Delegation Impossible? - Towards Novel Interfaces for Camera Motion

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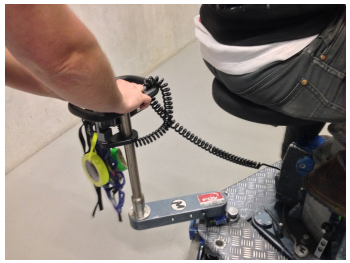
Abstract
When watching a movie, the viewer perceives camera motion as an integral movement of a viewport in a scene. Behind the scenes, however, there is a complex and error-prone choreography of multiple people controlling separate motion axes and camera attributes. This strict separation of tasks has mostly historical reasons, which we believe could be overcome with today's technology. We revisit interface design for camera motion starting with ethnographic observations and interviews with nine camera operators. We identified seven influencing factors for camera work and found that automation needs to be combined with human interaction: Operators want to be able to spontaneously take over in unforeseen situations. We characterize a class of user interfaces supporting (semi-)automated camera motion that take both human and machine capabilities into account by offering seamless transitions between automation and control.

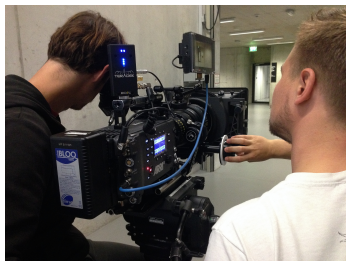
Author Keywords
Interactive automation; human-centered automation; user interfaces; cinematography; motion control; take-over.

ACM Classification Keywords
H.5.2 [User Interfaces)]: User-centered Design; H.5.3 [Group and Organization Interfaces)]: Computer-supported cooperative work

(a) Camera operator (middle), first assistant (right) and dolly grip (left) taking a shot



(b) Dolly grip (left) moves the dolly



(c) Camera operator (left) pans and tilts, the first assistant (right) pulls the focus

Figure 1: Camera crew shooting a scene

Introduction

Camera motion is a prominent stylistic tool to immerse people into a story. The seemingly integral motion of a camera, however, is often a complex and error-prone interplay between multiple people controlling various parameters such as camera position, orientation, zoom, iris and focus. The complex main task is divided and the subtasks are delegated to multiple people each controlling separate sets of parameters.

For example, figure 1 illustrates the required steps to shoot a *'phone call scene'*: 1) Kate comes around a corner talking on the phone. The camera crew waits for her appearance (figure 1(a)). 2) The very moment she appears, the camera moves along with her maintaining a fixed distance. The dolly grip starts moving the dolly (figure 1(b)) and the camera operator controls pan and tilt parameters to frame her slightly to the right (figure 1(c)). Kate stops surprised while the camera continues to move further away from her. The first assistant adjusts the focus wheel (figure 1(c)) to keep her head in focus.

This form of *human-human delegation* reduces the operator's workload but is error-prone: if one crew member fails her timing, the scene needs to be reshot. However, in unforeseen situations, e.g., when Kate stops earlier than scheduled, the crew can directly react. *Human-machine delegation* can also reduce workload: Machines can precisely control multiple parameters in synchrony, but they can't react in unforeseen situations.

We investigate this conflict in delegation, a.k.a. MABA-MABA[1] [4] in the context of camera operation and took an ethnographic approach by attending filmmaking classes and observing *field work* on a film set.

[1]MABA-MABA: **M**en **A**re **B**etter **A**t - **M**achines **A**re **B**etter **A**t

Then, we interviewed nine camera operators and identified seven technical and emotional issues, e.g., *high workload* and *being-in-control*, which are relevant for camera work. We found a trade-off in automation between workload and being in control: offloading work to automation leads to a loss of control; being fully in control leads to a high workload. Hence we argue that interfaces for camera operation ideally should provide a dynamic interplay between different levels of autonomy: tasks can be tentatively delegated, but then partially adjusted or completely taken over by the human operator later on.

Related Work

Fully automated systems exist in non-artistic contexts, such as air navigation, traffic control and plant or factory supervision [4]. They are meant to reduce workload, stress, fatigue and human error [2]. Over-automation, however, can cause over-reliance, leading to decision biases, skill degradation and loss of situational awareness [6]. This means that delegating tasks to automation plus the monitoring of the results can ironically even result in a higher overall workload for the user [1].

