Applied Mechanics and Materials Vol. 794 (2015) pp 555-562
© (2015) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMM.794.555

Submitted: 2015-04-29
Revised: 2015-06-10
Accepted: 2015-06-10

Three General Determinants of Support-Systems

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Submitted by: Prof. Jens P. Wulfsberg

Keywords: Human Aspects, Automation, Support

Abstract. Different research institutes and companies are developing technical systems to support or assist people at work and in daily life. The technical systems can be used for a wide range of different applications. Moreover, the systems have different forms with respect to their application. This paper will analyse and classify different forms of such systems in a general manner. The classification procedure will be illustrated by exemplary solutions.

Introduction

There are several different or similar technical systems for support and assistance that help people in different situations in everyday and professional life. These include, for example, automated systems like applications with autonomous industrial robots [1], systems for human-machine cooperation like robot based systems for welding [2], automated robots in the area of care [3], exoskeletons for rehabilitation [4] or for military applications [5], lifting aids/balancers [6], electric bikes [7], intelligent electric air brushes [8], or prostheses (e.g. hand prostheses [9]) as well as apps or web-based navigators like Google Maps. These solutions have in common that they support, assist or help people in order to, for example, relieve them or increase productivity in organisations. In literature, the different meanings as well as the operational differences of support, assist or help are unclear (see e.g. [10]). Partially, the same descriptions or wordings are used for different systems or interactions, especially for forms of support systems. To summarize, the proliferation of numerous and diverse forms of support systems, assistive devices, and technical aids has led to terminological confusion. A clarification is necessary in order to be able to address future challenges of research and system design with requisite precision. Additionally, the assessment of current solutions and the detection of gaps between them will be facilitated.

Approach

The study of support-systems has to face two particular challenges: one is to identify variable patterns of relation between some focal activity (e.g. work, task, action, behaviour) and the relevant "support" of this activity; the other one is to include issues of social embeddedness and thus acceptance of such systems. These challenges demand an interdisciplinary approach. They have to be tackled at least with respect to engineering and sociology. Yet there is no simple division of labour between engineering science and social science in this respect. The role of sociology is not just to incorporate some "human factor" or to investigate the acceptance of new technologies. It also adds competence with regard to non-linear interaction processes, in which organisms, cognition, material artefacts, expectations and stories, software programs, and cultural institutions are bound together into heterogeneous socio-technical networks. For this reason we will start with weak assumptions about "support" systems. Unnecessary restrictions that reduce the concept of "support" exclusively to "technical assistance of human beings" are suspended. A fundamental notion of support must rather recognize first and foremost that support is always related to some observable or desirable *activity*, which might be distributed across different organic, social or

technical entities. Taking this simple idea seriously changes the usual perspective. Now the main goal is not crafting management tools, machinery, or software as isolated components that solve a predefined problem, but to examine and design *systems* of activity-support relations. "Human activity plus technical support" now appears as only one possibility of activity-support relations out of many others. Another one might be, for example, "technical activity plus human support" or "mechanical activity plus organisational support". So one task is to find out how different forms of support and activity are specified by observers. What are the major determinants of classification, design, and assessment of support-systems? The result should be applicable to all types of possible systems, combinations, and levels. Its use would help to update and specify our ignorance.

The aim of this paper is to provide those major determinants that allow a specification of different systems for supporting, assisting, and helping. Such a specification will lay the basis for

- the conceptual system structure and general design of such systems, e.g. the kind of cooperation, interaction, and/or linkage between the relevant components (this concerns issues like the separation between activity and support, their serial or parallel coupling, or whether technological components of the system are wearable or stationary), as well as
- specific design decisions regarding the materials for technological elements, the degree of support (which basically amounts to defining the ratio of support and activity), the overall mobility options of the system, or the form of software programming (e.g. adaptive or non-adaptive programming).

