

What Happened While I Was Away? Leveraging Visual Transition Techniques to Convey Robot States in Multi-robot Teleoperation

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Abstract. In real-time multi-robot teleoperation, the operator faces a challenge of maintaining sufficient awareness of all robots in a team. We propose a novel approach to supporting operators, in instances where operators switch between controlling or observing multiple robots in a team. Just as how cinema or video games use visual and narrative techniques to support viewers when transitioning between scenes, we argue that multi-robot teleoperation interfaces should likewise leverage this transition time to provide pertinent information. That is, when switching to a new robot, the interface should take the opportunity to bring the operator up to speed, highlighting what happened while they were away, what current robot states are, and what specifics of the new robot being controlled are; thus, supporting situational awareness. In this paper, we outline this agenda and present our initial exploration and analysis of this *informative visual transition*.

Keywords: Teleoperation \cdot Multi-robot teleoperation \cdot Control transition \cdot Interface design

1 Introduction

Teleoperation is becoming increasingly common and affordable. The demand for multirobot teleoperation is increasing to reduce human hours in domains such as search and rescue [6], military reconnaissance, or exploration [11].

One way to assist teleoperators to control multiple robots is to increase robot autonomy (i.e., reducing the required operator effort). However, even advanced autonomous robots need the operator's involvement, when it encounters unexpected circumstances [7] or when it needs to make important final decisions [10]. When an operator takes control of a robot, they must switch their focus and control to the robot. Before this *control transition*, the operator may have been controlling a different robot or working on other tasks. For example, in Fig. 1, an operator, navigating a robot, receives a request from another; they must switch their focus to new robot and survey the situation before issuing any commands.

The control transition is cognitively taxing: an operator must understand the new robot's state, task history, and remote environment around it as quickly as possible (especially for time critical missions) to send appropriate robot commands. We propose a novel interface design paradigm in multi-robot tele-operation to support the operator's situation awareness during this control transition: *informative visual transition*. We propose to use the moment of visual transition in multi-robot teleoperator quickly establish situation awareness with the new robot.



Fig. 1. An operator switches control from one robot (left) to another that needs help (right); an operator must assess the current situation, recent events, and pay attention to the characteristics of the new robot in comparison to the previous.

Informative visual transition is commonly previous. employed in interface design even if not emphasized. The transition is highly employed in film and related media to emphasize transition to a new scene, such as using slow panning shots or dissolutions. On computing technologies, modern websites provide animated scrolling instead of an instant page update to highlight the change [12]. In multi-camera systems (including robot teleoperation), it is common to animate switching cameras to similarly emphasize the change [5], such as by shrinking one camera feed while expanding the other [9] or by zooming out first and in to the robot's location on a map [1, 2]. Perhaps most similar to teleoperation, video games commonly use scene changes to provide narrative or game-mechanic information using a loading screen (even if not necessary for the game) to convey the transition or provide relevant information during this time (Fig. 2). However, we do not yet have a clear understanding of how to leverage the moment of robot control transition to similarly convey helpful information to operators in teleoperation.

In this paper, we survey techniques from cinematography (transition and camera techniques) and video games (information on loading screens) to inform possibilities for multi-robot teleoperation. We summarize these techniques and discuss how they may be useful in multi-robot teleoperation, resulting in an initial design framework. Our work provides novel vocabularies and keywords which are useful to discuss and design future multi-robot teleoperation interfaces.

2 Teleoperation Information: What the Operator Needs to Learn During Control Transition

We propose three important things that teleoperation operators need to know when transitioning to controlling a new robot: emphasis that a transition is happening and that it has completed (feedback), what recently happened to the robot and the environment (history), and what the current situation is (current states, Fig. 3). We believe this breakdown is useful for analyzing other work and propose visual transitions in designing multi-robot teleoperation interfaces.

Transition Notice— feedback in user interfaces help users comprehend the system's status [8]. The same applies to the control transi-



Fig. 2. Example loading screens. The left provides a visual indicator when the player moves from one place to another (*Resident Evil, Capcom, 1996*). The right provides the next stage's context information (*Medal of Honor: Allied Assault, Electronic Arts, 2002*).

tion. With proper transition notice, the operator can understand that their control switches from one robot to another and reduce mode error in results. For example, with the informative visual transition, the operator knows that they are controlling a flying drone instead of a ground robot (more degrees of freedom in movements). It applies in every situation. When the operator initiates the control transition, the feedback helps knowing that the system responds to their command. If the system initiates the control transition, the transition notice helps the operator notice the transition and be ready for re-evaluating and paying attention to changes.

Event History— during the control transition, teleoperation interfaces should convey the event history of the remote environment to the operator so that they can understand the past progress toward the robot's task and set next plans. For example, by knowing the robot's path in search and rescue, the operator can focus on the area where the robot has not been through. The perception of current situation elements is an essential part of having situation awareness [3]. The same applies to the control transition. After the control transition, the operator needs to have the perception of elements (the state information of the new robot and the environment around it). The robot's event history also helps understanding how the robot ended up requesting the operator's attention.