Camera operation is an artistic work which requires room for improvisation and spontaneous adaptation to unplanned situations. Existing camera motion systems mostly only allow full delegation: Hexo+[2] (an autonomous drone for action sports) and IRIS [3] (an industrial robot used in Alfonso Cuarón's Gravity, 2013) provide only very limited room for spontaneity. Semi-automated systems, such as StypeKit[3] (a computer-supported crane used in the BBC's broadcast of the FIFA Worldcup 2014) provide full control of certain motion parameters by the operator, while others are controlled automatically.

[2]`http://www.hexoplus.com`
[3]`http://www.stypegrip.com/stype-kit`

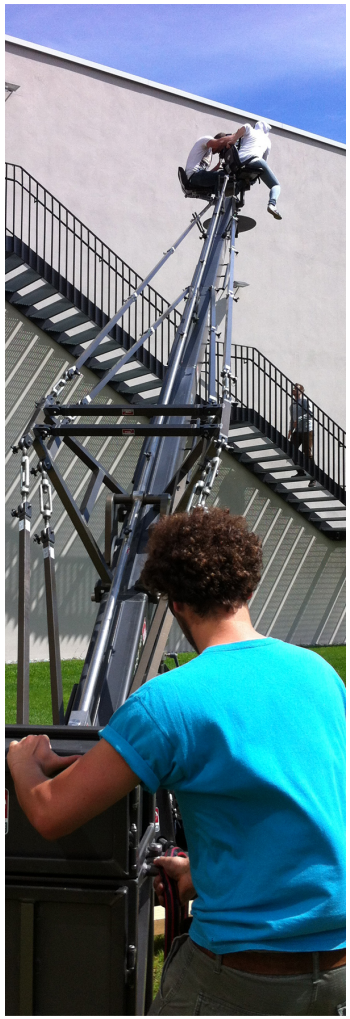


Figure 3: Camera operator and focus puller (in the air) and crane grip (on ground) following an actor (on staircase)

Such a straight division, however, might not always be necessary (or even reasonable): Sheridan et al. [7] define ten levels of autonomy (LOA) on a continuum from direct control to full autonomy. The LOA can be changed on purpose (e.g., when taking over control in semi-autonomous driving) and a task might be divided into sub-tasks with different LOA [5]. However, with any level of autonomy, a trade-off between *workload* and *unpredictability* (depending on competency) is inevitable.

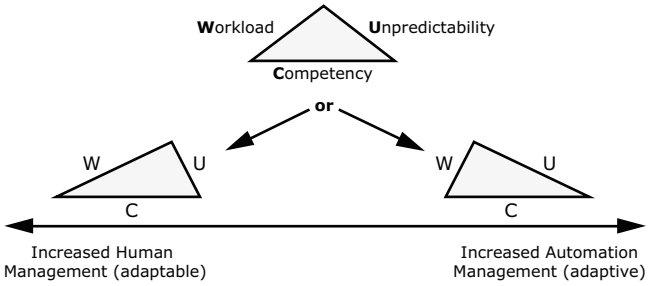


Figure 2: Workload (W), unpredictability (U) and competency (C) trade-off in adaptable/adaptive automation based on [5].

It changes with the LOA and affects the relationship between the human and the system (fig. 2). Its nature is either *adaptable* (user delegates tasks and decides on LOA) or *adaptive* (system chooses the LOA). In adaptable systems, as input is more direct, the workload is higher, but also the effects of one's actions are more predictable. Adaptive systems reduce the workload by applying more autonomy, but lead to less predictable outcomes.

Observations and Interviews

In observations and interviews, we could confirm the relevance of *workload* and *predictability* in the context of cinematographic work. As a preparation, we spent two weeks in a theoretical and a practical seminar at a local university for filmmaking. These seminars discussed how various camera setups, such as dollies and cranes, affect camera art work. In the practical seminar participants worked with various of these setups (figure 3). Additionally, we spent one day at the film set of a weekly program at a local television broadcasting company. After this preparation, we conducted interviews to identify relevant issues that camera operators face in their work.

Participants

We recruited nine camera operators (7 male, 2 female, from 22 to 63 years of age with 32.5 years of age in average). Seven of them studied filmmaking and five had advanced professional experience from national and local television companies or from working as a freelance.

Method

We conducted semi-structured interviews (1½ hour each) focusing on the circumstances of extreme situations requiring a lot of film takes or surprisingly few. The conversations were recorded for post-hoc analysis.

