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A Survey and Taxonomy of 3D Menu Techniques

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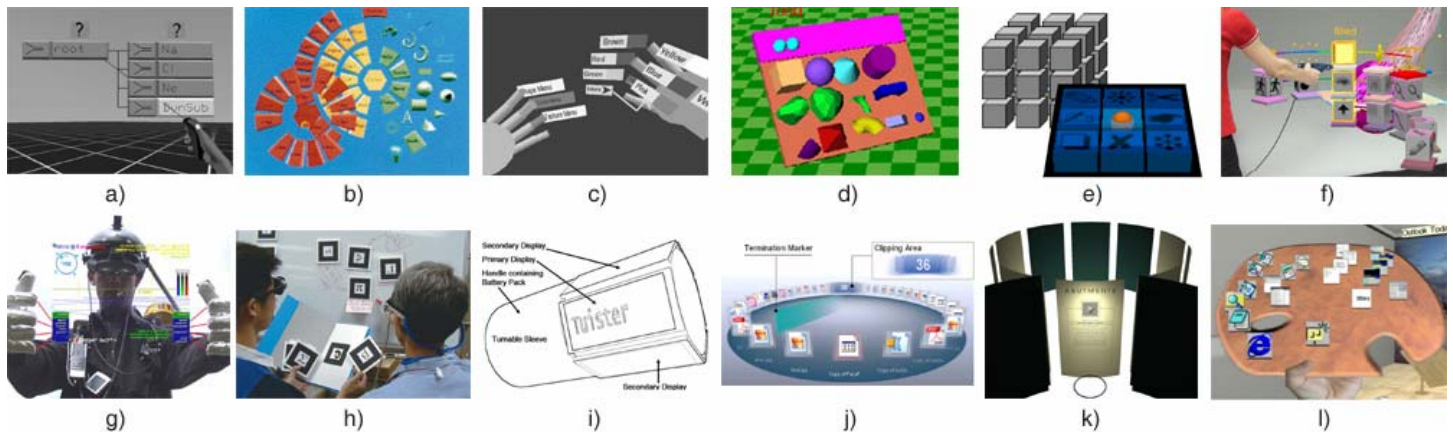
Outline

- Motivation
- Related Work: Classifications
- Survey of 3D Menus
 - Immersive VR | Augmented Reality | Desktop VR
- Classification Criteria & Taxonomy
- Conclusion & Future Work

Motivation

■ Situation and Problems

- Variety of interaction techniques developed in the field of VR and AR
 - Object selection, manipulation, travel & wayfinding well covered in existing taxonomies
 - Application/system control techniques in VEs not extensively studied [BW01]
 - Previous classification work only addresses immersive VEs, not Desktop VR or AR
- Menu generic task of its own [KKP*00], worth studying their design and use
 - Variety of distinct three-dimensional menu selection techniques available
 - Few works devoted solely to menu techniques (even less comparisons/classifications)



Motivation

- Challenges and Objectives
 - Comprehensive overview and classification of 3D menus for immersive and semi-immersive VEs, AR and tangible UIs, Desktop-VR
 - Propose detailed criteria for building a taxonomy of 3D menu solutions
 - Facilitate thorough comparison and evaluation of similar menu solutions
 - Choice of appropriate menu solutions for developers
 - Less re-inventing and building from scratch
 - Describe design space for 3D menu solutions: foster new developments
- Focus of this work
 - on graphical menus as part of application control
 - on classifying 3D menu widgets with geometric representation [CSH*92]
 - on techniques with potential for generalization

Related Work: Classifications

- Menu classification approaches
 - Frame of reference for virtual menu design by Jacoby and Ellis [JE92]
 - Design characteristics of menus:
invocation, location, reference frame, highlighting, selection etc.
 - Overview of interaction techniques for immersive VEs in book on 3D user interfaces by Bowman et al. [BKLP04]
 - System control → graphical menus →
adapted 2D menu, 1-DOF menu, 3D widget, TULIP
 - Incorporated characteristics:
placement, selection, representation and structure
 - Usability study of various immersive menu presentation and multimodal selection schemes by Kim et al. [KKP*00]
 - Reclassification of several 2D and 3D menu presentation styles in VEs
 - 5 menu display methods:
pull-down, pop-up, stack menu, object-specific, oblique/layered

Related Work: Widget Classification

- Widget classification scheme by Dachsel and Hinz [DH05] according to criteria intention of use/ interaction purpose
 - First classification devoted to desktop VR

