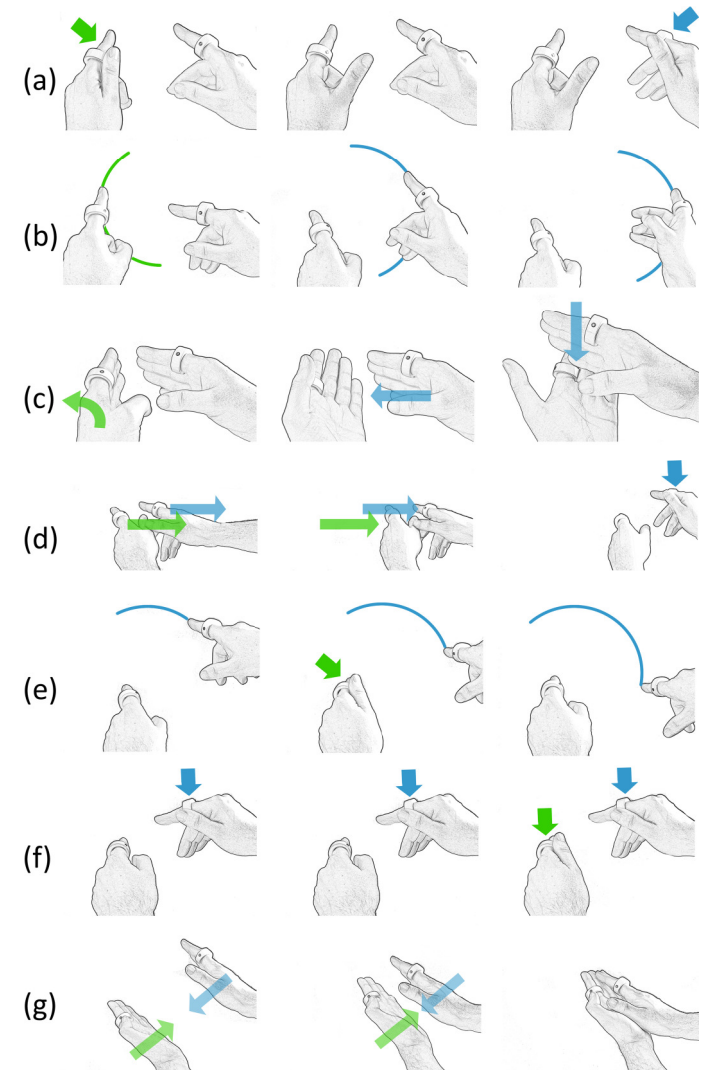


Figure 3: Visual illustrations for $L < R$ (a), $L m R$ (b), $L o R$ (c), $L s R$ (d), $L d R$ (e), $L f R$ (f), and $L = R$ (g).