We start with a discussion of activity and support as the decisive unit of analysis and subsequently identify three determinants that can be used for a specification of support-systems: the spatio-temporal relation of activity and support, their form of mutual integration, and the locus of control. Organisational choices about *supporting* or rather *substituting* an activity are contingent on particular combinations of these determinants. Additionally, these determinants prepare the ground for a possible classification of support systems and allow to distinguish between assistance, help/aid, and support, which are used almost synonymous so far. Each of them brings up and refers to different problems. Hence they should be distinguished in order to be able to address their technical and social conditions and consequences more precisely.

The Dual Activity-Support as the Unit of Analysis

In a very general sense any tool that has ever been devised can be considered as supporting some activity that would otherwise be much more time consuming, and/or costly, and/or less precise. This bears resemblance to the famous ideas of the philosophical anthropologist Arnold Gehlen. In his view human beings are doomed to invent technology due to their lack of instincts. Hence any technology has to be understood as supporting (by extension or relief) or substituting organs [11]. Yet such an assumption would be too extensive to be useful and it actually does not hold true. It ignores that any support device or action redefines the performance and the possibilities of the supported activity. There is no pool of activities waiting for support. Forms of support often call for new forms of activity that were probably not intended before. Does a knife support hunting for game or does it constitute new forms of hunting activity? Does it support killing or the preparation of food? Such issues cannot be settled objectively. They depend on some observer who specifies whether some thing or action supports an activity or not. This is also of utmost importance for any subsequently attempted classification or specification of support-systems: We will not get some kind of unquestionable categorization that will allow analysts to separate the supporting from the supported or diverse support-systems from each other. What we will get, however, are distinctions that different observers use in different contexts and with differing interests in order to construe a situation and to determine its stakes.

The observation of support is bound to the distinction between some activity on the one hand and the related support on the other. This distinction will often be a debatable, uncertain and even confrontational issue. For example, consider a manager who divides the collaboration of two or more workers into the ones who do the activity and the other ones who support them. This

assessment could deviate completely from the perception and interpretation of the workers. If this is the case then it will change the way the workers judge each other's activities in future, the way they collaborate, their relationship to the manager, and the distribution of motivation within the group. This indicates a general feature of this distinction: It conveys a difference in competence, status, or hierarchical position. Support is commonly valued as inferior in contrast to the activity that is supported. Such issues will also prove as pivotal for any analysis of the acceptance of support systems. However, any design of support systems inevitably distinguishes a supporting activity and a supported activity. Though both are activities eventually, we will call the supported one "focal activity" and the supporting one simply "support". Their conveyed valuation is contingent but should be kept in mind as one important consequence of this distinction.

The term "activity" stresses the dispersed character of the operation in question [12]. It covers individually attributed action as well as behaviour of organisms, but is not confined to them. Since we aim at getting a general idea of support-systems, the concept of activity is more potent and less restrictive than concepts like action or behaviour. In this respect the activities of computers, corporations, groups, robots, animals, human beings, muscles or nervous systems can all be discussed and examined as complex bundles of operations spread over different entities. Think of driving a modern car as an example. Driving is an activity that is spread over different participating entities: an engine, a computer, the driver, and different assistive systems. Normally, we would be inclined to pay attention only to the driver and his actions. Additionally we may observe technical systems like brake assist or distance control that support the driver's actions. But an observer of this specific activity-support unit in a specific situation could easily also bundle this activity-support unit into one single activity and observe that the crucial support of this activity comes from the co-driver and his instructions or his calm voice.