Direct 3D Object Interaction	
Object Selection	
Geometric Manipulation	
3D-Scene Manipulation	
Orientation and Navigation	
Scene Presentation Control	
Exploration and Visualization	
Geometric Exploration	
Hierarchy Visualization	
3D Graph Visualization	
2D-Data and Document Visualization	
Scientific Visualization	
System / Application Control	
State Control / Discrete Valuator	
Continuous Valuator	
Special Value Input	
Menu Selection	
Containers	

Survey of 3D Menu Techniques

- Survey: Menu solutions grouped with regard to their origin
 - ① Menus from immersive and semi-immersive VEs
 - ② Menus from augmented reality applications
 - ③ Menus from the field of desktop VR
- Observations
 - Development of menus within specific application context, scattered
 - Exceptions: e.g. command & control cube [GC01], TULIP menu [BW01], ToolFinger [Wes03], Spin Menu [GB05]
 - Most of the literature from the nineties, rooted in VR research

Survey: ① Immersive/Semi-immersive Menus



2D solutions in 3D environments

- Introduction of 2D-elements into VE: e.g. pop-up and pull-down 3D menus [JE92]
- Making 2D X-Windows widgets available within 3D contexts (e.g. hybrid 2D/3D UI in [CRF97])
- 'Classical' floating menu (e.g. [BL91,Min95,WG95,PS96,CFH97]), virtual equivalent of conventional pull-down menus floating in 3D space
- 3D fade-up menu in HoloSketch for fish-tank VR setting (3D pie menu [Dee95])



Glove-based menu selection

- More natural style of selection using fingers and hands, typically by finger pinches
- E.g. glove-based menu system Tinmith [PT01] or TULIP menu [BW01] using Pinch Gloves



Speech recognition enhanced menus

- Example: hands-off interaction technique with menu items as 2D overlays, speech recognition [Dar94]
- 3D Palette [BBMP97]: vocal commands in addition to tablet/pen selections



Hand-held menus

- Improvement: virtual menu (object palette) controlled with one hand, other hand selects items
- Examples: tear-off palette in CHIMP project [MBS97], JDCAD ring menu [LG94]

Survey: ① Immersive/Semi-immersive Menus

Prop-based 'physical menus'

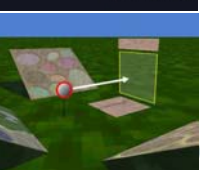
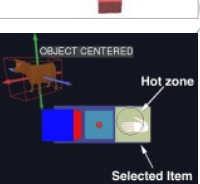
- Menu attached to tracked physical surfaces → confines 2D interaction to a virtual handheld object
- Selection of menu items with pen/stylus → *pen-and-tablet menus* [BKLP04]
- Examples: 3D Palette [BBMP97], Virtual Tricorder [WG95]

Workbench Menus

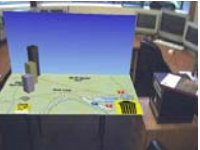
- Responsive workbench attractive for direct manipulation [GC01], menus typically toolboxes of 3D-icons
- Interaction done with stylus or by pinching gloves (e.g. in [CFH97]), also constrained mouse and two-handed approaches
- Examples: virtual tool rack [PS96], command & control cube (C³) [GC01] for holobench, Spin Menu [GB05] for quick selections

Menus with body-relative interaction

- Look-at-menu employs head orientation (look at an item) (e.g. [MBS97,NLB06])
- Take advantage of proprioception, e.g. menus being attached to the user's body
- Object or color palette in toolspaces & glances technique [PCDR99] with body-relative storage



Survey: ② Augmented Reality Menus



Similar to VR menus, usually hand-based

- Even combining both domains: e.g. Tinmith-Hand menu system [PT01] (glove-based system)
- Fingertip-based interaction FingARTips [BVBC04]: 3D object menu using gesture recognition of 2 fingers
- Personal Interaction Panel as a two-handed interface in Studierstube [SG97]: tablet-and-pen based approach or gloves and touchpad [VKL*02]
- Virtual Menu in the mixed reality stage planning application [BGH*04]: modal voice commands or buttons

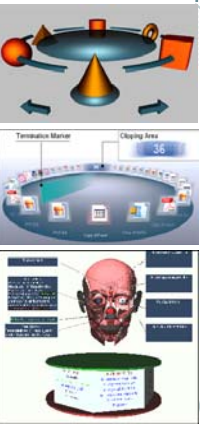
Using physical objects for interaction

- AR and TUIs: using physical objects like pads or paddles for interaction, often marker-based
- Example: menu tiles in the TILES interface [PTB*02], a book for presenting virtual objects
- Tools with real-world correspondence: e.g. TUISTER [BGK04] (Menu items on cylindrical display)