Results

Some of the problem areas we found address the social structure at the film set (e.g., "*Of course, the director agrees with the camera operator! He actually chooses his camera operator, so that they can work well together.*" (P08) or "*Technical/aesthetic expertise is one thing, but the ability to work in a team is another.*" (P01). However, since we focus on the design of tools for film production, we decided to categorize and report only those problem areas that can be addressed by user interface design. Seven major subjects came up repeatedly across the interviews. Quantitative data on the relevance of the issues is presented as (#subjects mentioning the issue/#mentions in total).

Contexts and Use of (Automated) Tools in Film Production

Scenic:

pre-planing, repeatable, often high budget, high use of tools

Documentary:

limited pre-planning possible, not repeatable, mid or low budget, limited use of tools

TV-Studio:

pre-planing, highly repeatable, often high or mid budget, high use of automated tools

Advertising:

pre-planing, repeatable, high budget, high use of automated tools

Sports:

pre-planing, repeatable, high budget, high use of tools, restricted angles

Table 1: Context and application of automated tools

1. Preparation (9/65)
In the preparation phase, the story, camera viewpoints, locations and logistics are dealt with. A lot of communication happens between the departments, e.g. camera department and director. Tools such as storyboards, moodboards, floorplans help with the communication. All participants mentioned the importance of preparation: *"Storyboard, floorplan, all sorts of things. (...) Sometimes there is a storyboard department that draws that. But a floorplan is done by the camera operators themselves and the shotlist is written following their conceptions. (...) And a grip who makes drawing or notes how this is handled in staging and with crane, dolly or steadicam."* (P 07).

2. Low Error Tolerance (9/50)
Generally, if an error occurs the shot is stopped and a new take is started. Operators work with the situation and know that in the final film minor errors are often not recognized by the audience (so there is a certain tolerance): *"So we rehearsed and shot that several times because something always wasn't right."* (P 09).

3. Need for Improvisation (9/39)
For high end productions a great amount of time is spent on prearrangement. However not everything can be planned ahead. While shooting, often situations occur that were not or could not be planned ahead of time. In a process of constant weighing up, camera operators need to react spontaneously and intuitively to the situation: *"It is rare that everything works smoothly (...) the problems can come from any direction: technical, personal, weather, motive or acting."* (P 07).

4. Constraints (9/38)
We identified six constraints, the most obvious of which are *time*, *money* and *space*. "*Staging, dolly / crane shots and then it's calculated how much the motive is besides the rent. The operator checks whether it's doable at all.*" (P 07). But also *aesthetics*, *rhythm* and *zeitgeist* affect the selection of techniques and tools. (e.g. *"The era of the grand gesture is over."* (P 04) meaning that crane motion is used less frequently due to faster rhythms through higher cutting rates being popular today).

5. High Workload (6/29)
In moving the camera or focusing during motion, mistakes are often made. Reasons can be found in the complexity of the task. In terms of focusing the participants reported several times about problems with curved movements. Especially when the actors and the camera move on different curves, distance estimation becomes a difficult task: *"This planning of camera movements (...) this is so difficult, I think it comes with experience."* (P 05).

6. Context Dependency (5/42)
The choice of tools and working process depend on the context. We identified five contexts that have different aspects to them (table 1) showing in which context the application of automated tools is likely. *"Working towards a certain picture and very technical preparation is common when it's a commercial."* (P 03).

7. Being in Control (4/12)
To the operators it is very important to be in control of the camera or dolly etc. They want to be able to change as much as possible manually. For this they prefer haptic feedback and solid tools: "*Every camera operator who looks through the eye-piece of three cameras or so does need this control or supremacy of the one who is in charge of the look.*" (P 02).

From these problem areas, we chose the ones (3, 5 and 7) that can be addressed by UI design for camera control.

Strategies in motion control with interplay

Full Task Delegation:

The operator delegates tasks to the machine. Both control separate tasks in different loops. A take-over or parameter adjustment form the operator might follow.

Partial Control:

The motion is basically controlled by the machine, but the operator can adjust parameters (e.g. speed or angles) relatively to the running motion. The operator adjusts parameters from outside the loop.

Take Over:

Temporary human control: the operator steps in the loop from outside the loop and might give control back to the machine later on.