References

1. James F. Allen. 1983. Maintaining knowledge about temporal intervals. *Comm. ACM* 26, 11, 832-843. <http://dx.doi.org/10.1145/182.358434>
2. Daniel Ashbrook, Patrick Baudisch, Sean White. 2011. NENYA: Subtle and eyes-free mobile input with a magnetically-tracked finger ring. In *Proc. of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*, 2043-2046. <https://doi.org/10.1145/1978942.1979238>
3. Blinq Smart Ring. 2018. <https://www.kickstarter.com/projects/904651122/blinq-smart-jewelry-worlds-1st-fine-jewelry-wearab/> Page last accessed: March 2018
4. Liwei Chan, Yi-Ling Chen, Chi-Hao Hsieh, Rong-Hao Liang, Bing-Yu Chen. 2015. CyclopsRing: Enabling Whole-Hand and Context-Aware Interactions Through a Fisheye Ring. In *Proc. of UIST '15*, 549-556. <https://doi.org/10.1145/2807442.2807450>
5. Petru-Vasile Cioată, Radu-Daniel Vatavu. 2018. In Tandem: Exploring Interactive Opportunities for Dual Input and Output on Two Smartwatches. In *Proc. of the 23rd Int. Conf. on Intelligent User Interfaces Companion (IUI'18)*, Article 60, 2 pages. <https://doi.org/10.1145/3180308.3180369>
6. Ashley Colley, Virve Inget, Tuomas Lappalainen, Jonna Häkkinen. 2017. Ring form factor: a design space for interaction. *Proc. of the 2017 ACM Int. Symp. on Wearable Comp. (ISWC '17)*, 178-179. <https://doi.org/10.1145/3123021.3123055>
7. Bogdan-Florin Gheran, Jean Vanderdonckt, Radu-Daniel Vatavu. 2018. Gestures for Smart Rings: Empirical Results, Insights, and Design Implications. In *Proc. of the 13rd ACM SIGCHI Conf. on Designing Interactive Systems (DIS'18)*. <https://doi.org/10.1145/3196709.3196741>
8. Sarthak Ghosh, Hyeon Cheol Kim, Yang Cao, Arne Wessels, Simon T. Perrault, Shengdong Zhao. 2016. Ringinteraction: Coordinated Thumb-index Interaction Using a Ring. In *Proc. of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '16)*, 2640-2647. <https://doi.org/10.1145/2851581.2892371>
9. Lei Jing, Zixue Cheng, Yinghui Zhou, Junbo Wang, Tongjun Huang. 2013. Magic Ring: a self-contained gesture input device on finger. In *Proc. of the 12th International Conference on Mobile and Ubiquitous Multimedia (MUM '13)*, Article 39, 4 pages. <https://doi.org/10.1145/2541831.2541875>
10. Wolf Kienzle, Ken Hinckley. 2014. LightRing: Always-available 2D input on any surface. In *Proc. of the 27th Annual ACM Symp. on User Interface Software and Technology (UIST '14)*, 157-160. <https://doi.org/10.1145/2642918.2647376>
11. Hai-Ning Liang, Cary Williams, Myron Semegen, Wolfgang Stuerzlinger, Pourang Irani. 2012. User-defined surface+motion gestures for 3d manipulation of objects at a distance through a mobile device. In *Proc. of the 10th Asia Pacific Conf. on Computer Human Int. (APCHI '12)*, 299-308. <https://doi.org/10.1145/2350046.2350098>
12. Logbar Inc. 2018. <https://logbar.jp/en/> Page last accessed: March 2018.¹
13. Meethu Malu. 2018. Designing and implementing accessible wearable interactions for people with motor impairments. *SIGACCESS Access. Comput.* 120, 24-27. <https://doi.org/10.1145/3178412.317>
14. Suranga Nanayakkara, Roy Shilkrot, Pattie Maes. 2012. EyeRing: an eye on a finger. In *Proc. of CHI '12 Extended Abstracts on Human Factors in Computing Systems (CHI EA '12)*, 1047-1050. <https://doi.org/10.1145/2212776.2212382>
15. Alexander Ng, John Williamson, and Stephen Brewster. 2015. The Effects of Encumbrance and Mobility on Touch-Based Gesture Interactions for Mobile Phones. In *Proc. of MobileHCI '15*, 536-546. <https://doi.org/10.1145/2785830.2785853>