Observers (e.g. engineers, interested bystanders, a participating entity or an organisation like a company) determine support by bracketing an activity out of social process. This is a necessary precondition for ascertaining support and also for the forms it takes (or might take) – e.g. whether moral support, financial support, technical support or personal support is the case or whether one of these forms is needed for the activity to be accomplished, facilitated or optimized. Once this distinction between activity and support is drawn, the "support" is framed as an activity that is marked as exclusively aligned to accomplishing the intention, purpose, or the course of the focal activity. That is, support is considered to have *no purpose, intention, or course of its own*. It is important to get this right to avoid misunderstandings. An individual could support somebody for strategic reasons, for example, in order to achieve own goals that are different from the ones that the supported activity is trying to achieve (note that most activities in our lives do not have built-in goals, but this should not bother us here). However, the immediate support operation itself must be effective – independently of any underlying interests and reasons. It must function as support. The crucial issue here is *how* the support is given, not *why* it is granted. This is exactly the meaning of the above given definition that support is considered not to have any purpose, intention or course of its own, but to be exclusively aligned to the activity that is to be supported. In case the support is getting a life of its own, which happens quite often, it either ceases to be observed as support or it is marked as problematic (just think, for example, about IT-support departments in large organisations that develop own policies).

To sum up, any activity can be accomplished either with support or without support. We have seen that this is an intricate issue: It depends on the interpretation of an observer (a) whether an activity is supported or not and (b) if it is seen as supported, where the line is exactly drawn, that is, what is framed as focal activity and support respectively. To depend on such vague terms as "interpretation" appears unsatisfactory at first. Yet it does not obstruct in any way the reasoning necessary for designing support systems. Rather it gives a richer picture of the practical situation in which some prospective support system is going to operate. What matters is that this distinction is drawn in everyday and working life and that it is above all a necessary precondition for the design of support systems. Any decision with regard to the design of such systems has to take into account that the resulting activity-support duality is the inseparable, fundamental unit of analysis.

Determinants of the Relations within Activity-Support Units

The above general considerations must now be specified. In this section we will introduce further distinctions that will bring us into the position to classify particular systems. The three basic determinants of activity-support duals are identified here as *spatio-temporality*, *integration*, and *locus of control*.

This is not an exhaustive list of determinants, but we found that no support system can be devised or examined without taking these three aspects into account. Note, that every determinant refers to the *relation* between focal activity and its support. Fig. 1 gives an overview for two possible paths and lays the ground for the further proceeding, in which each position will be explicated. The paths describe two forms of support from general into detail. All the three mentioned aspects are considered. The other positions might also be differentiated in the same way; that is, the distinctions given for this paths can also be applied to the other positions. Only two possible paths are illustrated in order to keep the complexity at bay. The basic idea behind this distinction will be described next.