Table 2: Strategires in motion control with interplay

Degree of Automation vs. Level of Autonomy

Different degrees of automation (DOA) reduce workload to different extents. We distinguish between *direct control*, *remote control* and *motion control* (figure 4):

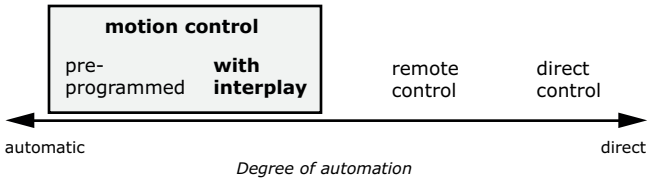


Figure 4: Degrees of automation

Direct Control: The camera is directly controlled by an operator next to it, mainly through panning or tilting.

Remote Control: Operators control the viewport indirectly from a distance, e.g., via a joystick.

Motion Control: This is an established term in cinematography and refers to tools that are equipped with motors and processors, in order to provide precise and repeatable movements. We distinguished between *pre-programmed motion* and *motion control with interplay*. In pre-programmed motion, the operator executes a motion once, which is then recorded and replayed by the machine. In motion control with interplay, the operator can still alter such a motion while it is being executed.

Motion control with interplay allows the reduction of workload through automation while still providing a substantial feeling of control. In this category we identified three strategies with different LOA: *Full Task Delegation*, *Partial Control* and *Take Over* (table 2). In figure 5 we categorized them in terms of their workload and unpredictability according to [5] as well as their LOA.

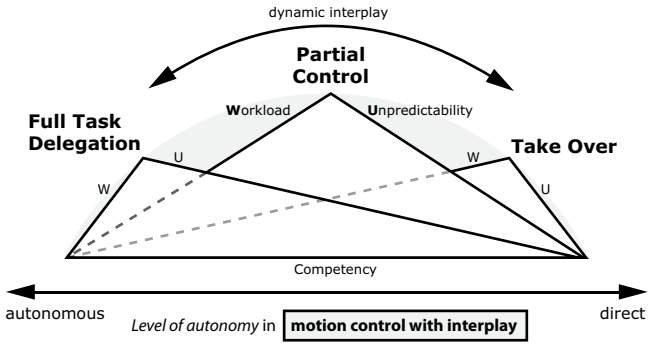


Figure 5: Level of autonomy in motion control with interplay

Designing Interfaces for Camera Motion with Varying DOA and LOA

Current interfaces in application domains of automation, such as tele-operation of unmanned vehicles, are designed for processes with clearly defined steps and straight task separation. We doubt that these interface concepts suit the context of filmmaking. Camera operators often quickly intervene during motion with aesthetic premises in mind. Even if an autonomous camera agent could be implemented, the resulting aesthetic would differ from a human one.

In addition, *smooth motion of heavy equipment*, *visual pattern recognition* and *spontaneous reaction* are intertwined in the single task of camera control. Therefore a fixed task division as suggested by [4] cannot be applied in this context. Although we generally argue against a fixed task division, we acknowledge that delegating certain subtasks to the machine temporarily is still a valuable part of the repertoire, as long as the user is fully in control of this delegation.

High workload and *wanting to be in control* are two important factors found in related work and our interviews. Workload can be reduced by delegation to automation. How much the workload is reduced depends on the chosen LOA, but with increasing autonomy, unpredictability increases inevitably [5]. We believe that this will provoke an even stronger feeling of loss of control. Allowing the user to switch the LOA when needed, to a level they think is right, however, might generate enough overall feeling of control to overcome the issue without sacrificing machine benefits totally. This means that dynamic transitions between the LOA under control of the user must be provided. This also addresses the need for improvisation we found in our interviews.

Summary and Future Work

Professional camera operators face a highly complex task when controlling multiple motion axes and camera parameters in real time. Automating entire subtasks can offer support, but also causes a loss of direct control. In fact, a strict division of tasks does not seem to be reasonable due to the intertwined nature of the tasks.

In our analysis, we focused on the issues of *high workload*, *wanting to be in control* and the *need for improvisation*. With *full task delegation*, *partial control* and *take over* we presented three strategies for designing human-centered automation in cinematographic work. We described them according to their level of autonomy and emphasized the *need for transitions* between these levels for an increased overall feeling of control.

We believe that a system following these strategies will use both human and machine capabilities better, because automation may support certain tasks without taking away all control. In future research we will provide concrete interface designs for the suggested strategies and conduct user studies with expert camera operators to verify our hypotheses.

Acknowledgments

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