Current States— up-to-date states of the robot and the environment help the operator determine what they can and should do next. The information regarding the surrounding environment provides a hint of the robot's assigned tasks. Mobile robots maintain a large set of internal states, including connectivity, battery level, inertial readings, gyroscope readings, servo positions, and so on. In multi-robot teleoperation, each robot's details with their configuration or embodiment help the operator reduce mode error in issuing any commands to the new robot. Since the information varies from robot to robot, we must provide at least some (if not all) of this information to the operator during the control transition in multi-robot teleoperation.

3 Initial Survey: Visual Transition Techniques in Other Fields

Regarding teleoperation information (*transition notice feedback, event history, and current states*), we are looking at the other fields to learn techniques to inform teleoperation design. We openly explored other areas of media which make specific efforts to carefully orient audiences to a new scene and situation to ensure that they can follow the story arc. This resulted in us landing on film and video games.

Film scene transitions happen by blending the visual effects of the two scenes. There are primarily seven effects and many varieties derived from them: cut, fade-in, dissolve, white-in, wipe, white-out, fade-out [5]. Visual effects, however, are ambiguous in terms of their meaning. For example, fading out after a character's death conveys a different feeling compared to fading out while people are laughing. However, as visual effects convey transition in any case, we marked them as transition notice in our classification and extended our survey to camera techniques which have deeper meaning in transition.

There are many camera techniques and their improvements in films. With novel hardware and knowledge, camera techniques keep evolving, and cinematographers introduce new techniques. For this reason, it may not be practical to list all existing techniques. We could not find academic publications regarding camera techniques in cinematography, possibly because they aim toward practical applications. Therefore, we picked a list from a web article (the title is *Film Studies 101* ... Freer & Gibbs [4]) as a part of our initial survey. We grouped the camera techniques based on our understanding of their purpose and effects and summarized in Appendix 1. We would like to note that some techniques can be combined with others and used for other purposes.

To move from one scene to another in video games, due to the volume of video game data (e.g., graphics texture, audio, etc.), loading the data from storage to working memory and unloading the unnecessary data from working memory are inevitable tasks. This transition can be used for players to keep their interest, follow the story arc, watch aesthetic visual works, or simply wait for data loading. However, we could not find academic references regarding loading screens in video games. Thus, we referenced journal articles and opinion videos.¹ We pick the video games that we know and classify their loading screens based on their characteristics (Appendix 2).

4 Control Transition and Visual Transition Techniques

There are many visual transitions conveys useful information; our question is how we can leverage them in multi-robot teleoperation interfaces. We connect the teleoperation information for the operator during the control transition and visual techniques from other fields (i.e., the initial design framework Fig. 3). Our focus is to introduce other fields' techniques and anchoring our future discussion of implementing our novel idea, informative visual transition in multi-robot teleoperation. Despite our effort, we admit that this is a proof-of-concept and requires further improvement. We leave the improvement as future work and focus on the potential of our framework.

¹ URL: (youtube.com/watch?v=RSV4rHCPJ0M), (youtube.com/watch?v=hhVT7ydgGxo), (youtube.com/watch?v=hhVT7ydgGxo), and (gamesradar.com/the-secret-art-of-the-video-game-loading-screen-and-why-they-wont-be-going-away-anytime-soon/).

Control Transition Information				
emphasis of the fact that a transition is happening (transition notice)	what happened to the robot and the environment (event history)	what the situation is (current states)		
knowing transition and completion of the control transition	the robot's task history changes in the environment known solutions	the robot's configuration the robot's internal states current challenges the environment		
Film: visual effects CT: transitional (high angle shot, tilt, zoom) CT: intensify (dolly zoom, Dutch tilt) VG: simple progression	CT: sequential (bridging shot, whip pan, the sequence shot) VG: things to read VG: session statistics VG: hints for location change	CT: exploration (aerial shot, establishing shot, top shot, pan) CT: emotional attachment (arc shot, close up) VG: interactive		
Visual Techniques (CT: camera techniques, VG: video games)				

Fig. 3. The three information types (upper half) for an operator during the control transition. By comprehending the information, the operator can have enough awareness to issue any commands. We can design informative visual transition using media techniques (bottom half) to support the operator during the control transition in multi-robot teleoperation.

5 Conclusion

We discussed a novel interface design paradigm in multi-robot teleoperation to provide teleoperation information during the control transition. When the operator must comprehend the rich information before issuing any commands, the informative visual transition can help the operator speed up their understanding. This concept can be useful in many situations: we can already find examples of informative visual transitions in various fields. We propose to leverage this for future multi-robot teleoperation interfaces to improve the teleoperation experience and increase the operator's task effectiveness. This paper provides vocabularies and keywords that explain how and why camera techniques and video games' loading screens can be relevant and useful to design informative visual transition. This is our initial step toward implementing the novel paradigm in multi-robot teleoperation interfaces, we leave the assignments as our future work.

Appendix 1. Selective camera techniques and our classification with short descriptions.