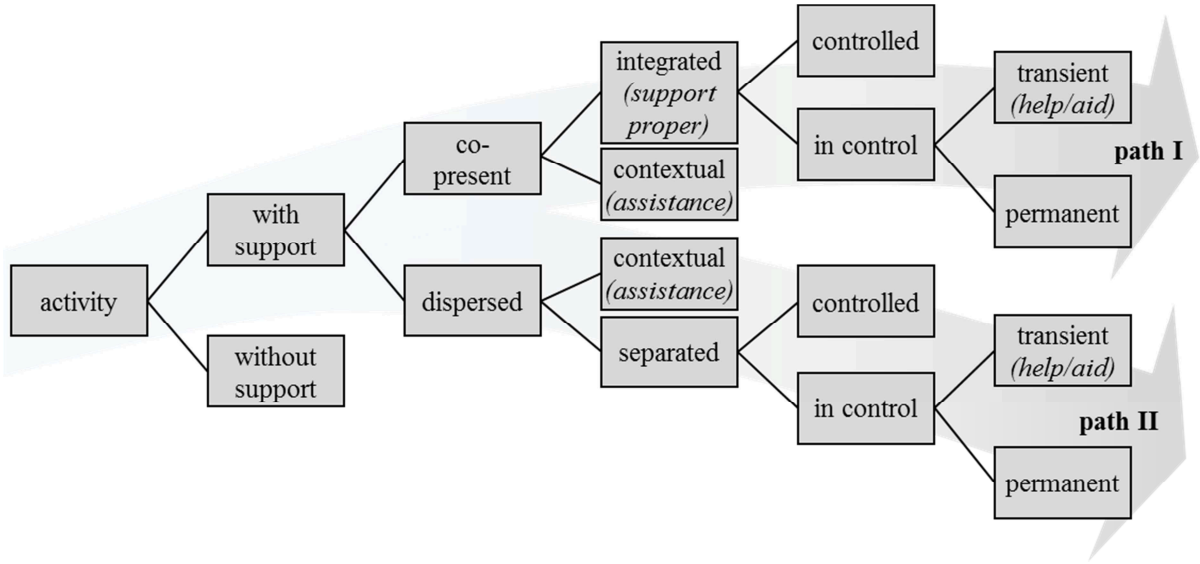

Figure 1: Classification of two paths

The Spatio-Temporal Relation between Activity and Support. Any supported activity may again be sub-divided into two classes. On the one hand a *co-presence* of the focal activity and its support, which amounts to a low spatial and temporal distance to each other; and on the other hand a spatially and temporally *dispersed* relation. Both classes do allow further differentiation. Co-presence means that the support is instantaneous and directly perceivable for an observer of the activity, e.g. a user or an organisation like a producing company or a nursing home. The spatial distance may vary in some degree but it has to stay within the limits of perception. In the case of exoskeletons, implants or in geriatric care for example, the spatial distance becomes minimal and the temporal relation between activity and support is synchronous. But support may also be granted across big, imperceivable distances and in an asynchronous form. There may even be long stretches of time in between (automated solutions with industrial robots, financial or moral support, virtual collaboration/organisation, certain expert/decision support systems etc.).

The Degree of Integration between Activity and Support as well as User and Support. Co-present supported activities can take integrated forms, that is, the support becomes constitutive for the performance of the activity – an integral though distinguishable part of the activity. If the activity is "walking at a certain pace" and it cannot be performed without any support then the support is constitutive for the activity. Activity and support are strongly integrated in this case and may even be coupled over direct material paths. But the support may also be contextual, that is, it could manipulate the conditions of the activity in a way that facilitates the performance. Assistance in a lab or the assistance of a manager is located here and one could go a step further and term "assistance" such contextual integration of co-present support. The character of a constitutive

integration is closer to what is indicated with "support" proper. Moreover, the kind of interaction, especially the direction, is different with respect to the contextual case. In case of the integrated solution, the interaction is bi-directional (e.g. user to technical system and other way around), otherwise it is one-dimensional (e.g. technical system to user).

Just like co-present support activities, dispersed supported activities can also take separated as well as contextual forms. In the case of separated forms, the activity will be divided in sub-activities. These sub-activities will be assigned to the support or non-support according to their properties. An example for this case is presented by a system which is based on the approach of human-machine cooperation. Here, the activity is divided in relation to the skills and abilities of human and machine. The difference with respect to the co-present support can be seen in the kind of interaction: it might be characterized as not high enough; "two system parts" are cooperating, but not in "one system".

The Attributed or Intended Locus of Control. Co-present and constitutive support of activities as well as separated support of activities can be observed and designed in a way that attributes the locus of control to the activity or to the support respectively. On the one side, the activity is *in control of* the support or the system user. The degree of support can be determined individually (e.g. able to switch off the support, leave the room or change the workplace). On the other side, the *support may control the activity*, a (quasi-)autonomy of the technical support (e.g. when you are "made" to walk although you can't). *Help/Aid* is a form of support that overtakes the control of an activity for a particular period of time (it may last for seconds or months), e.g., meal-assistance robot and lane departure warning system. As soon as the support is permanently in control over the activity the shift to substitution becomes probable.