Other explicit AR menu solutions

- 3D spherical menu [FC03] based on spherical menu layers, operation by simple 2D input devices (for rapid AR prototyping)

Survey: ③ Desktop VR Menus



Widget-based solutions

- Usage of VR solutions requires 3D widgets, high precision with mouse (point & click, drag) or keyboard
- Example: ring menu in a desktop version [Wid05] with additional buttons
- Another recent ring menu approach: generalized 3D carousel view [WPV05]
- Revolving stage menu (e.g. [Dac99]) or rondel [PRS97]: conventional flat menus arranged in a circle



Detail-and-context visualizations

- Screen space limitations especially for large (menu) hierarchies
- Examples: Cone trees [RMC91] and derivate solutions, polyarchy visualization technique [RCCR02]
→ focus on visualization
- Example: collapsible cylindrical trees [DE01] with rotating cylinders for menu items
→ focus on fast interaction



3D desktop solutions

- Examination of Win3D [W3D05], 3DNA [3DN04] and Sun's project Looking Glass [Sun05]
→ several 3D menu widgets, e.g. hinged menu [W3D05]
- Multitude of geometric menu layouts: fold-away layers, horizontal or vertical stacks, drawers, panoramic walls [3DN04], shelves, even wardrobes
- Loose layout: start palette of the Task Gallery [RvDR*00], painter's palette in 3D

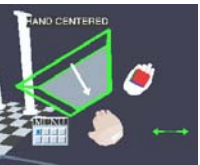
Taxonomy: Classification criteria & menu properties

■ Intention of use

- Number of displayed items: often limited, e.g. 4 with Boule menu ball [Bou99] or 26 for C³ [GC01]
- Hierarchical nature
 - Temporary option menus: short invocation, quick selection, limited number (≤ 7) of items (e.g. rotary tool chooser [Min95])
 - Single menus: longer visibility, greater number of items (e.g. toolbars, tool palettes [PS96,CFH97,BBMP97])
 - Menu systems = menu hierarchies with depth of 2, contain submenus (e.g. revolving stage/rondel [Dac99,PRS97])
 - Menu hierarchies: arbitrary number of items and sub menus, depth ≥ 3 (e.g. fade-up menus [Dee95])

■ Appearance and Structure

- Geometric structure (supporting geometry): flat list (floating menus), disc (e.g. carousel view [WPV05]), sphere (e.g. menu ball [Bou99]), cylinder (e.g. TUISTER [BGK04]), cube (e.g. C³ [GC01])...
- Structural layout: arrangement of items on the supporting geometry / within space: acyclic list, cyclic list (usually ring), matrix, free arrangements...
- Type of displayed data:
3D-objects (e.g. 3D palette [BBMP97]), text (e.g. TUISTER [BGK04]), icons (e.g. C³ [GC01]), images + text (e.g. generalized 3D carousel view [WPV05]), 3D-objects + text (e.g. fade-up menu [Dee95])
- Size and spacing important for selection error rate and overall space consumption



Taxonomy: Classification criteria & menu properties

■ Placement

■ Reference

- World (most desktop VR menus) | Object (e.g. combo box in [OAS02])
- Head (e.g. look-at-menu [MBS97]) | Body (e.g. TULIP [BMLP01])
- Device (e.g. PIP tool-palette [SG97])

■ Orientation influences required space (e.g. menu facing a user [Dar94])

■ Repositioning vs. fixed location

■ Invocation and availability

■ Visibility: any time, temporary (for selection), user-dependent

■ Invocation: selecting icon/miniature, context-related (object, other menu, background), free at arbitrary point, permanently visible

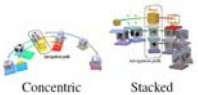
■ Animation: more possibilities than in 2D: blending, zooming-in, opening, expanding, collapsing, turning, rotating, fanning, drawing out menus or parts of it

■ Collapsibility: compressing or hiding menu without removing it (e.g. CCT menu [DE01])

Taxonomy: Classification criteria & menu properties

■ Interaction and I/O setting

- Feedback/highlighting provided by a menu [Shn98]
 - by movement of items, their animation, highlights, item changes in color, brightness, geometry, size, additional selection geometries, force feedback...
- Visualization of selection path: rarely with 3D menus (except spin menu [GB05])
- Dimensionality: proper match of the dimensions of interaction techniques and interaction tasks results in superior performance [DD05]
- Device dependence: Special hardware settings required? (e.g. tool finger [Wes03])
- Application type/origin: Developed for specific VR, AR, Desktop VR, 3D-Mobile setting?