16. Masa Ogata, Yuta Sugiura, Hirotaka Osawa, Michita Imai. 2012. iRing: Intelligent ring using infrared reflection. *Proc. of the 25th ACM Symp. on User Interface Soft. and Technology (UIST '12)*, 131-136. <https://doi.org/10.1145/2380116.2380135>
17. Teddy Seyed, Chris Burns, Mario Costa Sousa, Frank Maurer, Anthony Tang. 2012. Eliciting usable gestures for multi-display environments. In *Proc. of the 2012 ACM Int. Conf. on Interactive Tabletops and Surfaces (ITS '12)*, 41-50. <https://doi.org/10.1145/2396636.2396643>
18. Roy Shilkrot, Jochen Huber, Jürgen Steimle, Suranga Nanayakkara, Pattie Maes. 2015. Digital Digits: A Comprehensive Survey of Finger Augmentation Devices. *ACM Computing Surveys* 48, 2, Article 30 (Nov. 2015), 29 pages. <https://doi.org/10.1145/2828993>
19. Ovidiu-Ciprian Ungurean, Radu-Daniel Vatavu, Luis A. Leiva, Réjean Plamondon. 2018. Gesture Input for Users with Motor Impairments on Touchscreens: Empirical Results based on the Kinematic Theory. In *Proc. of CHI EA 2018*, 6 pages <https://doi.org/10.1145/3170427.3188619>
20. Radu-Daniel Vatavu. 2012. User-defined gestures for free-hand TV control. In *Proc. of (EuroITV '12)*, 45-48. <https://doi.org/10.1145/2325616.2325626>
21. Radu-Daniel Vatavu, Ionuț-Alexandru Zaiti. 2014. Leap gestures for TV: insights from an elicitation study. In *Proc. of the ACM Int. Conf. on Interactive Exp. for TV and Online Video (TVX '14)*, 131-138. <https://doi.org/10.1145/2602299.2602316>
22. Radu-Daniel Vatavu, Jacob O. Wobbrock. 2015. Formalizing Agreement Analysis for Elicitation Studies: New Measures, Significance Test, and Toolkit. In *Proc. of the 33rd Annual ACM Conf. on Human Factors in Comp. Systems (CHI '15)*, 1325-1334. <https://doi.org/10.1145/2702123.2702223>
23. Radu-Daniel Vatavu, Annette Mossel, and Christian Schönauer. 2016. Digital vibrons: understanding users' perceptions of interacting with invisible, zero-weight matter. In *Proc. of the 18th Int. Conf. on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '16)*, 217-226. <https://doi.org/10.1145/2935334.2935364>
24. Radu-Daniel Vatavu. 2017. Smart-Pockets: Body-Deictic Gestures for Fast Access to Personal Data during Ambient Interactions. *Int. J. Hum.-Comput. Stud.* 103, C (July 2017), 1-21. <https://doi.org/10.1016/j.ijhcs.2017.01.005>
25. Wave – control sounds with motion. 2018. <https://www.indiegogo.com/projects/wave-control-sounds-with-motion-music-technology#/> Page last accessed: March 2018
26. Mathias Wilhelm, Daniel Krakowczyk, Frank Trollmann, Sahin Albayrak. 2015. eRing: Multiple finger gesture recognition with one ring using an electric field. *Proc. of the 2nd Workshop on Sensor-based Activity Recognition and Interaction (IWOAR '15)*. <https://doi.org/10.1145/2790044.2790047>
27. Jacob O. Wobbrock, Meredith Ringel Morris, Andrew D. Wilson. 2009. User-defined gestures for surface computing. In *Proc. of CHI '09*, 1083-1092. <https://doi.org/10.1145/1518701.1518866>
28. Sang Ho Yoon, Yunbo Zhang, Ke Huo, Karthik Ramani. 2016. TRing: Instant and Customizable Interactions with Objects Using an Embedded Magnet and a Finger-Worn Device. *UIST '16*, 169-181. <https://doi.org/10.1145/2984511.2984529>
29. Ionuț-Alexandru Zaiti, Radu-Daniel Vatavu, Stefan-Gheorghe Pentiuc. (2013). Exploring Hand Posture for Smart Mobile Devices. In *Proc. of SouthCHI'13*. LNCS 7946, 721-731. http://dx.doi.org/10.1007/978-3-642-39062-3_52

ⁱ Ring ZERO has gone out of production, but the archived web page can still be reach using <https://web.archive.org/web/20170309191236/http://ringzero.logbar.jp/>