Support-Systems vs. Substitution

As mentioned above, different forms of support are possible and the observer plays an important role. In order to illustrate this, we consider the following production scenario: An organisation instructs an operating person to perform activities in order to produce some product (see Fig. 2). This vantage point can be used to demonstrate the importance of the observer. Two main outcomes may be distinguished:

1. A technical support can strengthen something or someone (by adding needed functionality/ies).
   Example 1: The operator is using a support system for the accomplishment of his activity: Functionality deficits or other needs are compensated by the technical support system. Thereby, his role will be strengthened without being substituted by a machine.
   Example 2: An organisation is using an automated solution with e.g. industrial robots: From an organisational point of view, e.g. the output or the quality can be increased by such a system in order to improve their market position.
2. Technical support may weaken the individual position in cases when something or someone is replaced.
   Example 1: Implementation of an automated solution with e.g. industrial robots: From the perspective of the staff or user, such a system can weaken the individual position, because the staff is replaced by a technical system. So, the machine is performing the activity of the staff.
   Example 2: An automated solution in an organisation, which is not flexible enough for product changes: At first, such a system will strengthen the position of the organisation (see example 2 from above). However, it is also possible, that such a system is not capable to produce all needed products. This might lead to a weakening of the position.

These examples show possible results of a technical support. They illustrate possible relations between support and activity contingent on the interests and/or position of an observer. This is also a description of a possible change of states. Support systems can strengthen and weaken respective positions. Especially the questions (a) who needs or uses the system, and (b) who observes the

activity, are pivotal for the classification. Potentials and risks are often closely linked to each other – support-system or substitution. Our hypothesis: *only systems in which the support is observer independent*, e.g. when both user and organisation share one position with regard to the support, *can be understood as viable support-systems*. All other systems can be seen as systems to support individual persons, organisations or networks, but not for all participants.

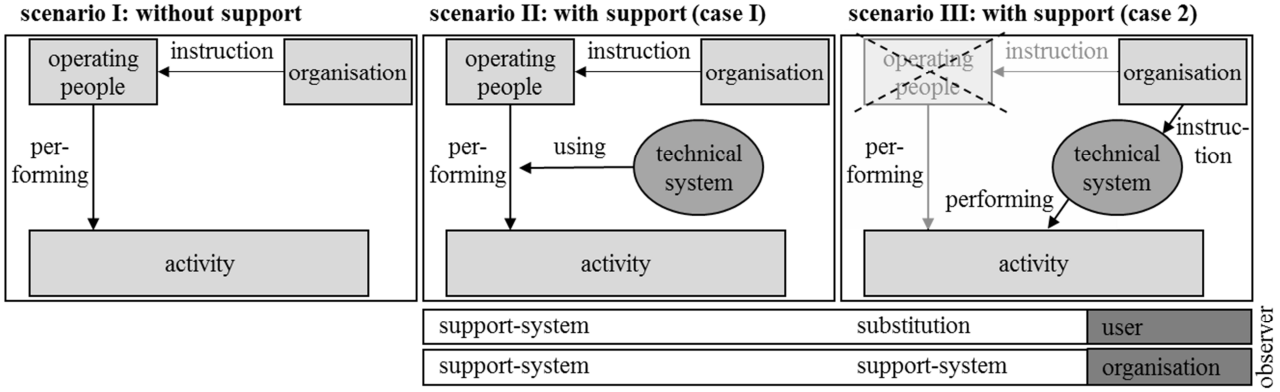

Figure 2: Possible scenarios for support-systems or substitution with regard to different observers

Exemplary Solutions

Based on our explanation, we finally describe the classification as well as our reasons for exemplary solutions from state of the art – hardware- and software-driven solutions. The classification, including a short explanation, is summarized in Table 1.

Conclusion

The last sections have illustrated the characterisation of technical support systems, assistive devices, and technical aids. As demonstrated, different criteria must be considered for the classification process. Incremental differences lead to the change of perception – support-system vs. substitution as well as support proper vs. assistance vs. help.

The described scheme can be employed for the design, development, and evaluation of systems which support, assist or help people. Such a systematisation can help developers to look for and find possible common views for different participating observers as well as to determine the main requirements for the system development – up to control strategies and guidelines. Support comes in different guises. Gaps between current solutions and demands can be identified.

This first approach to a classification model for support technologies can be expanded in further research and might also be specified for other paths. Moreover, the classification criteria can be refined in order to reach a more fine-grained analysis.