■ Combinability

- Can 3D menus be combined with other menus to build menu systems or hierarchies?
- Usually a different technique for top level:
e.g. revolving stage/rondel [Dac99, PRS97], spin menu [GB05]



Taxonomy: Classification criteria & menu properties

Summary

- Definition of the design scope and basis for evaluation
- Neither all orthogonal, nor equally applicable to every menu solution
- Comprehensive table online: www.3d-components.org/menus
 - Most of the surveyed menu solutions described according to these criteria

Intention of use	
<i>Number of displayed items</i>	limited or not
<i>Hierarchical nature</i>	temporary option menu, single menu, menu system, menu hierarchy
Appearance and Structure	
<i>Geometric structure</i>	None, list, disc, sphere, cylinder, cube...
<i>Structural layout</i>	acyclic list, cyclic list (ring), matrix, free arrangement, geometric structure
<i>Type of displayed data</i>	3D-objects, text entries, images, images & text, 3D-objects & text
<i>Size & spacing of items</i>	
Placement	
<i>Reference</i>	world, object, head, body, device
<i>Orientation</i>	
<i>Repositioning</i>	
Invocation and availability	
<i>Visibility</i>	whole time, temporarily, user-dependent
<i>Invocation</i>	icon/miniature, context dependent, free, none
<i>Animation</i>	various ways
<i>Collapsibility</i>	
Interaction and I/O setting	
<i>Dimensionality</i>	interaction device and task
<i>Feedback/highlighting</i>	various ways
<i>Visualiz. of selection path</i>	
<i>Device dependence</i>	input/output devices
<i>Application type</i>	VR, AR, Desktop VR, 3D-Mobile
Combinability	

Taxonomy: Classification criteria & menu properties

3D-Menus Criteria Catalog - Microsoft Internet Explorer

3D-Menus: Classification Criteria and Properties

Name	Hierarchical nature	Structural layout	Max. item-nr.	Geom. structure	Type of data	3D-obj.	text	images	images & text	3D-obj. & text	Siz
Pop-Up/Pull-Down Menu	temporary option menu	acyclic list	7	plane	text entries		x	x	x		littl
Look-At Menus	temporary option menu	acyclic list	7	plane	images	x	x	x	x	x	littl
Rotary Tool Chooser	temporary option menu	cyclic list (ring)	8	specific	images	x		x			littl
Spin Menu	temporary option menu	acyclic list	11	disc	images	x		x			littl
Command & Control Cube	temporary option menu	matrix	26	cube	images			x			me
Boule Menu Ball	temporary option menu	geometric structure	4	sphere	text entries		x	x			littl
Tool Finger	temporary option menu	geometric structure	7	cylinder	text entries		x				littl
Floating Menu	single menu	acyclic list	10	plane	text entries		x	x	x		littl
Drop-Down Menu	single menu	cyclic list (ring)	10	plane	text entries		x	x	x		littl
FingARtips	single menu	acyclic list	10	plane	3D-objects	x			x		littl
Tinmith-Hand	single menu	free arrangement	8	specific	text entries	x	x	x	x	x	littl
Pen & Tablet Menu	single menu	acyclic list	10	plane	text entries		x	x			littl
Chooser	single menu	acyclic list	arbitrary	plane	3D-objects	x		x			me
Virtual Tool Rack	single menu	acyclic list	12	plane	images			x	x		littl
Ring Menu	single menu	cyclic list (ring)	16	disc	3D-objects	x		x			me
Generalized 3D Carousel View	single menu	cyclic list (ring)	arbitrary	disc	images & text	x		x	x	x	me
3D Palette	single menu	matrix	12	plane	3D-objects	x		x			me
Panoramic Wall	single menu	matrix	40	plane	images			x	x		high
Shelf	single menu	matrix	20	plane	3D-objects	x				x	high
Menu Tiles Book	single menu	geometric structure	arbitrary	specific	images	x		x			me
Start Palette	single menu	free arrangement	arbitrary	plane	images	x		x	x	x	littl
Spin Menu with Crossed Layout	menu system	acyclic list	9 per layer	specific	images	x		x			littl
Revolving Stage/Rondel	menu system	cyclic list (ring)	7-10 per side	specific	text entries		x	x	x		high
Hinged Menu	menu system	geometric structure	16	specific	text entries, 3D-objects	x	x		x		me
Cross Chooser	menu system	geometric structure	10	specific	text entries		x	x	x		littl
Hierarchical Pop-Up Menu	menu hierarchy	acyclic list-matrix	arbitrary	plane	text entries		x				me
Hands-Off Interaction	menu hierarchy	acyclic list	arbitrary	plane	text entries		x				littl
Horizontal/Vertical Stack	menu hierarchy	acyclic list	10	plane	text entries		x	x	x		littl
Tinmith-Hand with Submenus	menu hierarchy	acyclic list	64	plane	text entries	x	x	x	x	x	littl
3D Fade-Up (Pie) Menu	menu hierarchy	cyclic list (ring)	arbitrary	disc	text entries	x	x	x			high
Spin Menu with Concentric/Stacked Layout	menu hierarchy	acyclic list	arbitrary	cylinder	images	x		x			littl
Collapsible Cylindrical Tree	menu hierarchy	cyclic list (ring)	arbitrary	cylinder	text entries		x	x			me
Cone Tree	menu hierarchy	geometric structure	arbitrary	cone	text entries		x	x			high
TUISTER	menu hierarchy	cyclic list (ring)	arbitrary	cylinder	text entries		x	x			littl
TULIP	menu hierarchy	free arrangement	arbitrary	specific	text entries		x				littl
Polyarchie	menu hierarchy	free arrangement	arbitrary	specific	text entries		x	x	x		me