	Explanation	Techniques
Transitional	 used in transitioning the story arc (e.g., an episode finishing by tilting the camera or a scene finishing by changing zoom focus) can be used to express simple transition between robots 	High Angle Shot—camera moves away to the sky while taking a subject downward (<i>The Shawshank</i> <i>Redemption 1994</i>) Tilt—camera changes its angle upward or down- ward (<i>Robert Altman's Nashville 1975</i>) Zoom—camera is at a fixed place while shifting its focus to another (<i>The Conversation 1974</i>)
Intensify	 provide feeling of dreamlike, unsettle, surreal, and so on can be used to express a robot under intensive situations 	Dolly Zoom —camera takes a subject or an environment while moving and shifting its zoom at once (<i>Jaws 1975</i>) Dutch Tilt —the camera is physically tilted to convey an unsettled feeling (<i>Mission: Impossible 1996</i>)
Sequential	 used to show events and happen- ings in the order of their occurrence can be used to show task history of the new robot while transitioning 	 Bridging Shot—scene is stitched by multiple scenes translucently (<i>Indiana Jones 1981</i>) Whip Pan—screen quickly swipes scenes after scenes with whip sound (<i>Hot Fuzz 2007</i>) The Sequence Shot—camera follows a subject capturing every moment (<i>Touch of Evil 1958</i>)
Exploration	 used to show the stage and the environment where the story happens can be used to show the new robot's environment 	 Aerial Shot—camera flies around (<i>The Sound of Music 1965</i>) Establishing Shot—camera flies over buildings with narration (<i>The Shawshank Redemption 1994</i>) Top Shot—camera takes the ground from the perpendicular angle in the sky (<i>Taxi Driver 1976</i>) Pan—camera pans in 360-degree to capture the environment (<i>Brian de Palma's Blow Out 1981</i>)
Immersion	 while every camera technique makes the audience immerse into the film, these provide an immer- sive feeling toward a character or an environment teleoperation is already like this 	 Handheld Shot—camera is held by a character (Scorsese's Mean Streets 1973) Point-of-view Shot—camera takes scenes from a character's perspective (Doom 2005 and Hardcore Henry 2015) Locked-down Shot—camera is locked like a sur- veillance camera (Manhattan 1979) Tracking Shot—camera follows a subject and tracks them (Paths of Glory 1957)
Emotional Attachment	 help people emotionally attach to fictional characters – that is, en- hance emotional attachment for the audience to the characters can be used to show the current robot's exterior status 	Arc Shot—camera circles around subjects while keeping its focus on (<i>De Palma's Carrie 1976</i>) Close Up—camera takes the full face in the frame (<i>The Passion of Joan of Arc 1928</i>) Deep Focus—scene has a sharp focus on all levels including fore-, middle-, and back-ground (<i>Citizen</i> <i>Kane 1941</i>) Over-the-shoulder Shot—camera takes a subject over another's shoulder (<i>The Godfather 1972</i>)

Observing Characters	• primarily for the audience to ob- serve characters and environments in a film	 Cowboy Shot—a stereotypical cowboy duel scene (<i>The Good, The Bad and The Ugly 1966</i>) Long Shot—camera takes a subject from head to foot (<i>Lawrence of Arabia 1962</i>) Low Angle Shot—camera takes subject(s) from the low angle to show authority (<i>Matrix 1999</i>) Medium Shot—camera takes a subject's upper body, facial expressions, and their actions (<i>The Searchers 1956</i>) Two Shot—camera takes two in one frame (<i>Mag- nolia, 1999</i>)
Supportive	• used in a supportive manner for film making	 Crane Shot—a shot using a crane (Gone with The Wind 1939) Library Shot—a shot pulled from a library (Tarzan 1958) Matte Shot—a scene with foreground action and background painted (Planet of The Apes 1968) Money Shot—a shot with money (Independence Day 1996) Steadicam Shot—a shot using a hydraulically balanced camera (Goodfellas 1990)

Appendix 2. Video game loading screens and our classification based on the information that the scene conveys.

	Explanation	Techniques
Things to Read	 provide stories, lore, and tips can be used to provide the new robot's task history and changes in the environment 	Medal of Honor: Allied Assault 2002; Dragon Age: Inquisition 2014; Middle- earth: Shadow of Mordor 2014; Just Cause 3 2015; Assassin's Creed Odyssey 2018
Session Statistics	 provide summary statistics can be used to provide the ro- bot's task history 	DOOM 1993; Rocket League 2015
Hints for Location Change	 provide a hint of location change can be used to show the locational relationship between two robots during the control transition 	<i>Resident Evil 1996; Mass Effect 2008</i> (ele- vator scene); <i>Dragon Age: Origins 2009</i> (moving on the map); <i>Destiny 2 2017</i> (enter- ing a planet)
Interactive	 provide a mini-game or a training can be used to provide a short training session while presenting the robot's current configuration 	Assassin's Creed 2007; Bayonetta 2009; FIFA 19 2018
Simple Progression	 indicate the loading progress of- ten with artwork or sound effect can be used to visualize the tran- sition itself as a transition notice 	Hexen: Beyond Heretic 1995; Battlefield 1942: The Road to Rome 2003; XCOM 2 2016

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