Summary

Several technical systems have been developed and are developed in order to support, assist or help people in everyday and/or working life. Such systems can implement very different forms of "support". Until today, the terminology is a somewhat confused. This paper introduces determinants for a classification of such systems supporting activities – and allows a distinction between support, assistance, and help. Three basic determinants characterise activity-support duals. These three aspects are spatio-temporality between activity and support, their form of integration, and the locus of control within this dual. The classification results are also highly dependent on the observer of the activity-support relation. The classification of exemplary systems from the state of the art are outlined in this paper. Systems performing different tasks can now be assigned to different categories.

Table 1: Classification for selected solutions from state of the art (organisations are for example "producing companies" or "nursing homes")

System/approach	Classification	Kind of support with observer …		Explanation
		… user	… organisation	
(autonomous) industrial robot, e.g. [1]	With support, dispersed relation, activity in control of support	Substitution	Support-System	Industrial robots are performing activities automatically as well as spatially and temporally dispersed. The user will be substituted by this system, but from an organisational point of view such systems are also supporting the activity.
Systems based on human-machine-cooperation, e.g. [2]	With support, co-presence, assistance by robots, activity usually transient in control of support	Help	Support-System	Activity is divided into sub-activities for human and robot. Both are usually working together, but are spatially or temporally separated. From the point of view of the user, the user receives help, from an organisational point of view such systems are supporting the activity.
Lifting aids/balancer, e.g. [6]	With support, dispersed activity, system assistance, activity in control of user	Help/Support-System	Support-System	Activity is divided into sub-activities which are performed by the system or human being. System control always remains in the hands of the user. So such a system helps without substitution of the staff.
Assembly seat, e.g. [13]	With support, co-presence, integrated, in control of the user	Help/Support-System	Support-System	An assembly seat is not replacing the staff. Such a device is in control of the user. Its use is probably always limited to time period (that's why we said help). In the view of organisation, such a system supports the staff in order to increase e.g. the ergonomic.
Care robots, e.g. [3]	With support, dispersed relation, activity permanent in control of support	Substitution	Support-System	Robots like the care-o-bot are performing activities autonomously. In the organisational point of view, e.g. nursing homes, such a system represents a support-system although the system substitutes the caregiver.
Exoskeleton for e.g. military applications [5]	With support, co-presence and direct integration, activity in control of support/user	Support-System	Support-System	High degree of integration of technical system and user. Systems are controlled directly by the user in real-time. This is a support-system from the point of view of both user and organisation.
Exoskeleton for rehabilitation, e.g. [4]	With support, co-presence and assistance, usually temporally in control of support	Help	Support-System	Rehabilitation exoskeleton assists the patient and the therapist. From a user's point of view, this device helps to perform the activity. From an organisational perspective such a system can be seen as support-system.
Electric bike, e.g. [7]	With support, direct interaction, in control of user	Help /Support-System	Support-System	Such a system is helping the (aging) user by simultaneous energy supply. Thus, the activity is performed simultaneously by the technical support and the user, but not permanently, only if necessary (help). Observer independent, we can see such devices as support-system.
Prostheses, e.g. hand prostheses [9]	With support, co-presence and integrated, in control of user or by technic	Support-System	Support-System	In general, such systems support handicapped persons without replacement by a machine, thus it is a support-system. In general, the control is performed by the user. However, it can also be carried out by the technology.
Apps or web-based navigator, like Google Maps	With support, in general co-presence, contextual, but also dispersed possible	Support-System	Support-System	In general, apps like Google Maps are planned as contextual support that means assistance (user can watch). In cases of a navigator, such an app can change the state – dispersed approach. So, the activity, e.g. finding of a building, is divided into sub-activities of the user and the app.

Acknowledgement

This research is funded by the Federal Ministry of Education and Research (BMBF) program for an interdisciplinary build-up of competence in human machine interaction for demographic changes. Supervision is provided by VDI/VDE INNOVATION GmbH. The sole responsibility for the manuscript contents lies with the authors.

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