Taxonomy of 3D Menus

- Taxonomy
 - According to criterion intention of use, further subdivision to appearance and structure
 - To support 3D user interface developers
 - Similar solutions already summarized
 - Exclusive assignment neither always possible nor necessary, some overlaps exist
 - Web Version: www.3d-components.org/menus
 - Observations
 - Mainly single menus
 - Clear (geometric) structures preferred
 - No sharp border between temporary option menus | single menus, menu systems | menu hierarchies
 - Distinction still useful

Temporary Option Menus	
List	
	Pop-up & pull-down menus [JE92, WG95]
	Look-at menus [MFPBS97, BGH*04]
Ring	
	Rotary tool chooser [Min95]
	Spin menu [GB05]
Matrix	
	Command & Control Cube [GC01]
Geometric structure	
	Boule menu ball [Bou99], Tool finger [Wes03]
Single Menus	
List	
	Drop-down menus [SPH*95, Min95, CRF97, AS02]
	FingARtips [BVBC04], Tinmith-Hand [PT01]
	Pen-and-tablet menus [AS95]
	Chooser [Wid05], virtual tool rack [PS96]
Ring	
	Ring menus [LG94, Wid05]
	Generalized 3D carousel view [WPV05]
Matrix	
	3D palettes [MFPBS97, BBMP97, CFH97, SG97]
	Panoramic wall [3DN04]
Geometric structure	
	Shelves, horiz./vertical stacks [KKP*00, W3D05]
Free layout	
	Menu book [PTB*02]
	Start palette [RvDR*00]
Menu Systems	
List	
	Spin menu with crossed layout [GB05]
Ring	
	Revolving stage/rondel [Dac99, PRS97]
	Spherical menu [FC03]
Geometric structure	
	Hinged menu, Cross chooser [W3D05]
Menu Hierarchies	
List	
	Hands-off interaction [Dar94]
	Tinmith-Hand with submenus [PT01]
Ring	
	3D fade-up (pie) menu [Dec95]
	Spin menu with concentric layout [GB05]
	Collapsible cylindrical trees [DE01]
Geometric structure	
	Cone trees [RMC91], TUISTER [BGK04]
Free layout	
	TULIP [BW01]
	Polyarchies [RCCR02]

Conclusion & Future Work

- Summary
 - Comprehensive survey of 3D menu solutions for all areas of the MR continuum
 - Contribution to the unexplored area of application controls in the field of 3D UIs
 - Classification categories/properties to describe, compare and classify menus
 - Serve as axes and as a solid foundation for taxonomies and classifications
 - Not all categories and properties suitable for building a taxonomy, some better for filtering
 - Taxonomy according to the intension of use and structural layout
 - Allows developers to evaluate the suitability of a menu solution for a particular application
 - Numerous other classification approaches conceivable, depending on goal
 - Design space allows researchers to create new / to improve existing solutions

Conclusion & Future Work

- Research directions and future work
 - Further menu development
 - Combination of several menu techniques largely unexplored area by now
 - Development of new solutions using empty or promising gaps within the taxonomy
 - Examples: non-linear detail-and-context techniques for bigger hierarchies; acyclic lists dominate the field, exploration of other geometric structures
 - Standardization
 - Ground is laid for an agreement on well-established 3D menu techniques eventually leading to standardization
 - Consistent specification necessary, also of 3D interaction elements in general
→ IEEE VR 2006 workshop on specification of MR user interfaces
 - Community effort to improve Website
 - Additions, Wiki-powered, support of complex queries...

Discussion

Website: www.3d-components.org/menus

E-mail: dachselt@acm.org

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